Submitted: 07 April, 2024 Accepted: 31 May, 2024 Published: 08 January, 2025 DOI:10.22514/sv.2025.008

Open Access
Signa Vitae

ORIGINAL RESEARCH

Comparing foot and hand cardiopulmonary resuscitation: a non-inferiority, crossover, randomised controlled simulation study

Kui Ja Lee[1,†], Hee Eun Kim[2,†], Seung Min Park[2,3], You Hwan Jo[2,3], Hae Chul Yang[2], Yong Won Kim[4], Dong Keon Lee[2,3,*], Dong-Hyun Jang[3,5,*]

[1]Department of Paramedicine, Kyungdong University, 26495 Wonju, Republic of Korea
[2]Department of Emergency Medicine, Seoul National University Bundang Hospital, 13620 Seongnam, Republic of Korea
[3]Department of Emergency Medicine, Seoul National University College of Medicine, 03080 Seoul, Republic of Korea
[4]Department of Emergency Medicine, Dongguk University Ilsan Hospital, Dongguk University College of Medicine, 10326 Goyang, Republic of Korea
[5]Department of Public Healthcare Service, Seoul National University Bundang Hospital, 13620 Seongnam, Republic of Korea

***Correspondence**
goldenegg@snu.ac.kr
(Dong Keon Lee);
jang0621@snu.ac.kr
(Dong-Hyun Jang)

† These authors contributed equally.

Abstract

Background: High-quality chest compression is crucial during cardiopulmonary resuscitation. The present simulation study aimed to evaluate whether the chest compression method using the foot is comparable to that using the hand. **Methods**: This was a prospective, crossover, non-inferiority, randomised controlled simulation study. Non-inferiority tests were conducted for chest compression depth and rate. To determine non-inferiority, the lower limit of the confidence interval was compared to a pre-specified inferiority margin of −5 mm for chest compression depth. The compression rate was analysed in the same manner, with −17 compressions/min as the inferiority margin. **Results**: Seventy-two participants were enrolled in this study. The mean chest compression depth was 53.3 (±5.6) mm with foot chest compression (FCC) and 51.5 (±5.8) mm with hand chest compression (HCC). The mean difference between FCC and HCC was 1.8 (95% confidence interval (CI), −0.1 to 3.7) and FCC was not inferior to HCC in compression depth. The mean chest compression rates were 107.6/min and 112/min for FCC and HCC, respectively. The mean difference between FCC and HCC was −4.5/min (95% CI, −1.6 to −7.3) and FCC was not inferior to HCC for the chest compression rate. **Conclusions**: The results suggest that chest compression using the foot showed non-inferior performance regarding compression depth and rate compared with chest compression using the hand after brief training. **Clinical Trial Registration**: NCT06719401.

Keywords

Chest compression; (Foot) cardiopulmonary resuscitation; Simulation study

1. Introduction

Cardiopulmonary resuscitation (CPR) is a cornerstone intervention aimed at restoring circulation in patients with cardiac arrest, and high-quality chest compressions are essential for successful resuscitation during CPR [1–4]. However, in some extra-hospital settings, it may be difficult or impossible to perform chest compressions using both hands in accordance with guidelines.

Foot chest compression (FCC) is an alternative to hand chest compression (HCC) in situations where HCC is not possible. For example, FCC may be considered for rescuers who are infirm, underweight, have an arm injury, or are fatigued [5–8]. Despite its potential utility, FCC has not been widely studied. The 2005 International Liaison Committee on Resuscitation guidelines recommend FCC as an alternative to HCC when rescuers cannot use their arms and hands; however, there is no further mention of this technique in subsequent guidelines [9].

Recent studies on CPR simulations using the foot have reported inconsistent results regarding the comparative effectiveness of foot CPR and hand CPR in terms of the study population, method of foot compression, and statistical analysis. In a study comparing FCC and HCC in 105 school children aged 12 to 15 years, there was no significant difference in chest compression depth, but FCC showed poor results in terms of correct frequency and full release [10]. Another study comparing 21 medical workers showed no significant difference in compression depth between the two methods. When a footstool was additionally used, FCC showed better results [11]. A study targeting 20 medical professionals also reported no significant differences in compression depth or rate [12]. However, a study of 65 nursing students showed differences in chest compression quality in terms of correct depth, rate, and full release of compression [13]. In addition, several previous studies have reported that chest compression using the hands can show differences in performance depending on gender, body weight, and baseline demographic characteristics; however, there is a lack of evidence on differences in chest compressions using the foot [5, 6, 8].

The aim of the present simulation study was to compare the effectiveness of HCC with that of FCC and investigate the differences in their efficacy based on the characteristics of the rescuer through subgroup analysis. We designed this study as simulation study to evaluate the efficacy of the FCC method as an alternative to HCC without exposing patients to risk.

2. Materials and methods

2.1 Study design and setting

This is a prospective, crossover, non-inferiority, randomised controlled trial conducted from October to November 2022. We hypothesised that the FCC method is not inferior to the existing HCC method regarding depth, rate, and chest compression position.

