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Comparing Self-Learning Skill Stations and Instructor-Led Courses for Cardiopulmonary Resuscitation Skill Retention Among Hospital Nurses: A Randomized Controlled Trial

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Abstract

In-hospital cardiac arrest remains associated with high mortality, and effective cardiopulmonary resuscitation (CPR) is critical for patient survival. Conventional instructor-led (IL) CPR courses demand considerable resources, whereas automated, feedback-driven skill stations (SS) may offer a practical alternative for frequent skills maintenance. This study investigated whether CPR performance differs between IL and SS training approaches. One hundred twenty-nine hospital nurses were randomized into three retraining strategies: skill station with 2-month refresher (SS-R), skill station without refresher (SS), and instructor-led training (IL). Assessments were conducted at baseline, 2 months, and 8 months. For initial comparisons, the two SS groups were pooled (c-SS) when compared to IL. Despite differences in baseline characteristics across groups, pooled SS and IL participants demonstrated similar CPR performance at baseline and at 2 months. At 8 months, the SS group achieved a higher proportion of correct ventilations (71%) than the IL group (54%; $p = 0.04$), while overall CPR quality remained comparable. Longitudinally, SS-R participants increased compression depth by 3.4 mm from baseline ($p = 0.02$) and by 2.8 mm relative to the 2-month assessment ($p = 0.02$). Retraining at 2 months did not result in significant differences between SS-R and SS at the final evaluation. Automated skill stations with real-time feedback support CPR performance equivalent to instructor-led courses over 8 months. These stations may provide a scalable solution for ongoing CPR skill retention in hospital settings.

Keywords: CPR, Self-directed learning, Instructor-led training, Skill retention, Technical skills, Resuscitation, Randomized trial

Introduction

In-hospital cardiac arrest remains a major cause of hospital mortality, with survival to discharge estimated at approximately 25% and a one-year adjusted survival rate around 13% [1,2]. Over the past decades, improvements in both resuscitation techniques and post-resuscitation care have enhanced outcomes, especially in patients with non-shockable rhythms. Prompt and high-quality cardiopulmonary resuscitation (CPR) is widely recognized as a key determinant of both short- and long-term survival [3]. International guidelines, including those from the International Liaison Committee on Resuscitation (ILCOR) and the European Resuscitation Council (ERC), highlight not only the standards for high-quality CPR but also the critical role of training, education, and implementation in clinical practice [4–6].Conventional instructor-led CPR training is labor-intensive and costly, creating a demand for alternative approaches that maintain effectiveness while reducing resource requirements [7]. Skill retention is another challenge, as CPR abilities decline over time, although the exact pattern of this deterioration is not fully defined [8–11].

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Feedback-driven, instructor-free CPR skill stations (SS) offer a potential solution to facilitate frequent and accessible retraining within hospital environments. The primary aim of this study was to examine the null hypothesis that performance following SS training does not differ from traditional instructor-led (IL) CPR training. Secondary objectives included evaluating skill retention at 2 and 8 months and assessing the impact of an additional retraining session at 2 months.

Materials and Methods

Study design

This investigation was structured as a randomized controlled trial with a superiority framework and was carried out between September 2010 and July 2011. Approval for the study was granted by the Norwegian Centre for Research Data (NSD, application no. 18-878), and all participants provided written informed consent prior to enrollment.

Participants were initially organized by hospital ward and then randomly allocated to one of three training interventions using a lottery method conducted by PCJ and TH. A priori power analysis indicated that 40 participants per group were required to detect a clinically significant 20% difference in chest compression depth, with 80% power (β = 0.8) and a significance threshold of 0.05 (α = 0.05).

The three study groups were as follows: the first received skill station training with a refresher session at 2 months (SS-R), the second completed skill station training without any retraining (SS), and the third participated in conventional instructor-led CPR training (IL). A schematic overview of the study design is provided in **Figure 1**.

