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Simulation and education

Effects of monthly practice on nursing students' CPR psychomotor skill performance☆

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ABSTRACT

Aims: The study examined the effects of brief monthly practice on nursing students' CPR psychomotor skill performance at 3, 6, 9, and 12 months compared to a control group with no practice, and of repeating the initial BLS course at 12 months.
Methods: Nursing students ($n = 606$) completed either HeartCode™ BLS or an instructor-led course and were then randomly assigned to an intervention group practice schedule, consisting of experimental (6 min of monthly practice on a voice advisory manikin) or control (no practice) and test out month. Every 3 months, a subset of students was randomly selected from both groups for reassessment of their CPR psychomotor skills. Outcome measures were compression rate and depth, percent of compressions performed with adequate depth, percent performed with correct hand placement, ventilation rate and volume, and percent of ventilations with adequate volume.
Results: At 3 months, there were no differences between the groups in mean ventilation volume ($p = 0.71$), but with practice by 6 months students were able to ventilate with an adequate volume; this skill continued to improve with monthly practice. In the control group, the mean ventilation volumes were less than the recommended minimum throughout the 12 months. The control group had a significant loss of ability to compress with adequate depth between 9 and 12 months ($p = 0.004$). By practicing only 6 min a month, students maintained or improved their CPR skills over the 12-month period.
Conclusion: The findings confirmed the importance of practicing CPR psychomotor skills to retain them and also revealed that short monthly practices could improve skills over baseline.

Studies have documented that the quality of cardiopulmonary resuscitation (CPR) by nurses and physicians is often poor, even when they have been trained in CPR.[1–6] While poor performance of CPR may be due to ineffective initial training, it is more likely the result of a lack of retention of skills. Without refreshers and practice, CPR skills are not retained over time.[7–10] Smith et al.[11] evaluated registered nurses' (RNs) ($n = 133$) retention of basic life support (BLS) and Advanced Cardiovascular Life Support (ACLS) skills after initial training: RNs retained their skills in BLS for a short time, only 3–6 months, followed by continued deterioration of those skills.

These findings are consistent with a meta-analysis on skill decay that revealed a loss of acquired skills from nonuse or a lack of practice of them.[12] In many clinical settings, nurses, physicians, and other providers use CPR skills infrequently and need periodic practice and reassessment of those skills. Studies suggest that practice of CPR skills on voice advisory manikins (VAMs) is effective for skill acquisition and retention.[13–19] Using a portable manikin with automated corrective feedback, nurses, physicians, and other staffs ($n = 420$) in PICU refreshed their CPR skills on a monthly basis.[20] The practice sessions were brief, less than 5 min. Assessment of the skills of 20 providers showed that the time to competently perform CPR skills was significantly less among providers who refreshed two or more times/months than those who refreshed less frequently. In the Public Access Defibrillation (PAD) trial, short retraining sessions enabled laypersons to maintain their CPR skills.[8]

Few studies have examined the outcomes of short practice sessions on retention of CPR skills, and none of this research has been done with nursing students. The primary aim of this study was to examine the effects of brief monthly practice (6 min) on nursing students' CPR psychomotor skill performance at 3, 6, 9, and 12 months compared to a control group with no practice sessions. A secondary aim was to examine the effect on psychomotor skills of repeating the initial BLS course at 12 months. Outcome measures were (1) compression rate (avg/min), (2) compression depth (mm), (3) percent of compressions performed