The primary outcomes of this study were the mean chest compression depth (mm) and mean chest compression rate (n/min) for 2 min. The secondary outcomes were the proportions of adequate compression depth (%), adequate compression rate (%), adequate compression depth and rate (%), correct chest compression position (%), and compression with full release (%). According to the 2020 American Heart Association (AHA) Cardiopulmonary Resuscitation and Emergency Cardiovascular Care guidelines, adequate compression depth is defined as a compression of 50–60 mm, and adequate compression rate is defined as compression at a rate of 100–120/min. The correct chest compression position was measured using a manikin simulator to ensure that the lower half of the sternum was compressed accurately. If the location of chest compression was not selected correctly, the movement of the chest, which should move horizontally to the ground when compressed correctly, was instead tilted, and this was deemed as an incorrect compression.

2.2 Participants enrolment

Participants were recruited through a poster on the information board of a university, following the approval of the IRB (Institutional Review Board). The inclusion criteria for participants were adults aged >18 years who had been certified as an AHA basic life support (BLS) provider or had undergone equivalent BLS training. Applicants who met the following criteria were excluded because they were judged unable to perform adequate chest compressions: (1) physical or cognitive disabilities, and (2) musculoskeletal injuries, such as limb injuries. Additionally, as the present study was conducted during the coronavirus disease (COVID)-19 pandemic, individuals diagnosed with COVID-19 and quarantined or complained of fever or respiratory symptoms suspected to be COVID-19 were excluded.

The purpose of the study was explained to those who met the inclusion criteria including the right to withdraw their consent. Subsequently, participants completed a written informed consent form to participate in the study.

2.3 Simulation design

Participants were subjected to a brief educational session that covered the theoretical content of chest compressions, including the importance of the position, depth, rate, and full release of chest compressions. Education was provided following the 2020 AHA Cardiopulmonary Resuscitation and Emergency Cardiovascular Care guidelines [3]. Additionally, the session provided further explanation of the chest compression methods using two hands or feet.

After completing the educational session, participants were divided into a foot-hand group (F-H group) and a hand-foot group (H-F group) according to whether FCC or HCC was performed first, through random allocation, and then moved to independent rooms (Room A for the F-H group and Room B for the H-F group). This study used a crossover design. Participants assigned to the F-H group first performed training and testing using the FCC method, and then performed training and testing using the HCC method, while participants assigned to the H-F group proceeded in the opposite order (Fig. 1).

Participants underwent a training session before each test to practice chest compressions and familiarise themselves with the measurement environment. After completing the training session, participants were given a 5 min rest in a separate room. Subsequently, they were taken to the test room to assess their chest compression abilities. In the test room, a manikin that could measure the quality of the chest compression was placed in a supine position on the floor in the middle of the room. No support structure was provided for balance during training and actual test. Upon entering the test room, the instructor presented the following scenario: “You have found a patient with no consciousness, breathing or pulse. Perform chest compressions immediately”. Participants performed HCC or FCC using the selected method during the period, which was recorded for 2 min without the use of an audio-visual feedback device. Once the test was completed, participants were guided at the end of the session, and they moved back to a separate room for a 30 min washout period before proceeding with the second part of the study. After the washout period, participants performed the same training and test sessions using a different chest compression method (Fig. 1).

2.4 Training section (chest compression)

During the training session, participants from each group were assigned to an independent practice room and allowed to practice the chest compression method to be tested. The training session was a brief, less than 5 min self-practice period designed for participants who were already familiar with HCC and aware of the key elements of high-quality chest compression to learn proper positioning and maintaining balance during FCC. During the training session, an audio-visual feedback device was used to inform participants whether their chest compressions were being performed correctly.

HCC was performed according to the 2020 AHA Cardiopulmonary Resuscitation and Emergency Cardiovascular Care guidelines [3]. For the FCC method, participants removed their shoes, located the sternum with one foot, placed the heel of their foot on the lower half of the sternum, and compressed with the entire sole of their foot parallel to the sternum (Video 1). The foot placed on the sternum should not cover the xiphoid process. Pressure during chest compression should not be applied directly to the xiphoid process, as this can lead to complications such as xiphoid process fracture and

