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# Effectiveness of a video-based refresher on cardiopulmonary resuscitation skill retention in college students: A single-blind randomized controlled trial

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## Abstract:

**OBJECTIVES:** Cardiopulmonary resuscitation (CPR) skills decline within months after training, particularly among lay college students. We evaluated whether a brief video-based refresher improves 6-month CPR skill retention.

**METHODS:** We conducted a single-blind randomized controlled trial among 2<sup>nd</sup>-year college students in Seoul, South Korea, who had completed Basic Life Support (BLS). Participants were randomized to an experimental group ( $n = 33$ ) that received a 2-min video refresher at 3 months or to a control group ( $n = 30$ ) with no refresher. CPR competencies – cardiac arrest recognition, emergency medical system (EMS) activation, chest compressions, and automated external defibrillator (AED) use – were assessed immediately after training and at 6 months using a standardized checklist.

**RESULTS:** At 6 months, the experimental group showed significantly better retention for cardiac arrest recognition ( $P = 0.003$ ), EMS activation ( $P = 0.003$ ), and chest compression performance ( $P = 0.020$ ) than the control group. AED use did not differ significantly between groups ( $P = 0.235$ ).

**CONCLUSION:** A brief video refresher delivered 3 months after BLS significantly enhances 6-month retention of key CPR skills in college students. This low-cost, scalable strategy may help maintain CPR competence where repeated hands-on training is hard to provide.

## Keywords:

Basic life support, cardiopulmonary resuscitation, college students, skill retention, video refresher

## Introduction

Basic Life Support (BLS) training equips laypersons with essential skills to respond to cardiac emergencies. Cardiopulmonary resuscitation (CPR), the cornerstone of BLS, can restore circulatory and respiratory function in individuals experiencing cardiac arrest and is strongly associated with

improved survival rates.<sup>[1]</sup> Despite the widespread dissemination of BLS education to both healthcare providers and the general public,<sup>[2,3]</sup> numerous studies have demonstrated that CPR skills deteriorate substantially within a few months of training.<sup>[4-6]</sup> Skill decay is particularly pronounced during the 3–6 month interval after training, when reduced proficiency may compromise effective bystander response in out-of-hospital cardiac arrest.<sup>[7-9]</sup>

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**Box-ED Section****What is already known about this topic?**

- Cardiopulmonary resuscitation (CPR) skills commonly deteriorate within 3–6 months after Basic Life Support (BLS)
- In-person refreshers and simulation practice can help, but are resource-intensive.

**What is the controversy, and why is it important?**

- The effectiveness of brief, video-based CPR refreshers in lay college students remains unclear
- College students often lack low-cost, easily accessible refresher options despite frequent initial training.

**How was this study conducted?**

- Single-blind randomized controlled trial of 2<sup>nd</sup>-year college students who completed BLS
- The intervention group received a 2-min video refresher at 3 months; controls received no refresher
- CPR performance (arrest recognition, EMS activation, chest compressions, and automated external defibrillator [AED] use) was assessed immediately posttraining and at 6 months using a standardized checklist.

**What are the key findings?**

- At 6 months, the video group showed better retention in arrest recognition, EMS activation, and chest compression performance than controls
- AED use was similar between groups
- A brief, video-based refresher is a low-cost, scalable option to help sustain CPR skills where repeated hands-on training is difficult.

Retention of CPR skills remains a critical challenge. Without reinforcement, trained individuals often demonstrate significant declines in chest compression quality, ventilation performance, and automated external defibrillator (AED) use.<sup>[6,9]</sup> Although periodic refreshers – such as instructor-led reviews or simulation-based practice – have been proposed,<sup>[10]</sup> these approaches are resource-intensive and difficult to sustain at scale for non-healthcare populations.

College students are an important, yet underserved, target group. They are frequently present in public spaces – such as campuses, social gatherings, and sports facilities – where cardiac arrests may occur.<sup>[11]</sup> However, they often lack ongoing access to refresher opportunities and may experience faster skill decay than healthcare professionals.<sup>[12,13]</sup> Existing research on CPR skill retention has largely focused on medically trained individuals, leaving an evidence gap regarding feasible strategies for general student populations.