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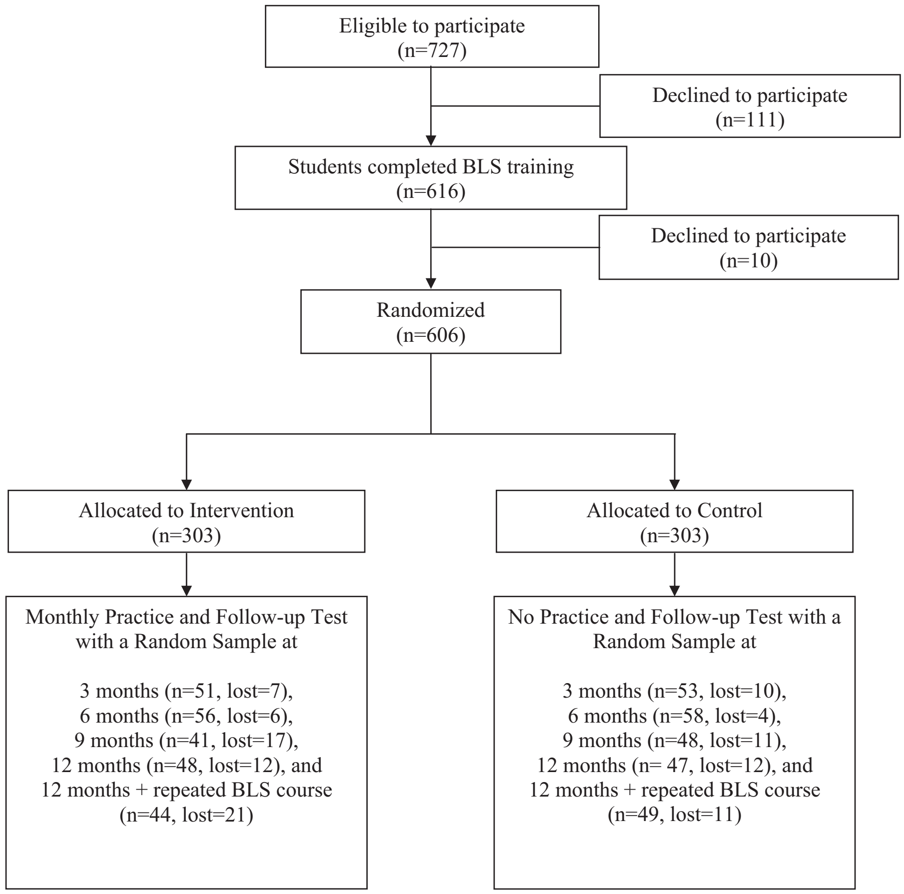

Fig. 1. Participants' progress in the study.

with adequate depth, (4) percent of compressions performed with correct hand placement, (5) ventilation rate (avg/min), (6) ventilation volume (ml), and (7) percent of ventilations with adequate volume.

1. Methods

This randomized trial was conducted over one year to examine the effects of brief practice of CPR skills on performance. Ten volunteer schools of nursing from across the United States were randomized into one of the two types of American Heart Association BLS Healthcare Provider courses: (1) HeartCode™ BLS with VAM feedback or (2) standard instructor-led (IL) training with traditional manikins.[21,22] Of the 727 eligible nursing students, 83% ($n = 606$) completed the CPR training randomized to their school and were then randomly assigned (with equal probability) to an intervention group practice schedule, consisting of experimental (6 min of monthly practice on a VAM) or control (no practice) and test out month. Every 3 months, a subset of students was randomly selected from both groups for reassessment of their CPR psychomotor skills. Thus, students' CPR skills were evaluated at 3, 6, 9, or 12 months; the final group of participants (12R) remaining at the end of the study repeated their initial BLS course (either the HeartCode or IL) and were then reassessed on their psychomotor skills. Participation in the study ended as each of the subsets of students was reassessed because the testing simulated a practice session. Fig. 1 shows the number of participants randomized and number lost prior to reassessment ($n = 111$) for all 10 groups (experimental or control for each of 5 reassessment times).

1.1. Participants

The participants were beginning nursing students enrolled in diploma (13%), associate degree (44%), and baccalaureate (43%) nursing programs. They were predominantly female, with 44 (15.8%) male students in the experimental group and 41 (15.4%) in the control group. This multi-site study was approved by the University's Institutional Review Board. Each student provided written consent to participate in it.

1.2. Intervention groups

Students randomly assigned to the experimental group practice schedule went to the skills laboratory in their school of nursing each month and practiced their CPR skills on sensored Resusci Anne™ adult manikins (Laerdal Medical, Stavanger, Norway) for 6 min total—2 min each of compressions, ventilations with bag-valve-mask (BVM), and single rescuer CPR. Because there were usually multiple students in the skills laboratory, participants used headphones to hear the feedback from the VAM and avoid being distracted by others. Students practiced their CPR psychomotor skills using only the verbal feedback and prompts from the VAM. Site coordinators ensured that the study protocol was followed but did not guide students during practice sessions. The control group students were not assigned to any additional CPR practice sessions.