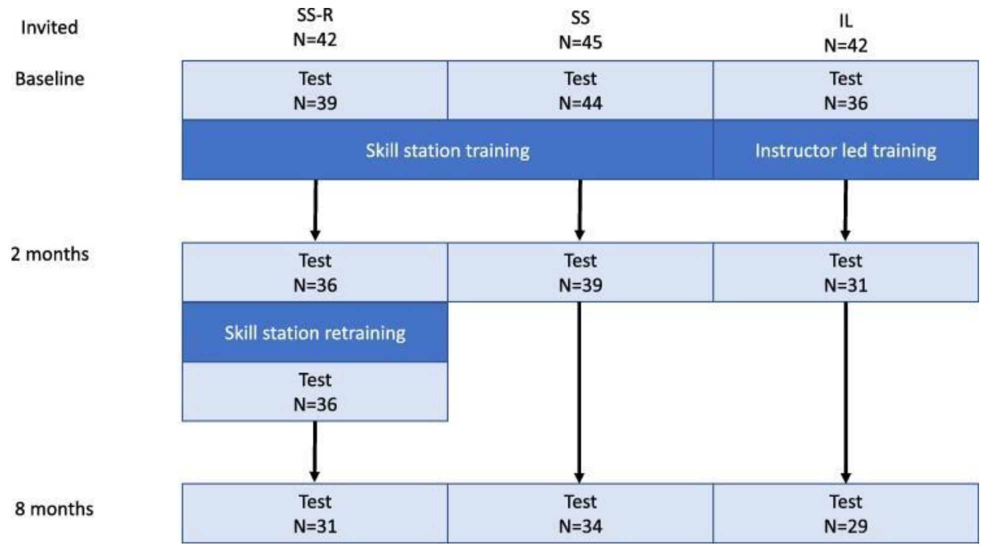

Figure 1. Study Flow and Training Allocation

Participating nurses were randomized by ward into three groups: skill station training with a 2-month refresher (SS-R), skill station training without a refresher (SS), and conventional instructor-led training (IL). Reasons for loss to follow-up were not documented.

Skill station training

Training was conducted using the Rescue Anne Skill Station (Laerdal Medical AS, Stavanger, Norway), an automated CPR training system that does not require a human instructor. The system includes a screen-based instructional module, a manikin with embedded sensors, and real-time voice feedback. Training followed previously described protocols [12]. Participants practiced chest compressions and ventilations separately, receiving automated feedback until they achieved satisfactory performance, followed by a minimum of three full CPR cycles. After completing the session, participants could proceed directly to testing or continue practicing. All performance data and adherence to the CPR algorithm were automatically recorded by the system.

Instructor-Led training

The IL group received a 120-minute theoretical and practical CPR course following hospital protocol. Instructors were experienced (>5 years) anesthetic or intensive care nurses or paramedics from Ålesund Hospital, certified by the Norwegian Resuscitation Council in Basic and Advanced CPR.

Blinding and outcomes

Participant blinding was not possible due to the nature of the interventions. The primary outcome was chest compression depth, with a 20% increase predefined as clinically relevant. Secondary outcomes included compression rate, proportion of correct compressions, hands-off time, leaning, ventilation volume, ventilation duration, proportion of correct ventilations, and overall test pass rate.

Testing schedule

All participants were assessed at baseline, 2 months, and 8 months using the skill station without feedback. Each test consisted of four rounds of single-rescuer CPR at a 30:2 ratio; the last three rounds were used for analysis. An instructor provided a standardized introduction to the skill station at baseline but offered no additional CPR instruction.

Follow-Up and comparisons

The final assessment occurred at 8 months post-baseline. For SS and IL groups, this corresponded to 8 months after the last CPR training, whereas SS-R participants were tested 6 months after their 2-month refresher. Comparisons between SS-R and SS allowed evaluation of the retraining effect. To increase statistical power, SS-R and SS were pooled into a combined SS group (c-SS) for baseline and 2-month comparisons with IL. For the final assessment, only SS and IL were compared to avoid confounding from the 2-month retraining.

Study population

A total of 129 registered nurses were enrolled from seven wards at Ålesund Hospital, deliberately selected to represent diverse clinical areas. Of those approached, 119 (92.2%) completed the initial assessment. Further details on participant demographics are provided in Table 1. Every nurse had previously undergone the hospital's routine basic CPR course, which was conducted in an instructor-led format. Over the study period, participant numbers gradually decreased because of drop-out (no reasons were documented), resulting in final group sizes of 31 (SS-R), 34 (SS), and 29 (IL) at the 8-month assessment.

Table 1. Baseline characteristics of the three study arms: skill station with 2-month retraining (SS-R), skill station without retraining (SS), and conventional instructor-led training (IL). All participants had completed the hospital's standard instructor-led basic CPR training prior to enrolment

	Skill station retraining (SS-R)	Skill station (SS)	Instructor-led (IL)	p-value
Participants tested at baseline	39	44	36	
Age, mean (SD), years	40.7 (10.6)	41.0 (11.0)	36.3 (11.2)	0.12
Gender, male:female (male proportion)	2:37 (5%)	2:42 (5%)	3:33 (9%)	0.75
Months since previous standard CPR course, mean (SD)	8 (10)	14 (8)	11 (7)	0.02
Lost to follow-up by 2 months, n (%)	3 (7.7%)	5 (11.4%)	3 (8.3%)	0.83
Additional loss to follow-up by 8 months (total 6 months after baseline), n (%)	6 (15.4%)	8 (18.2%)	8 (22.2%)	0.75