Video-based refreshers may offer a pragmatic, low-cost, and scalable solution. Digital learning platforms offer flexible access to concise demonstrations of key CPR steps, including cardiac arrest recognition, emergency medical service (EMS) activation, chest compressions, and AED use.<sup>[14,15]</sup> Such interventions are well-suited to bridge the interval between initial BLS training and real-world application, when decay is most likely.<sup>[16,17]</sup> However, the effectiveness of brief video refreshers among nonhealthcare college students has not been clearly established.

Therefore, this study evaluated whether a brief video refresher delivered 3 months after initial BLS training improves CPR skill retention at 6 months among college students. By targeting a nonhealthcare population, this study seeks to provide evidence for a practical and scalable approach to maintaining CPR competence in the community.

**Methods****Study design**

This study was a single-blind randomized controlled trial evaluating 6-month CPR skill retention after initial Basic Life Support (BLS) training among college students. Participants were randomized 1:1 via a web-based randomizer to either an experimental group, which received a 2-min video refresher at 3 months posttraining, or a control group, which received no refresher. Outcome assessors were blinded to group assignment (single-blind). CPR performance was assessed immediately after training (baseline) and at 6 months (follow-up) using a standardized checklist. The primary objective was to determine whether the video refresher improved retention of key CPR competencies compared with no refresher.

**Participants**

This study was conducted between October 2023 (training and baseline assessment) and April 2024 (6-month follow-up) among 2<sup>nd</sup>-year students in the College of Education at a university in Seoul, South Korea. Recruitment proceeded as voluntary, consecutive enrollment within the predefined October 2023 window, following in-class announcements describing the study purpose, procedures, and the right to withdraw at any time. Eligibility criteria were: (a) age  $\geq 18$  years; (b) no prior professional medical training; (c) no CPR certification within the past 12 months; and (d) availability for both the initial training and follow-up assessments. All participants provided written informed consent.

In total, 73 students enrolled and underwent BLS training and baseline assessment in small groups of 15–18 to maximize hands-on practice. Participants were randomized 1:1 to the video refresher group

or control. During follow-up, 10 participants did not complete the 6-month assessment and were excluded from the per-protocol analysis. Thus, 63 participants were included in the final analysis (video group  $n = 33$ ; control  $n = 30$ ). Outcome assessors were blinded to group allocation throughout.

### Randomization and blinding

After recruitment and baseline procedures, participants were randomized in a 1:1 ratio to the video refresher or control group using a web-based randomizer (Randomizer.org). Each participant was assigned a unique identification number (1–73), which was entered into the program to generate a computer-produced simple randomization sequence (no stratification or blocking). This approach aimed for approximately equal allocation across groups.

Group assignments were implemented by a study coordinator not involved in outcome assessment. Outcome assessors were blinded to group allocation (single-blind), and no crossover between groups occurred during follow-up. Allocation concealment was maintained by implementing the computer-generated sequence centrally and by separating sequence generation/implementation from outcome assessment.

### Intervention

#### *Cardiopulmonary resuscitation training (October 2023)*

The initial training followed the joint CPR guidelines of the Korea Disease Control and Prevention Agency (KDCA) and the Korean Association of Cardiopulmonary Resuscitation (KACPR). Sessions were delivered by BLS instructors certified by the American Heart Association (AHA) and the KACPR. The curriculum integrated brief didactics with small-group hands-on practice and covered cardiac arrest recognition, activation of the EMS, high-quality chest compressions (depth, rate, full recoil, and minimal interruptions), ventilation, and AED use. Each session lasted approximately 4 h, and instructors provided real-time formative feedback to support skill acquisition and accuracy. Educational materials used in the course are available on the KACPR website [Video 1].

#### *Video-based refresher (January 2024)*

At 3 months posttraining (January 2024), participants randomized to the intervention arm received a 2-min video refresher via Email and mobile messaging. The video provided a concise review of the BLS sequence – cardiac arrest recognition, EMS activation, chest compressions, ventilation, and AED prompts – with onscreen cues and voice-over to reinforce correct actions. The script and sequencing reflected the KDCA–KACPR joint guidelines and were reviewed by the study's certified BLS instructors for content accuracy before distribution. Participants were encouraged to view the

video at their convenience; no formal monitoring or tracking of viewing frequency was implemented. The control group received no refresher. Representative captured frames are presented in Figure 1.