In the initial BLS training, two types of manikins were used in the IL courses: Resusci Anne® (Laerdal, Stavangar, Norway) labeled as Manikin A and manikins with a hard molded face, nose, and breastplate labeled as Manikin B. The Resusci Anne Manikin (A)

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had the same design as the VAMs in the HeartCode™ BLS course. We adjusted for this with our data analysis at baseline.[21]

1.3. Assessment of CPR psychomotor skills

For the skills reassessment, students performed 3 min each of compressions, ventilations with BVM, and single rescuer CPR at all of the time points using a Laerdal Resusci Anne SkillReporter™ manikin. Performance was evaluated based on compression rate and depth (between 38 and 51 mm),[23] percent of compressions performed with adequate depth, percent of compressions performed with correct hand placement, ventilation rate and volume (between 500 and 800 ml), and percent of ventilations with adequate volume. The data were collected via the SkillReporter software and sent electronically to the data center.

1.4. Data analysis

Data were summarized as means (standard deviation) for continuous measures and as frequencies (%) for categorical measures. Demographics between the experimental and control groups and between participants who completed and terminated early from the study were summarized and compared using the independent *t*-test and Chi-square test. For each CPR outcome measure, linear mixed models were run to examine the influence of intervention group practice schedule (experimental or control), course type (HeartCode, IL manikin type A, and IL manikin type B), reassessment time (3, 6, 9, 12, or 12R months), and all corresponding two-way interaction terms. Students' baseline values were included as a covariate in the model to adjust for differences at baseline. School was modeled as a nested factor within course type.

For each CPR outcome measure, the initial models examined included the baseline demographic variables as well as two-way interaction terms. Non-significant model terms and interactions were eliminated. The final model included fixed effects for intervention group, reassessment time, and the intervention × reassessment time interaction with baseline values and course type as covariates. Although no differences in CPR outcomes at test out were found between the two course type groups (HeartCode and IL manikin types A and B), this factor was included in the final model to ensure that all assessments of the intervention were adjusted for course type. For outcomes with a significant interaction term between intervention and reassessment time, stratified analyses comparing groups at each test out month and comparing test out months for each group were performed including an adjustment for multiple comparisons.

For the 111 participants who dropped out of the study prior to final testing and for 21 participants with partially incomplete testing results, missing data were imputed using the Markov Chain Monte Carlo (MCMC) method with a single chain and Jeffreys priors. The baseline and test out data along with attribute variables (intervention group, course type, reassessment time) were used as predictors of the missing data. This process allowed final models to be based on data for all 606 participants. For CPR outcomes, a square root transformation or arcsine transformation (for outcomes expressed as percentages) was used to obtain normality. All significance testing was done at 0.05 level (two-sided) and using the SAS software (version 9.1; *t*-test [PROC TTEST], Chi-square tests [PROC FREQ], mixed linear models analysis [PROC MIXED], and imputation for missing data [PROC MI]).

2. Results

The demographic background of participants in the experimental and control groups (respectively) was comparable: age (years), 28.7 ± 9.7, 27.4 ± 8.2; previous CPR course, *n* (%) 264 (87.7), 274 (91.0); currently certified, *n* (%) 232 (76.8), 241 (80.1); and performed CPR in an actual resuscitation, *n* (%) 18 (6.2), 19 (6.4). Students who completed the study, and were reassessed at 3, 6, 9, 12, or 12R months, were similar in demographic background to participants who terminated the study early; the only difference was a slightly lower percentage of prior CPR certification among participants who withdrew compared to those who completed the study (82.4% vs. 90.9% respectively, $p = 0.03$). As anticipated, the rate of attrition was highest for the 12-month reassessment groups.

2.1. Compression rate and depth

The compression rates for students in both groups were within the acceptable range (Table 1). The control group mean compression rate was significantly higher than the experimental group ($F = 11.05$ [1, 592], $p = 0.0009$), and the mean compression rates increased with time from initial training ($F = 6.2$ [4, 592], $p < 0.0001$). The interaction between group and reassessment time was not significant, $F = 0.12$ (4, 592), $p = 0.9$.