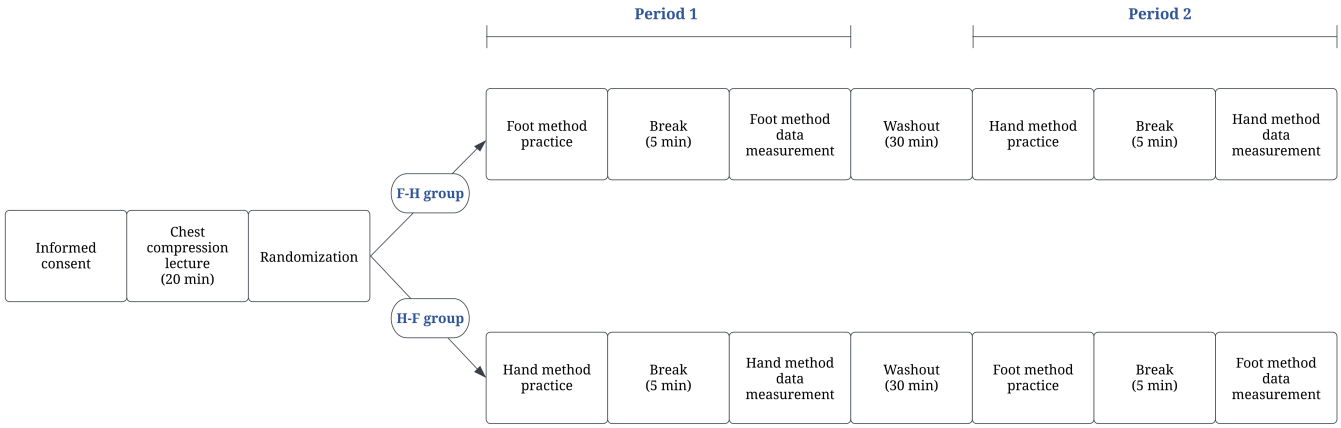

FIGURE 1. Flowchart of the study design. F-H group: foot-hand group; H-F group: hand-foot group.

VIDEO 1. The position of foot chest compression. The embedded movie may also be viewed at: https://oss.signavitae.com/mre-signavitae/article/187687133108494360/video/video1.avi.

associated liver damage [14, 15]. During FCC, participants were instructed to position their heels, which exert the most pressure, below the lower half of the sternum to prevent direct compression of the xiphoid process and position their feet facing the head of the manikin. To maintain a stable position during chest compressions, the other foot should be placed on the side of the manikin.

The instructors who assisted in the training session during the study were individuals with BLS instructor certification issued by the AHA. The instructors were not provided with any prior information regarding the randomisation or crossover design. Instead, they were asked to provide advice on incorrect posture or inadequate compressions during the training sessions.

2.5 Randomisation

Stratified permuted block randomisation was used to allocate participants into two groups: foot-hand chest compression (F-H group) and hand-foot chest compression (H-F group). The block size was set to four, and the stratification factor was sex.

Random numbers were generated using the randomised permuted block design in the R-package software (version 4.1.2 R Foundation for Statistical Computing, Vienna, Austria) by an independent researcher who was not involved in this study; the randomisation sequence was implemented in the electronic

case report form software (MyECRF, 2.0, Lunaair, Wonju, South Korea).

2.6 Sample size calculation

To achieve high-quality chest compressions, the most critical factor emphasised in the CPR guidelines is adequate compression depth. Compared with other factors, the depth of chest compression can affect patient outcomes, even with small differences [1, 4, 16, 17]. Therefore, we calculated the sample size based on the depth of chest compressions.

To ensure an appropriate sample size for the parameters of both methods, a non-inferiority margin was defined based on previous studies. Considering that a decrease of 5 mm has been linked to lower survival rates after cardiac arrest and that an increase in compression depth of 5 mm during instructor-led training has been observed in comparison with pre-training, a non-inferiority margin of −5 mm was established [16, 18, 19]. Based on an expected standard deviation of 10 mm [18–21], an alpha of 5%, and a power of 80%, the sample size was determined to be 66 participants considering a 2 × 2 crossover design. The sample size was increased to 72 participants, to account for a potential dropout rate of 10%. Finally, 36 students were enrolled in each of the F-H and H-F groups.

This power level was also sufficient to conduct non-inferiority testing for the chest compression rate using a non-inferiority margin of −17 compressions per minute and a standard deviation of 20 compressions per minute. The determination of the non-inferiority margin and standard deviation of the chest compression rate was based on previous studies [18–21].

2.7 Data collection and processing

After obtaining written informed consent, personal information, such as age, sex, weight, and height, was collected for analysis according to the participants' baseline characteristics.

The manikin used for training and testing was the Laerdal Resusci Anne QCPR (Laerdal Medical Corporation, Stavanger, Norway), and the quality of chest compressions was measured using the compression-only mode connected to the manikin, which was the Laerdal SimPad PLUS with SkillReporter (Laerdal Medical Corporation, Stavanger, Norway). Test measurements were performed continuously for 2 min.

The data stored in the feedback device and measured during the test were extracted using Simpad software (Simpad PLUS 7.4.2, Laerdal Medical Corporation, Stavanger, Norway) and converted to an Excel (2210, Microsoft Corporation, Redmond, WA, USA) file for analysis.

2.8 Statistical analysis

In a non-inferiority trial, the null hypothesis posits that the FCC method is inferior to the HCC method. In this study, the non-inferiority of the mean compression depth and rate of FCC compared with those of HCC was evaluated using a one-sided 95% confidence interval (CI). To determine the non-inferiority of FCC as a method for chest compressions compared with HCC, the lower limit of the CI was compared with a pre-specified inferiority margin of −5 mm for the chest compression depth. The compression rate was analysed in the same manner as the compression depth, with −17 compressions/min as the inferior margin.