### Data collection

#### *Timing and setting*

Data were collected at two time points: Immediately after the initial BLS training (October 2023) and at 6 months (April 2024). Both assessments used a standardized, scenario-based practical test.

#### *Assessment procedure*

Participants completed a simulated out-of-hospital cardiac arrest scenario requiring cardiac-arrest recognition, EMS activation, chest compressions, ventilation, and AED tasks. Performance was evaluated using (i) a structured checklist and (ii) objective sensor-based metrics captured on an adult Laerdal Little Anne manikin (Laerdal Medical AS, Stavanger, Norway) retrofitted with the IMLAB CPR Add-on Kit (AoK) (I. M. LAB Inc., Seocho, Seoul, South Korea), with data stored via the CPR plus application (Android/iOS). The system provided real-time and recorded measures of compression depth (mm), rate ( $\text{min}^{-1}$ ), full chest recoil (%), and hand position/ventilation events. Outcome assessors were blinded to group allocation and followed a uniform scoring protocol.

#### *Pre-test (October 2023)*

Immediately posttraining, all participants completed the scenario to index immediate skill acquisition. Checklists and sensor outputs were recorded for all domains.

#### *Posttest (April 2024)*

At 6 months, the same scenario and scoring protocol were used to assess retention. The primary comparison



**Figure 1:** Still image from Cardiopulmonary resuscitation (CPR) refresher video. Still frame captured from a brief (~2-min) CPR refresher video conducted as a staged simulation on a training manikin under instructor supervision. The refresher reinforces high-quality compression targets (rate 100–120/min, depth 5–6 cm), complete chest recoil, and minimal interruptions between cycles. Faces and identifying features are not displayed; no identifiable individuals are shown. The video also illustrates correct automated external defibrillator operation and pad placement on an adult torso

contrasted the video refresher and control groups at follow-up. Adequacy thresholds for compression quality followed KDCA–KACPR guidance (e.g. depth  $\geq 50$  mm [ $\approx 5$  cm], rate 100–120/min, full recoil  $\geq 90\%$ ) and were applied consistently across both time points.

## Outcome measures

### Primary outcome

The prespecified primary outcome was chest compression performance at 6 months. Performance was quantified using objective sensor-based metrics recorded by the manikin system: Compression depth (mm), rate ( $\text{min}^{-1}$ ), and full chest recoil (% of cycles). Adequacy thresholds followed KDCA–KACPR guidance, with depth  $\geq 50$  mm ( $\approx 5$  cm), rate 100–120/min, and full recoil  $\geq 90\%$ . For interpretability, we report each metric as a continuous value and as a binary indicator (meets/does not meet the adequacy threshold). A compression-quality composite (all three thresholds met simultaneously) was also calculated. The between-group comparison at 6 months was prespecified as the primary analysis; baseline values were summarized to index immediate posttraining acquisition.

### Secondary outcomes

Secondary outcomes were assessed using a structured checklist derived from KACPR guidelines and organized into three domains with predefined score ranges: Recognition and EMS activation (0–6), capturing timely identification of cardiac arrest and activation of emergency medical services; compressions and ventilation (0–14), encompassing correct hand position, adequate depth ( $\geq 50$  mm), rate (100–120/min), full recoil ( $\geq 90\%$ ), minimal interruptions, airway opening, and effective breaths; and AED tasks (0–12), including power-on, correct pad placement, adherence to prompts, and safety checks. Domain scores were summed to a total score of 0–32. Where appropriate, we report effect-size estimates (e.g. mean difference or odds ratio) with 95% confidence intervals (CIs) for domain and total scores.

### Assessment and blinding

At both time points (immediately posttraining in October 2023 and at 6 months in April 2024), blinded certified instructors conducted checklist assessments using a uniform protocol, while sensor data were captured automatically by the manikin system. If two raters independently scored the checklists after calibration, inter-rater agreement ( $\kappa$ ) is reported in the Statistical Analysis or Supplementary Materials.

### Statistical analysis

Analyses were conducted in IBM SPSS Statistics, version 29.0 (IBM Corp., Armonk, NY, USA). All tests were two-sided ( $\alpha = 0.05$ ; exact  $P$  values reported).