Practice was essential for students to maintain their ability to compress with adequate depth. The differences in compression depth and percent of compressions performed with adequate depth between students who had brief monthly practices on a VAM and the control group were significant ($F = 4.77$ [1, 592], $p = 0.03$; $F = 7.53$ [1, 592], $p = 0.006$ respectively). In the experimental group, students' mean compression depths were within the accepted range (between 38 and 51 mm),[23] with no loss of this skill over the 12 months ($p = 0.31$). The compression depths ranged from 38.6 (SD = 6.7) mm at 3 months to 40.3 (SD = 6.6) mm at 12 months and 39.9 (SD = 5.9) mm following retraining (Fig. 2). The control group, however, had a significant loss of ability to compress with adequate depth between 9 ($M = 39.6$, SD = 6.8 mm) and 12 ($M = 36.5$, SD = 7.7 mm) months ($p = 0.004$). Students in the control group who repeated their BLS training (12R) were not able to regain this skill, and their mean compression depth decreased further to 35.2 (SD = 7.0) mm.

Similarly, in the control group the percent of compressions performed with adequate depth also decreased significantly after the 9-month reassessment ($p = 0.05$). At 9 months those students delivered 55.7% of their compressions with adequate depth, the same as the experimental group. However, 3 months later students who had not practiced beyond their initial training performed only 36.5% of their compressions with adequate depth; that improved only slightly with retraining (40.7%) (Fig. 3). In contrast students who practiced compressions 2 min a month continued to improve in their ability. At 12 months they performed 59.2% of their compressions with adequate depth, the highest percentage across the reassessment times. Significant interaction terms between group and reassessment time were found for mean compression depth ($F = 4.36$ [4, 592], $p = 0.002$) and percent of compressions performed with adequate depth ($F = 2.90$ [4, 592], $p = 0.02$).

2.2. Hand placement

There were no differences between the groups in use of correct hand placement during compressions ($p = 0.32$). The percentage of compressions with the correct hand position varied from approximately 79 to 92% in both groups.

2.3. Ventilation rate and volume

Although there were no statistical differences between the experimental and control groups for ventilation rate ($p = 0.09$), there were significant differences in mean ventilation volumes, $F = 35.26$ (1, 592), $p < 0.0001$ (Table 1). At 3 months, the mean

Table 1
CPR skill comparisons by group and test out month.

CPR skill	Test out month	Experimental group		Control group		Mixed linear model[a]		
		Mean	SD	Mean	SD	Effect	F (df1, df2)	p-Value
Compression rate (avg/minute)	3	96.7	14.7	99.3	17.4	Group	11.05 (1, 592)	0.0009
	6	95.4	11.0	100.0	14.6	Test out month	6.20 (4, 592)	<0.0001
	9	98.2	12.4	101.1	18.0	Group × test out	0.12 (4, 592)	0.98
	12	98.6	11.9	103.3	18.8			
	12R	103.0	10.7	106.8	13.2			
Compression depth (mm)	3	38.6	6.7	36.6	9.5	Group	4.77 (1, 592)	0.03
	6	38.3	6.8	39.1	8.6	Test out month	0.77 (4, 592)	0.59
	9	38.3	6.9	39.6	6.8	Group × test out	4.36 (4, 592)	0.002
	12	40.3	6.6	36.5	7.7			
	12R	39.9	5.9	35.2	7.0			
Compression depth (percent with adequate depth)	3	50.5	33.5	46.7	35.2	Group	7.53 (1, 592)	0.006
	6	48.1	32.4	47.6	36.2	Test out month	0.88 (4, 592)	0.48
	9	55.4	36.6	55.7	33.0	Group × test out	2.90 (4, 592)	0.02
	12	59.2	31.6	36.5	33.6			
	12R	58.1	31.2	40.7	33.2			
Hand placement (percent correct)	3	79.5	29.8	79.3	31.2	Group	1.00 (1, 592)	0.32
	6	91.2	17.9	81.6	32.0	Test out month	2.84 (4, 592)	0.02
	9	86.0	25.6	82.2	32.5	Group × test out	0.55 (4, 592)	0.70
	12	84.4	24.9	79.3	29.6			
	12R	87.9	24.0	91.7	15.4			
Ventilation rate (avg/minute)	3	12.2	7.2	12.0	7.5	Group	2.90 (1, 592)	0.09
	6	10.1	4.8	10.2	8.4	Test out month	1.60 (4, 592)	0.17
	9	9.8	4.5	10.7	7.3	Group × test out	0.88 (4, 592)	0.48
	12	11.0	4.7	9.9	7.4			
	12R	11.0	4.7	9.6	7.0			
Ventilation volume (ml)	3	487.0	210.3	474.7	228.2	Group	35.26 (1, 592)	<0.0001
	6	514.0	208.4	424.4	267.3	Test out month	3.69 (4, 592)	0.006
	9	554.6	165.6	442.4	240.5	Group × test out	1.91 (4, 592)	0.11
	12	565.4	147.8	430.7	231.7			
	12R	620.7	211.0	513.6	259.1			
Ventilation volume (percent with adequate volume)	3	38.1	30.0	39.2	33.4	Group	20.0 (1, 592)	<.0001
	6	45.5	31.1	37.2	33.8	Test out month	2.34 (4, 592)	0.05
	9	51.8	29.7	38.2	36.5	Group × test out	1.32 (4, 592)	0.26
	12	52.2	30.9	38.5	36.1			
	12R	56.9	30.3	42.7	34.3			