For clinical data, continuous variables are expressed as mean (±standard deviation), and categorical variables are expressed as frequency (percentage). For chest compression depth and rate, non-inferiority tests were conducted by comparing the mean difference and 95% CI of the results measured by the FCC and HCC methods against pre-specified non-inferiority margins. To compare the proportions of adequate compression depth, adequate compression rate, adequate compression depth and rate, and compression with full release, the Chi-square test or Fisher's exact test was used as appropriate. Each FCC and HCC performed by a single participant was considered paired during analysis. For chest compression depth and rate, subgroup analyses according to FCC and HCC were performed first, followed by sex and body mass index (BMI) of participants.

Except for testing the compression depth and rate using the one-sided non-inferiority test, the other parameters were analysed using two-sided tests. p-values < 0.05 were considered statistically significant. Data were analysed using SPSS (version 25.0; IBM SPSS, Inc., Chicago, IL, USA).

3. Results

Seventy-two participants were enrolled in the study, with 36 allocated to the F-H and H-F groups. The baseline characteristics of the participants are shown in Table 1. All participants could successfully complete 2 min of chest compression without losing their balance or falling.

Table 2 shows the chest compression quality measured among participants for the FCC and HCC methods, respectively. The mean difference of chest compression depth between FCC and HCC was 1.8 (95% CI, −0.1 to 3.7). Considering the defined non-inferiority margin of −5 mm, FCC was not inferior to HCC in terms of compression depth. The mean difference of chest compression rate between FCC and HCC was −4.5/min (95% CI, −1.6 to −7.3). Therefore, with the predefined non-inferiority margin of −17/min, FCC was not inferior to HCC based on the chest compression rate.

There was no significant difference in the percentage of participants having mean compression depth of 5–6 cm in the FCC and HCC groups (61.2% *vs.* 67.7%, respectively $p = 0.223$). However, the percentages of participants having mean compression rate of 100–120 compression/min were significantly lower in the FCC group (69.4% *vs.* 87.5%, $p < 0.001$). The percentages of correct chest compression position and chest compression with full release were also lower in the FCC group (84.3% *vs.* 99.5%, $p < 0.001$ and 61% *vs.* 73.4%, $p = 0.003$, respectively). In the subgroup analysis by group, sex and BMI, both compression depth and rate in FCC were non-inferior to those in HCC (Table 3).

4. Discussion

In the present study, FCC was not inferior to HCC regarding mean chest compression depth. In the analysis of each com-

TABLE 1. Baseline characteristics of the study participants.

	Total (n = 72)	H-F group (n = 36)	F-H group (n = 36)	*p*
Age (yr)	22.2 ± 1.9	21.9 ± 1.6	22.4 ± 2.1	0.262
Male	23 (31.9)	12 (33.3)	11 (30.6)	0.800
Weight (kg)	64.5 ± 11.7	66.3 ± 12.5	62.8 ± 10.8	0.210
Height (cm)	165.9 ± 7.4	167.6 ± 6.7	164.2 ± 7.8	0.051
Body mass index (kg/m^2)	23.3 ± 3.3	23.5 ± 3.6	23.2 ± 3.0	0.692
Sole size (mm)	245.9 ± 15.2	247.4 ± 13.2	244.4 ± 17.0	0.420

F-H group: foot-hand group; H-F group: hand-foot group.

TABLE 2. Chest compression quality according to chest compression methods.

	FCC (n = 72)	HCC (n = 72)	*p*
Mean compression depth (mm)	53.3 ± 5.6	51.5 ± 5.8	0.035
Adequate compression depth (%)	61.2 ± 28.6	67.7 ± 35.1	0.223
<50 mm compression depth (%)	24.0 ± 28.8	30.6 ± 36.3	0.248
>60 mm compression depth (%)	13.8 ± 24.7	1.7 ± 3.4	<0.001
Mean compression rate (n/min)	107.5 ± 10.5	112.0 ± 6.2	0.001
Adequate compression rate (%)	54.7 ± 24.2	76.4 ± 24.5	<0.001
Adequate compression depth and rate (%)	35.5 ± 25.2	53.3 ± 33.5	<0.001
Correct chest compression position (%)	84.3 ± 33.7	99.5 ± 2.3	<0.001
Compression and full release (%)	61.0 ± 31.1	73.4 ± 33.6	0.003

Data are expressed as mean ± standard deviation. FCC: foot chest compression; HCC: hand chest compression.

TABLE 3. Subgroup analyses of the chest compression depth and rate.