Descriptive statistics (mean  $\pm$  standard deviation [SD] or  $n$ , %) summarized characteristics and outcomes. The prespecified primary comparison was the between-group difference at 6 months for chest compression metrics (depth, rate, and full recoil), tested with independent samples  $t$ -tests. Normality (Shapiro–Wilk) and homogeneity of variances (Levene’s) were checked; when variances were unequal, we used Welch’s  $t$ -test. Within-group change from baseline to 6 months was evaluated with paired  $t$ -tests. For checklist domain scores and total score at 6 months, independent samples  $t$ -tests were used, and we report effect sizes with 95% CIs.

### Reporting

We followed the CONSORT guidelines for randomized trials. A CONSORT flow diagram is presented in Figure 2. The refresher intervention is described in the Methods section. Representative captured frames are shown in Figure 1.

### Ethical considerations

This study was approved by the Institutional Review Board of the Seoul Metropolitan Government–Seoul National University Boramae Medical Center (IRB No. 30-2023-85; approval date: June 22, 2023). All participants provided written informed consent, and all procedures complied with the Declaration of Helsinki and applicable institutional regulations. All participants provided written informed consent before enrollment and were assured of voluntary participation, confidentiality, and anonymity. All procedures complied with the Declaration of Helsinki and applicable national/institutional regulations.

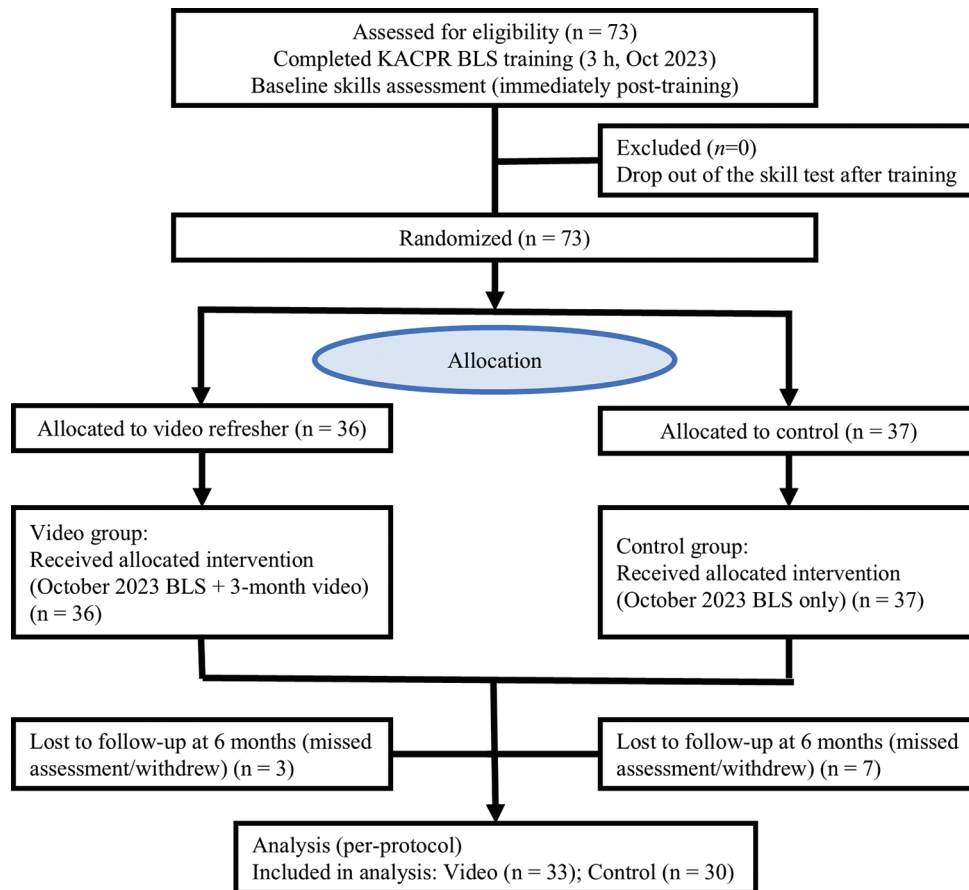
## Results

### Baseline characteristics

Table 1 summarizes baseline characteristics for the video refresher ( $n = 33$ ) and control ( $n = 30$ ) groups. Age (years, mean  $\pm$  SD), sex ( $n$ , %), prior CPR experience ( $n$ , %), and CPR training within the past 12 months ( $n$ , %) were similar between groups. Between-group comparisons used independent samples  $t$ -tests for continuous variables and  $\chi^2$  (or Fisher’s exact, as appropriate) for categorical variables; no statistically significant differences were observed (two-sided  $P > 0.05$  for all comparisons).