CPR performance measures

All CPR data were captured automatically by the skill station and later extracted for analysis. The key metrics recorded included compression rate (per minute), compression depth (mm), full chest recoil, percentage of compressions meeting guideline criteria (depth 41–63 mm, rate 90–120/min, recoil with ≤7 mm leaning), ventilation volume (mL), percentage of ventilations within target range (400–1000 mL), hands-off time per cycle (ms), and correct ventilation timing (inflation 0.5–2 s, 2-second pause, total hands-off ≤15 s per cycle). An overall pass was awarded if the participant scored >0.7 and successfully delivered three cycles of approximately 30 adequate compressions (27–35 allowed) followed by two correct ventilations with acceptable interruptions and no excessive leaning.

Statistical methods

Group means were compared using independent-samples t-tests and changes within the same group over time were evaluated with paired t-tests. Categorical outcomes were analysed with chi-square tests. Continuous variables are presented as mean ± SD; categorical variables as counts and proportions. No adjustment for multiple comparisons was made. Analyses were carried out in Stata 15.0.

Results and Discussion

Pre-Intervention (Baseline) performance

Testing was performed just before the assigned training intervention. Because randomisation was unstratified, the interval since the last routine CPR course varied across groups **(Table 1)**: on average 8 months in the SS-R group, 14 months in the SS group, and 11 months in the IL group (N = 119, $p = 0.02$).
Detailed baseline results appear in **Table 2**. Before any study training, the groups already showed notable differences in several parameters: average compression rate (102/min in SS-R, 112/min in SS, 106/min in IL; $p = 0.03$), percentage of guideline-compliant compressions (40%, 20%, and 40%, respectively; $p = 0.03$), average ventilation volume (649 mL, 613 mL, and 875 mL; $p = 0.001$), percentage of correct ventilations (70%, 40%, and 40%; $p < 0.001$), and the proportion who passed the test outright (5 of 39, 0 of 44, and 1 of 36; $p = 0.02$). Compression depth and hands-off time were comparable across groups at this point.
Table 2. Overview of CPR performance metrics for chest compressions, ventilations, and overall test outcomes across the three study groups: skill station with 2-month retraining (SS-R), skill station without retraining (SS), and instructor-led training (IL). Measurements are shown at baseline, 2-month, and 8-month assessments. Data for the SS-R group immediately following the 2-month refresher are also included. Longitudinal comparisons were performed using paired-samples t-tests; $p < 0.05$, $p < 0.01$, and *$p < 0.001$ indicate statistical significance.

Table 2. CPR performance metrics for chest compressions, ventilations, and overall test outcomes