*Chest compression depth (mm) Mean difference (95% confidence interval)			†Chest compression rate (n/min) Mean difference (95% confidence interval)	
Group			Group	
	F-H Group	2.7 (0.1 to 5.3)	F-H Group	−8.9 (−13.0 to −4.9)
	H-F Group	0.9 (−1.8 to 3.5)	H-F Group	0 (−3.9 to 3.8)
Sex			Sex	
	Male	1.1 (−2.0 to 4.3)	Male	−8.1 (−14.1 to −1.9)
	Female	2.1 (−0.2 to 4.4)	Female	−2.7 (−5.7 to 0.2)
BMI			BMI	
	Low (<25 kg/m^2)	0.7 (−1.5 to 3.0)	Low (<25 kg/m^2)	−4.2 (−7.6 to −0.8)
	High (≥25 kg/m^2)	4.8 (1.3 to 8.3)	High (≥25 kg/m^2)	−5.1 (−10.6 to 0.4)

F-H group: foot-hand group; H-F group: hand-foot group; BMI: body mass index.
**Mean difference of −5 mm was set for non-inferiority margin.*
†Mean difference of −17/min was set for non-inferiority margin.

pression performed to determine whether an accurate depth of 5–6 cm was achieved, there was no significant difference in the proportion of compressions that achieved an adequate depth between the FCC and HCC methods. In terms of chest compression rate, FCC was not inferior to HCC regarding mean compression rate, but the ratio of maintaining an adequate compression rate among each compression was higher in HCC than in FCC. Previous studies on FCC have involved participants who were either medical professionals or laypersons whose CPR training status was unknown, and have reported different results depending on the participant group. In our study, we measured the quality of chest compression in subjects who were not medical professionals but had received basic CPR training, and who were more likely to be bystander CPR providers in actual sudden cardiac arrest situations. Our findings suggest that FCC is not inferior to HCC in terms of mean chest compression depth and mean compression rate in this participant group.

Most current CPR guidelines do not offer guidance on performing CPR in special scenarios in which the rescuers are not

able to perform chest compressions with both hands. However, as any method of chest compression is better than no chest compressions, we have decided to explore this alternative method of chest compressions. Unconventional approaches to chest compressions, such as utilising the foot, present potential options for situations where using the arms for compressions is not feasible (such as rescuer arm injury) or when minimal patient–rescuer contact is preferred [12, 22]. Although our study findings suggest some shortcomings of FCC compared to chest compressions using both hands, particularly in terms of depth, which is arguably the most crucial aspect of chest compressions, as per the guideline-recommended method, FCC is deemed non-inferior. Therefore, FCC has the potential to be used as a method of chest compression in special circumstances. However, during training, particular attention should be paid to the possibility of excessively deep compressions and incomplete release between chest compressions.

The most important factor in inducing adequate circulation in patients with cardiac arrest during CPR is the appropriate depth of chest compressions [3, 16]. In a study comparing HCC and FCC in schoolchildren to determine whether FCC is superior to HCC in underweight children, no significant difference between FCC and HCC was reported [10]. The equivalence of FCC and HCC was not evaluated in this study; however, the proportion of participants who achieved appropriate chest compression depth was similar between the FCC and HCC methods. Two recent studies evaluating whether FCC can provide adequate chest compressions compared with HCC showed conflicting results depending on the participant group. A study conducted after a brief explanation of HCC and FCC methods to nursing students reported that FCC provided an inappropriate chest compression depth compared with HCC [13]. However, a study conducted after a brief explanation of the FCC method targeting medical professionals in emergency departments or intensive care units reported that FCC provided a chest compression depth that was not inferior to that of HCC [12]. In our study, we provided additional education and practice time on the FCC method to participants who have undergone AHA BLS or equivalent training. The results showed that chest compressions using FCC were not inferior to those using HCC regarding chest compression depth.

Another important component of adequate chest compressions that induces adequate circulation in patients with cardiac arrest is the appropriate rate of chest compressions [3, 23, 24]. In previous studies related to FCC, analyses of whether the FCC method could provide an appropriate chest compression rate for patients with cardiac arrest also showed inconsistent results, depending on participants groups. In studies conducted on schoolchildren and nursing students, chest compression performed using the FCC method showed a slower chest compression rate than the HCC method [10, 13]. In contrast, the study conducted on medical professionals showed that FCC was not inferior to HCC regarding chest compression rate [12]. In the evaluation of the chest compression rate in participants included in the present study, FCC was not inferior to HCC regarding the mean compression rate. However, the ratio of compressions that maintained an adequate compression rate was significantly lower in the FCC group. One possible explanation for this finding is that it was difficult to maintain a consistent chest compression rate with FCC, as it requires balancing on one foot, which can be challenging compared to the HCC method. Failing to maintain a consistent compression rate can compromise chest compression quality. Hence, while the mean compression depth was within the predefined noninferiority margin, it may be difficult to conclusively assert non-inferiority.