### Between-group comparison at 6 months

At the prespecified primary endpoint, 6 months after BLS training, the experimental (video refresher) group ( $n = 33$ ) showed consistently better performance than the control group ( $n = 30$ ) on most checklist domains [Table 2]. For cardiac arrest recognition and EMS activation, the experimental group scored  $5.09 \pm 0.81$  versus  $4.47 \pm 0.78$  in controls, a mean difference of 0.62 (95% CI: 0.23–1.01;



**Figure 2:** CONSORT flow diagram. Seventy-three college students were assessed for eligibility and randomized following October 2023 Basic Life Support (BLS) training to a video refresher group ( $n = 36$ ; BLS plus a 2-min refresher at 3 months) or control ( $n = 37$ ; BLS only). At the 6-month endpoint, 3 (video) and 7 (control) participants did not complete the follow-up assessment. The per-protocol analysis included 33 participants in the video group and 30 in the control group. Outcome assessors were blinded; the prespecified primary endpoint was the 6-month skills' assessment

**Table 1: Homogeneity analysis of baseline characteristics between experimental and control groups**

Characteristics	Experimental group ( $n=33$ , $n$ %)	Control group ( $n=30$ , $n$ %)	<i>P</i>
Age, mean±SD	20.9±1.5	20.7±1.4	0.720
Grade (2 <sup>nd</sup> year)	33 (100)	30 (100)	
Gender			
Male	14 (42.4)	13 (43.3)	0.942
Female	19 (57.6)	17 (56.7)	
Previous CPR experience			
Yes	0	0	N/A
No	33 (100)	30 (100)	
CPR training in the last 2 years	2 (6.1)	3 (10)	0.531

No statistically significant differences were found between groups, indicating baseline homogeneity. CPR: Cardiopulmonary resuscitation, SD: Standard deviation, N/A: Not applicable

$t = 3.094$ ;  $P = 0.003$ ; Hedges  $g = 0.77$ ), indicating a moderate advantage. Chest compressions and ventilation were likewise superior in the experimental group ( $12.18 \pm 1.16$  vs.  $11.47 \pm 1.22$ ), with a mean difference of 0.71 (95% CI: 0.12–1.30;  $t = 2.362$ ;  $P = 0.020$ ;  $g = 0.59$ ), also in

the moderate range and aligned with the study's primary focus on compression quality.

For AED tasks, the experimental group had a higher mean ( $10.30 \pm 1.86$ ) than controls ( $9.83 \pm 1.12$ ), but the difference (0.47) was not statistically significant (95% CI:  $-0.28$ – $1.22$ ;  $t = 1.227$ ;  $P = 0.235$ ;  $g = 0.30$ ), consistent with the interpretation that AED performance remained similar between groups at follow-up. When domain scores were aggregated, the total checklist score ( $0$ – $32$ ) favored the experimental group ( $27.57 \pm 2.38$  vs.  $25.77 \pm 2.29$ ), yielding a mean difference of 1.80 (95% CI:  $0.65$ – $2.95$ ;  $t = 3.058$ ;  $P = 0.002$ ;  $g = 0.76$ ) [Table 2].