		Group	Baseline	2 months	2 months versus baseline (p-values)	2 months test following retraining	2 months test versus retest (p-values)	8 months	8 months versus baseline (p-values)	8 months versus 2 months (p-values)
Compressions	Frequency compressions pr min.	SS-R	102 (16.1)	100 (8.1)	*0.94*	105 (7.6)	*0.001***	98 (11.0)	*0.54*	*0.60*
		SS	112 (18.8)	111 (11.4)	*0.87*			111 (11.8)	*0.90*	*0.88*
		IL	106 (18.6)	108 (11.7)	*0.89*			106 (17.1)	*0.16*	*0.10*
	Depth mm	SS-R	44.4 (8.6)	45.0 (6.4)	*0.66*	48.7 (4.3)	*<0.001****	47.8 (6.6)	*0.02**	*0.02**
		SS	45.8 (7.9)	45.7(7.9)	*0.36*			46.6 (8.7)	*0.20*	*0.71*
		IL	46.3 (7.8)	44.9 (7.6)	*0.72*			45.8 (9.5)	*0.53*	*0.85*
	Proportion of compressions with leaning	SS-R	0.049 (0.10)	0.001 (0.01)	*0.03**	0.002 (0.01)	*0.52*	0.006 (0.02)	*0.05*	*0.24*
		SS	0.052 (0.18)	0.012 (0.05)	*0.14*			0.013 (0.06)	*0.08*	*0.98*
		IL	0.005 (0.01)	0.013 (0.06)	*0.49*			0.031 (0.12)	*0.24*	*0.13*
	Proportion correct compressions	SS-R	0.39 (0.36)	0.57 (0.36)	*0.05*	0.96 (0.05)	*<0.001****	0.45 (0.37)	*0.49*	*0.08*
		SS	0.21 (0.26)	0.47 (0.41)	*0.001***			0.43 (0.04)	*0.008***	*0.65*
		IL	0.36 (0.37)	0.46 (0.37)	*0.15*			0.34 (0.40)	*0.44*	*0.09*
Ventilations	Volume ml	SS-R	649 (270)	591 (221)	*0.24*	716 (145)	*<0.001****	646 (183)	*0.84*	*0.06*
		SS	614 (334)	629 (196)	*0.32*			649 (198)	*0.05*	*0.53*
		IL	875 (382)	723 (316)	*0.04**			697 (261)	*0.01**	*0.66*
	Proportion correct ventilation time	SS-R	0.85 (0.22)	0.83 (0.28)	*0.70*	0.94 (0.18)	*0.02**	0.87 (0.15)	*0.694*	*0.18*
		SS	0.70 (0.31)	0.88 (0.19)	*0.003***			0.80 (0.26)	*0.047**	*0.13*
		IL	0.80 (0.30)	0.80 (0.34)	*0.77*			0.73 (0.30)	*0.40*	*0.27*
	Proportion correct ventilations	SS-R	0.71 (0.29)	0.71 (0.32)	*0.91*	0.91 (0.19)	*<0.001****	0.75 (0.24)	*0.60*	*0.31*
		SS	0.41 (0.31)	0.72 (0.34)	*<0.001****			0.71 (0.31)	*0.001***	*0.92*
		IL	0.40 (0.37)	0.65 (0.38)	*0.01**			0.54 (0.36)	*0.16*	*0.11*
	Hands-off time ms	SS-R	10488 (3643)	9709 (2241)	*0.34*	8966 (3030)	*0.10*	9894 (3416)	*0.60*	*0.37*
		SS	12286 (5372)	9886 (3794)	*0.01**			9811 (2312)	*0.002***	*0.70*
		IL	11135 (4330)	9739 (3867)	*0.12*			10310 (3965)	*0.26*	*0.58*
Passed test	N (%)	SS-R	5/39 (12.8%)	8/36 (22.2%)	*0.28*	35/36 (97.2%)	*<0.001****	5/31 (16.1%)	*0.69*	*0.53*
		SS	0/44 (0.0%)	8/39 (20.5%)	*0.001***			6/34 (17.6%)	*0.004***	*0.63*
		IL	1/36 (2.7%)	6/31 (19.3%)	*0.03**			2/29 (6.9%)	*0.43*	*0.17*

The combined skill station group c-SS was statistically equal to IL at baseline with the exception of mean proportion of correct ventilations (N = 119, $p = 0.02$)

Skill retention
Participants were reassessed for CPR skill retention two months after their initial training. Across most performance metrics, there were no significant differences between the combined skill station groups (c-SS) and the instructor-led group (IL). The only exception was mean ventilation volume, which, while adequate in both groups, was higher in the IL group (723 mL vs. 610 mL; N = 106, $p = 0.03$). The overall proportion of participants who passed the test did not differ significantly between c-SS and IL (16/75 vs. 6/31, $p = 0.69$).
At the 8-month follow-up, the SS-R and SS groups performed similarly for most CPR parameters, except that SS-R demonstrated a lower mean compression rate (98 vs. 111 compressions/min; N = 65, $p < 0.001$). In longitudinal intragroup comparisons, compression rates remained stable across all groups. Notably, SS-R was the only group to show a significant increase in compression depth over time, achieving 3.4 mm deeper compressions (7.6% increase; N = 36, $p = 0.02$) compared to baseline and 2.8 mm deeper (6.3% increase; N = 31, $p = 0.02$) relative to the 2-month assessment. Overall, the 2-month refresher did not produce additional measurable benefits in the final evaluation.
When comparing final 8-month outcomes between SS and IL, the SS group achieved a higher proportion of correct ventilations (71% vs. 54%; N = 63, $p = 0.04$), while all other CPR performance metrics were statistically comparable.

Skill performance immediately following retraining

As per the study protocol, the SS-R group received an additional instructor-free skill station session immediately after the 2-month test. Performance assessment immediately post-retraining revealed marked improvements across all measured parameters. The number of participants passing the test increased dramatically, from 8/36 before retraining to 35/36 immediately afterward, as summarized in **Table 2**.

The primary finding of this study is that hospital nurses who underwent CPR recertification via a skill station demonstrated comparable performance to those trained through traditional instructor-led sessions, both at 2 and 8 months post-training. Skill retention at the 2-month mark was notably consistent across groups, with roughly 20% of participants meeting the test criteria regardless of the training method. Apart from ventilation volumes, all other measured parameters showed no significant differences between the groups at this time point.