In a study comparing the FCC method with the HCC method to compare the quality of chest compression and the degree of rescuer fatigue, the FCC showed a performance comparable to that of the HCC [11]. In this study, chest compressions performed using the FCC method on the floor yielded similar results as the HCC method in terms of compression depth and rate, and the degree of rescuer fatigue was also similar. Furthermore, this study reported that using a footstool of appropriate height while performing FCC could provide better chest compression depth to the patient and significantly reduce the degree of rescuer fatigue. In our study, it was determined that preparing footstools may not always be feasible in urgent cardiac arrest situations; thus, footstools were not used. In addition, while using additional support such as walls and pillars can improve chest compression quality by aiding in balance, such support may not always be readily available in emergency situations. Therefore, we opted against using support structures in this study, as in previous studies [10, 12, 13]. However, the findings of this study imply that there is still potential for improvement in FCC techniques. Moreover, because the body part that uses more force varies depending on posture, it can help maintain effective chest compressions for a longer period when CPR is required by a single rescuer [25].

One of the main reasons for the inconsistent results of chest compression quality in previous studies comparing FCC with HCC may be the differences in clinical experience and education according to participant group. In two studies conducted on medical workers working in clinical settings, the quality of chest compressions through the FCC was not inferior to that through the HCC. However, in a study conducted on nursing students, chest compressions through FCC showed some inferiority compared with HCC. The difference between the results of these two studies can be attributed to the disparity in participants' levels of CPR education and clinical experience. Even if they are not familiar with the FCC method, a more experienced participant would be able to self-assess whether their chest compressions are being effectively transmitted. The present study was conducted with members of the general public who had an AHA BLS license or received equivalent education, although they were not healthcare providers. In real-life situations, individuals who are most likely to perform CPR with appropriate quality on patients before the arrival of the emergency medical service as bystanders will be similar to participants in our study. These individuals are not medical personnel but were presumed to be familiar with the chest compression method recommended in the CPR guidelines. Our results indicated that after providing training and practice on FCC to a certain degree in this participant group, the performance regarding chest compression depth and rate, the most important factors for high-quality chest compression, was not inferior compared with their performance using the familiar HCC method. FCC differed from HCC regarding full release;

however, the FCC method could be further improved through additional education and practice, assuming that participants had more opportunities to encounter and practice HCC.

We showed that the proportion of incomplete release between compressions was significantly higher in FCC compared to HCC. During CPR, chest compression can be defined as the repetition of a process in which the heart is filled with blood during sufficient decompression and then ejected with sufficient compression. Accordingly, various CPR-related guidelines emphasise the need for full release during chest compression [3, 4]. This suggests that even if FCC is non-inferior to HCC in terms of chest compression depth, it may be difficult to consider them as having the same quality of chest compression from the perspective of generating blood flow in actual patients. While our study did not investigate the extent to which full release was not performed well, it is difficult to conclude that there is no difference in effect owing to this. However, it is possible that this difference may be because of maintaining balance during compression. Therefore, the availability of structures for support, such as walls or pillars, can improve performance, although the exact extent of this improvement remains uncertain.

FCC exhibited a higher rate of compressions deeper than 6 cm and a lower proportion of accurate chest compression positions than HCC. Excessive depth or compression in incorrect positions may potentially lead to complications by damaging organs in those areas [14, 15, 26]. This difference might arise from FCC being a less familiar technique and requiring attention to balance for proper positioning. Further research is necessary to explore whether the development of additional educational methods could lead to improved outcomes in addressing these issues.

Several studies have reported that the quality of chest compressions can vary depending on the physical characteristics of the rescuers [5, 8]. Accordingly, we hypothesised that the physical characteristics of participants might be the cause of the inconsistent results in previous studies on FCC. In addition, although a wash-out time of approximately 30 min was allowed in the middle of the study, it was assumed that the HCC performed earlier might have affected the quality of the FCC. However, in the subgroup analysis, the depth or rate of chest compression through FCC was not inferior to that of HCC, regardless of which technique was performed first, and regardless of the sex or BMI of participants.

During the course of this study, the introduction, training, and test sessions were conducted consecutively on the same day. Since most out-of-hospital cardiac arrest occur unexpectedly, bystander CPR is often performed without prior training. From this perspective, it is possible that the training process immediately before testing may have caused bias in the test results. However, this study targeted participants who were certified as AHA BLS providers or had undergone equivalent BLS training. Consequently, the training session itself was brief, consisting of less than a 5 min self-practice period for participants focused on proper positioning and maintaining balance during chest compressions. Given the brevity of the training session, its impact on the study results in terms of performance changes that might occur with extensive practice is likely to be minimal. The effectiveness of CPR-related simulation education diminishes after approximately 3–6 months [18]. Although a comprehensive investigation into the long-term effects of training sessions on FCC was not conducted in this study, future developments in educational programs, including simulations, should consider such long-term effects.