## Discussion

### Principal findings

In this single-blind randomized controlled trial of college students, a 2-min video refresher delivered at 3 months produced better 6-month retention of CPR competencies compared with no refresher. The intervention group outperformed controls in cardiac arrest recognition and EMS activation and chest compressions and

**Table 2: Retention of cardiopulmonary resuscitation skills between experimental and control groups at 6 months**

Variables	Experimental ( <i>n</i> =33), mean±SD	Control ( <i>n</i> =30), mean±SD	Mean difference (experimental–control)	95% CI of difference	<i>t</i>	<i>P</i>	Hedges' <i>g</i>
Recognition and EMS	5.09±0.81	4.47±0.78	0.62	0.23 to 1.01	3.094	0.003	0.77
Compressions and ventilation	12.18±1.16	11.47±1.22	0.71	0.12 to 1.30	2.362	0.020	0.59
AED tasks	10.30±1.86	9.83±1.12	0.47	–0.28 to 1.22	1.227	0.235	0.30
Total score (0–32)	27.57±2.38	25.77±2.29	1.8	0.65 to 2.95	3.058	0.002	0.76

Mean difference (Exp–Cont): Experimental group minus control group, 95% CIs are from Independent-samples comparisons, two-sided *P*-values are shown, Hedges' *g* includes small-sample correction. The prespecified primary comparison was at 6 months. EMS: Emergency medical services, AED: Automated external defibrillator, SD: Standard deviation, CIs: Confidence intervals

ventilation with moderate effect sizes, whereas AED task performance did not differ between groups at follow-up (*P* = 0.235). These results support a low-dose, low-cost strategy to mitigate the well-documented decline in CPR skills during the critical 3–6-month interval after training.

### Retention of cardiopulmonary resuscitation skills

The intervention group's superior performance in cardiac arrest recognition and EMS activation underscores the value of reinforcing early cognitive/decision steps that initiate the chain of survival in out-of-hospital cardiac arrest.<sup>[18]</sup> Brief, targeted videos can refresh declarative knowledge and procedural sequencing, helping to avert early decay; given the established link between prompt recognition and EMS activation and improved outcomes,<sup>[19]</sup> a scalable, on-demand video approach is well-suited to broad implementation.<sup>[20]</sup>

For psychomotor performance, the intervention group retained higher quality in chest compressions and ventilation, domains that are central to maintaining perfusion.<sup>[21]</sup> In our trial, performance was tracked not only by checklist items but also by objective sensor-based metrics aligned with guideline targets – depth ≈ 50 mm (≈ 5 cm), rate 100–120/min, and full recoil – supporting the interpretation that the refresher improved compression quality rather than merely checklist completion. These findings are consistent with prior work documenting rapid skill decay within months of training<sup>[7-9]</sup> while highlighting that a 2-min, spaced video refresher can meaningfully mitigate this decline in a nonhealthcare student population.

The flexibility and adaptability of video refreshers further strengthen their utility. Prior research among nurses has shown video-based CPR self-learning to achieve outcomes comparable to instructor-led formats,<sup>[22]</sup> and asynchronous access allows learners to review content when schedules permit – an advantage for college students with variable commitments.

Notably, AED task performance did not differ significantly between groups at 6 months. This pattern is plausible given the intuitive, prompt-driven

interface of modern AEDs, which can standardize key steps (power-on, pad placement, and “stand clear” prompts) and thereby compress between-group variability even without refreshers.<sup>[23,24]</sup> Two additional factors may have contributed: (i) a ceiling effect, because many AED checklist items are binary and quickly mastered at baseline, and (ii) outcome insensitivity, since our domain score did not capture time-critical subcomponents (e.g. time-to-pad placement or time-to-first analysis/shock) that might be more responsive to brief video cues. Furthermore, the trial may have been underpowered for AED outcomes relative to compression–ventilation (larger SDs with similar sample size), making small advantages harder to detect. Looking ahead, repeated microrefreshers focused on pad placement landmarks, safety clearing, and minimizing hands-off intervals – paired with objective time metrics – may better elucidate AED-specific benefits while complementing improvements in recognition and compression quality documented here.

### Implications for cardiopulmonary resuscitation training

The findings of this study have significant implications for CPR training strategies, particularly for nonhealthcare populations. College students represent a vital demographic due to their frequent presence in public spaces where sudden cardiac arrests may occur.<sup>[12]</sup> However, as demonstrated in this study, CPR skills tend to decline rapidly without ongoing reinforcement, underscoring the need for sustainable strategies to maintain proficiency. Short, video-based refreshers scheduled at the 3-month mark – when decay accelerates – offer a practical way to deliver “spaced” reinforcement without additional in-person sessions. Video-based refreshers provide an accessible, cost-effective, and scalable approach, allowing learners to revisit core CPR procedures on demand without requiring repeated in-person instruction.<sup>[7]</sup> Programs can embed brief reminders (e.g. LMS/email/text) with one-click access to a 2-min clip and pair refreshers with quick, objective manikin checks when feasible, minimizing faculty time while maintaining quality.