The main objective of this trial was to determine whether chest compression quality could be significantly improved, as both compression depth and rate are crucial determinants of successful resuscitation and post-arrest outcomes. Notably, the 2010 ILCOR and ERC guidelines were published shortly after the start of this study and emphasized a stronger focus on compressions, recommending rates above 100 per minute and a depth exceeding 5 cm, which are stricter than the metrics used here [13, 14]. Later evidence suggests that even a 5 mm difference in compression depth can influence survival and favorable outcomes [15]. Given this, the current study was underpowered to detect smaller differences, such as a 10% variation between groups.

At the 8-month follow-up, most CPR performance measures remained similar across groups. An exception was the proportion of correct ventilations, which was higher in the SS group compared to IL. Overall test pass rates at this point were modest—approximately 17% for SS-R and SS versus 7% for IL—but these differences were not statistically significant. A pooled comparison of c-SS versus IL at this stage was not conducted to avoid potential bias, as half of the participants had received a retraining session at 2 months.

The relatively low pass rates observed may reflect the strict criteria applied by the automated skill assessment system, which, although more precise than human observers, tends to be less lenient [16]. Real-world studies also indicate that CPR quality often falls below guideline standards [17, 18]. Comparing results across studies is challenging due to variability in assessment timing and reported outcomes, highlighting the need for standardized reporting in CPR skill research [8, 19].

It is well established that CPR technical skills are acquired rapidly immediately after training, a pattern clearly demonstrated in this study for the SS-R group following the 2-month refresher. However, these skills deteriorate over time, typically returning to baseline within approximately one year [20, 21]. While this study was not designed to determine optimal retraining intervals, the findings provide insight into skill decay. Performance at 2 months exceeded baseline levels, while results at the 8-month evaluation generally fell between baseline and 2-month values, consistent with previous reviews suggesting rapid skill decline between 6 weeks and 6 months post-training [8].

Interestingly, the SS group, which had the longest average interval since previous CPR training (14 months), was the only group to demonstrate a significant improvement at 8 months compared to baseline. Conversely, among baseline test passers, 5 of 6 participants had the shortest interval since last retraining (SS-R group, 8 months), emphasizing the importance of frequent refreshers for maintaining high-quality CPR skills.

Previous research has shown that CPR skill stations are effective for initial skill acquisition and for identifying health professionals in need of retraining [22, 23]. Short, periodic refresher sessions between standard courses can improve skill retention for up to a year [24], and automated skill stations may offer a practical method for maintaining competence through brief, frequent practice sessions, such as monthly or every 2–3 months [25,26]. Although the overall level of evidence remains limited, current recommendations support integrating CPR training with feedback, debriefing, and performance monitoring to optimize skill retention and quality [19].

The study was not registered on ClinicalTrials.gov or other trial registries, as registration was not a requirement at the time of its initiation and conduct. Another limitation was that randomization of participants resulted in uneven groups with respect to the time since their last CPR training, leading to significant differences in baseline CPR skill levels. Although compression rates varied between groups at baseline, all remained within guideline-recommended ranges, suggesting that this difference was not clinically meaningful. When the skill station groups were combined into a pooled c-SS group and compared to the instructor-led (IL) group, performance was similar both at baseline and at the 2-month assessment. Moreover, two months after retraining, skill performance was equivalent across groups despite initial differences at baseline.

Additional limitations include the absence of correction for multiple testing, which could increase the risk of type I errors. Furthermore, higher-than-expected attrition at the 8-month follow-up resulted in smaller group sizes than the target of 40 participants per group, reducing statistical power for the final evaluation. Previous discussions have suggested that variability in CPR instructor performance could contribute to poor skill retention [27]; however, all instructors in this study were highly experienced and followed national life support recertification standards.

Conclusion

Hospital nurses who received CPR retraining via skill stations demonstrated similar performance at both 2 and 8 months compared with those trained using conventional instructor-led sessions. The only notable difference was a higher proportion of correct ventilations in the skill station group at 8 months. Immediate post-retraining performance was strong, but skills declined rapidly thereafter, consistent with previous findings. At 2 months, the overall test pass rate was approximately 20%. Feedback-enabled skill stations appear to be a feasible approach to support the frequent retraining necessary to maintain high-quality CPR. While the optimal retraining interval remains undetermined, short refresher sessions between standard CPR courses warrant further investigation as a potential strategy to improve skill retention.

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