Our study has several limitations. First, we conducted a simulation study using manikins. In actual cardiac arrest situations, the scene may be more chaotic and surrounding environment may influence the CPR. Although there may be differences between simulation environments using manikins and real-life scenarios, simulation-based education and research are widely utilised and are effective in medical fields where directly training on patients could raise ethical concern [27–29]. Our study, thus, holds significance in this aspect. Second, participants were recruited through a poster on the information board of a university. Because most participants were university students who showed voluntary interest in the study, the participants were relatively young, with a mean age of 22 years, and they were healthy individuals without any disabilities. In addition, it is highly likely that many of them had an interest in the process of CPR. Foot CPR has emerged as an alternative to HCC for laypersons who are unable to use their hands (owing to certain disabilities, age or field situations). Further research may be necessary to include a wider population. Third, in actual cardiac arrest situations with only one rescuer, the rescuer must perform multiple CPR cycles alone, whereas this simulation study only assessed CPR cycles for 2 min. Therefore, prolonged fatigue and fading were not fully evaluated. Fourth, the potential for excessive compression was not adequately evaluated in the study. Although no significant difference in the proportion of adequate depth was found between the two methods, the FCC method may lead to deeper compression in some cases.

5. Conclusions

The results suggest that chest compression using the foot showed non-inferior performance regarding compression depth and rate compared to chest compression using the hand after brief training. However, the proportion of adequate rate, correct chest compression position, and full release was lower with FCC, making it difficult to conclude whether the overall CPR quality was adequate and equal. These findings suggest that upon training, FCC could be used as an alternative method of chest compression in special circumstances when HCC is either infeasible or inappropriate, even though its quality may not match that of HCC.

ABBREVIATIONS

FCC, foot chest compression; HCC, hand chest compression; CI, confidence interval; CPR, cardiopulmonary resuscitation; AHA, American Heart Association; BLS, basic life support; COVID-19, coronavirus disease-19; BMI, body mass index; IRB, Institutional Review Board.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

SMP and YHJ—supervised the overall research. SMP and DKL—designed the research study. KJL, HEK and HCY—performed the simulation and collected the data. YHJ and YWK—provided help and advice on simulation. HCY, DHJ and DKL—analysed the data. KJL, HEK, YWK, DKL and DHJ—wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Institutional Review Board (IRB) of Seoul National University Bundang Hospital (B-2205-758-302). Participants completed a written informed consent form to participate in the study. The study was retrospectively registered with ClinicalTrials.gov (Registration No.: NCT06719401).

ACKNOWLEDGMENT

The authors thank Division of Statistics in Medical Research Collaborating Centre at Seoul National University Bundang Hospital for statistical analyses.

FUNDING

This research was funded by National Research Foundation of Korea (NRF) grant funded by the Korean government, grant number NRF-2022R1F1A1074361.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Nichol G, Daya MR, Morrison LJ, Aufderheide TP, Vaillancourt C, Vilke GM, *et al*. Compression depth measured by accelerometer *vs.* outcome in patients with out-of-hospital cardiac arrest. Resuscitation. 2021; 167: 95–104.

[2] Gugelmin-Almeida D, Tobase L, Polastri TF, Peres HHC, Timerman S. Do automated real-time feedback devices improve CPR quality? A systematic review of literature. Resuscitation Plus. 2021; 6: 100108.

[3] Panchal AR, Bartos JA, Cabanas JG, Donnino MW, Drennan IR, Hirsch KG, *et al*. Part 3: adult basic and advanced life support: 2020 american heart association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2020; 142: S366–S468.

[4] Olasveengen TM, Semeraro F, Ristagno G, Castren M, Handley A, Kuzovlev A, *et al*. European resuscitation council guidelines 2021: basic life support. Resuscitation. 2021; 161: 98–114.

[5] Peberdy MA, Silver A, Ornato JP. Effect of caregiver gender, age, and feedback prompts on chest compression rate and depth. Resuscitation. 2009; 80: 1169–1174.

[6] Shin SY, Kim JH, Roh SG. The relationship between body composition and chest compression in adult—a manikin study. Annals of the Romanian Society for Cell Biology. 2021; 25: 1223–1232.

[7] Bae GE, Choi A, Beom JH, Kim MJ, Chung HS, Min IK, *et al*. Correlation between real-time heart rate and fatigue in chest compression providers during cardiopulmonary resuscitation: a simulation-based interventional study. Medicine. 2021; 100: e25425.

[8] Küçükceran K, Ayranci M, Muhammet Ö. The impact of body mass index values on the quality of cardiopulmonary resuscitation: a manikin study. Clinical and Experimental Health Sciences. 2021; 11: 269–272.

[9] International Liaison Committee on Resuscitation. 2005 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Part 2: adult basic life support. Resuscitation. 2005; 67: 187–201.

[10] Kherbeche H, Exer N, Schuhwerk W, Ummenhofer W, Osterwalder J. Chest compression using the foot or hand method: a prospective, randomized, controlled manikin study with school children. European Journal of Emergency Medicine. 2017; 24: 262–267.

[11] Takahashi Y, Saitoh T, Okada M, Satoh H, Akai T, Mochizuki T, *et al*. The potential of leg-foot chest compression as an alternative to conventional hands-on compression during cardiopulmonary resuscitation. Hong Kong Journal of Emergency Medicine. 2019; 26: 106–110.

[12] Ott M, Krohn A, Bilfield LH, Dengler F, Jaki C, Echterdiek F, *et al*. Leg-heel chest compression as an alternative for medical professionals in times of COVID-19. The American Journal of Emergency Medicine. 2021; 50: 575–581.