The flexibility of such digital interventions is well aligned with the growing adoption of online learning

platforms in higher education.<sup>[25]</sup> As universities and colleges increasingly incorporate digital content into curricula, integrating video CPR refreshers offers a practical method to sustain life-saving competencies.<sup>[21]</sup> Institutions can operationalize this model by (i) integrating refresher links within existing BLS modules, (ii) automating semester-based prompts at ~ 3 months posttraining, and (iii) capturing simple process indicators (e.g. completion tick and optional play count) to support quality improvement without creating learner burden. This model can be expanded beyond educational institutions into other sectors – including corporate settings and community organizations – where structured CPR retraining may not be feasible. Where resources permit, interactive add-ons (e.g. brief quizzes, microscenarios, or VR “quick drills”) can be offered as optional layers to enhance engagement, while keeping the core intervention ultra-brief. The evolving digital landscape also presents opportunities to enhance learning through interactive features, such as virtual reality simulations, gamified assessments, or adaptive quizzes, which may further improve retention and engagement.

Furthermore, the simplicity and low implementation cost of video-based refreshers make them particularly suitable for deployment in underserved or resource-limited communities.<sup>[26]</sup> In such settings, where access to formal CPR training programs is often constrained, digital solutions can bridge gaps in emergency preparedness. Equity-oriented rollouts can leverage campus Wi-Fi kiosks, shared devices, or offline-capable clips to reduce access barriers and emphasize low-bandwidth formats to widen reach. With increasing availability of AEDs in public spaces, it is critical that bystanders – not only recognize cardiac arrest but also initiate effective CPR – regardless of prior medical training or background. Scalable, low-barrier interventions like video refreshers could play a pivotal role in improving bystander response and, ultimately, survival rates from out-of-hospital cardiac arrest.

### Limitations

This single-institution trial in 2<sup>nd</sup>-year college students (South Korea) limits generalizability to other age groups, settings, or training levels. We did not track video-viewing frequency, so dose–response effects of exposure could not be evaluated. Primary analyses were per-protocol, and outcomes were proximal (checklist and sensor metrics); in addition, the AED domain did not include time-to-event measures (e.g. time-to-pad placement). The study was single-blind, which may allow expectancy effects despite assessor blinding and objective sensors. Finally, we did not adjust for multiplicity in secondary/exploratory tests, and the optimal dose/timing of microrefreshers remains

uncertain – points to be addressed in larger, multisite trials.

## Conclusion

In this single-blind randomized controlled trial of college students, a 2-min video refresher delivered 3 months after BLS training was associated with better 6-month retention of CPR competencies – particularly cardiac arrest recognition, EMS activation, and chest compression performance – compared with no refresher. AED task performance did not differ between groups, consistent with the prompt-driven design of modern devices, and underscores the value of reinforcing manual CPR components. Given its brevity, low cost, and scalability, integrating brief, targeted video refreshers into existing CPR curricula is a practical approach to bolster bystander readiness and public preparedness for out-of-hospital cardiac arrest. Future work should optimize dose and timing (e.g. scheduled microrefreshers), incorporate time-sensitive process measures (e.g. time-to-pad placement), and evaluate long-term effectiveness across diverse settings.

### Author contributions statement

- Kyeongmin Jang: Conceptualization; Methodology; Investigation; Data curation; Formal analysis; Writing – original draft; Writing – review and editing; Supervision
- Sung Hwan Kim: Investigation; Data curation; Writing – review and editing; Visualization.

All authors met ICMJE authorship criteria and approved the final manuscript.

### Conflicts of interest

None Declared.

### Ethical statement

Approved by Seoul Metropolitan Government–Seoul National University Boramae Medical Center Institutional Review Board (IRB No. 30-2023-85; approval date: June 22, 2023). Written informed consent was obtained from all participants.

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None.

### Video legend

**Video 1:** Refresher video.

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