[13] Otero-Agra M, Santiago-Urgal N, Hermo-Gonzalo MT, Fernández-Méndez M, Fernández-Méndez F. CPR by foot. An alternative in special circumstances? A randomized simulation study. The American Journal of Emergency Medicine. 2021; 43: 1–6.

[14] Ümit TB, Sogut O, Az A, Cakmak S, Demirel I. Relationship between measures of thoracic diameter and cardiopulmonary resuscitation-induced thoracoabdominal injury. Revista da Associação Médica Brasileira. 2022; 68: 1470–1475.

[15] Saksobhavivat N, Phattharapornjaroen P, Suksukon P, Atiksawedparit P, Chalermdamrichai P, Saelee R, *et al*. Optimal chest compression position for cardiopulmonary resuscitation determined by computed tomography image: retrospective cross-sectional analysis. Scientific Reports. 2023; 13: 22763.

[16] Stiell IG, Brown SP, Nichol G, Cheskes S, Vaillancourt C, Callaway CW, *et al*. What is the optimal chest compression depth during out-of-hospital cardiac arrest resuscitation of adult patients? Circulation. 2014; 130: 1962–1970.

[17] Atiksawedparit P, Sathapornthanasin T, Chalermdamrichai P, Sanguanwit P, Saksobhavivat N, Saelee R, *et al*. Using computed tomography to evaluate proper chest compression depth for cardiopulmonary resuscitation in Thai population: a retrospective cross-sectional study. PLOS ONE. 2023; 18: e0279056.

[18] Riggs M, Franklin R, Saylany L. Associations between cardiopulmonary resuscitation (CPR) knowledge, self-efficacy, training history and willingness to perform CPR and CPR psychomotor skills: a systematic review. Resuscitation. 2019; 138: 259–272.

[19] Nas J, Thannhauser J, Vart P, van Geuns R, Muijsers HEC, Mol J, *et al*. Effect of face-to-face *vs* virtual reality training on cardiopulmonary resuscitation quality. JAMA Cardiology. 2020; 5: 328.

[20] Roppolo LP, Pepe PE, Campbell L, Ohman K, Kulkarni H, Miller R, *et al*. Prospective, randomized trial of the effectiveness and retention of 30-min layperson training for cardiopulmonary resuscitation and automated external defibrillators: the American airlines study. Resuscitation. 2007; 74: 276–285.

[21] Bylow H, Karlsson T, Claesson A, Lepp M, Lindqvist J, Herlitz J. Self-learning training versus instructor-led training for basic life support: a cluster randomised trial. Resuscitation. 2019; 139: 122–132.

[22] Hung TY, Wen CS, Yu SH, Chen YC, Chen HL, Chen WL, *et al*. A comparative analysis of aerosol exposure and prevention strategies in bystander, pre-hospital, and inpatient cardiopulmonary resuscitation using simulation manikins. Scientific Reports. 2023; 13: 12552.

[23] Idris AH, Guffey D, Aufderheide TP, Brown S, Morrison LJ, Nichols P, *et al*. Relationship between chest compression rates and outcomes from cardiac arrest. Circulation. 2012; 125: 3004–3012.

[24] Idris AH, Guffey D, Pepe PE, Brown SP, Brooks SC, Callaway CW, *et al*. Chest compression rates and survival following out-of-hospital cardiac arrest. Critical Care Medicine. 2015; 43: 840–848.

[25] Trenkamp RH, Perez FJ. Heel compressions quadruple the number of bystanders who can perform chest compressions for 10 minutes. The American Journal of Emergency Medicine. 2015; 33: 1449–1453.

[26] Hellevuo H, Sainio M, Nevalainen R, Huhtala H, Olkkola KT, Tenhunen J, *et al*. Deeper chest compression—more complications for cardiac arrest patients? Resuscitation. 2013; 84: 760–765.

[27] Demirtas A, Guvenc G, Aslan Ö, Unver V, Basak T, Kaya C. Effectiveness of simulation-based cardiopulmonary resuscitation training programs on fourth-year nursing students. Australasian Emergency Care. 2021; 24: 4–10.

[28] Laco RB, Stuart WP. Simulation-based training program to improve cardiopulmonary resuscitation and teamwork skills for the urgent care clinic staff. Military Medicine. 2022; 187: e764–e769.

[29] Faghihi A, Naderi Z, Keshtkar MM, Nikrouz L, Bijani M. A comparison between the effects of simulation of basic CPR training and workshops on firefighters' knowledge and skills: experimental study. BMC Medical Education. 2024; 24: 178.

How to cite this article: Kui Ja Lee, Hee Eun Kim, Seung Min Park, You Hwan Jo, Hae Chul Yang, Yong Won Kim, *et al*. Comparing foot and hand cardiopulmonary resuscitation: a non-inferiority, crossover, randomised controlled simulation study. Signa Vitae. 2025; 21(1): 60-68. doi: 10.22514/sv.2025.008.