[a] Mixed linear model using post-CPR skill as outcome, group (experimental or control) and test out month (3, 6, 9, 12, or 12R) as main effects, a group × test out month interaction term, and including pre-CPR skill and teaching method (HeartCode, IL Manikin A or IL Manikin B) as covariates.

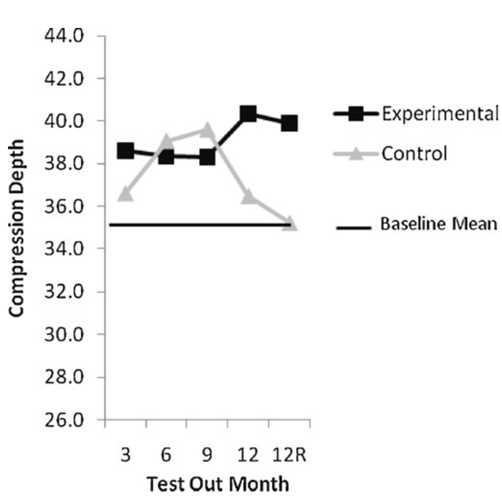

Fig. 2. Mean compression depth (in mm) by group and test out month. Mean compression depth (in mm) for experimental (6 min monthly practice) and control (no practice) groups at each reassessment time. Baseline mean is average compression depth for both groups combined immediately after CPR training.

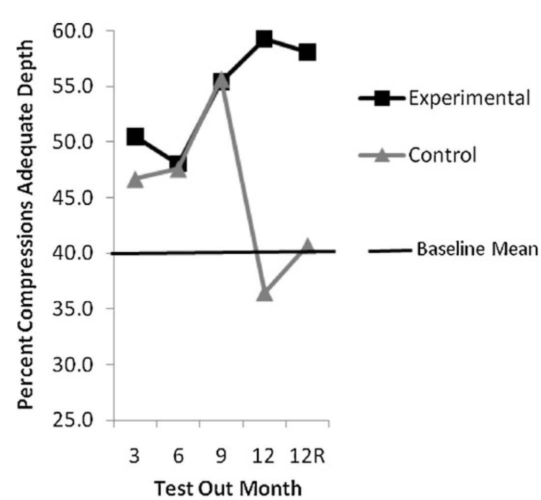

Fig. 3. Percent of compressions with adequate depth by group and test out month. Percent of compressions with adequate depth for experimental (6 min monthly practice) and control (no practice) groups at each reassessment time. Adequate depth between 38 and 51 mm.[23] Baseline mean is average percent of compressions with adequate depth for both groups combined immediately after CPR training.

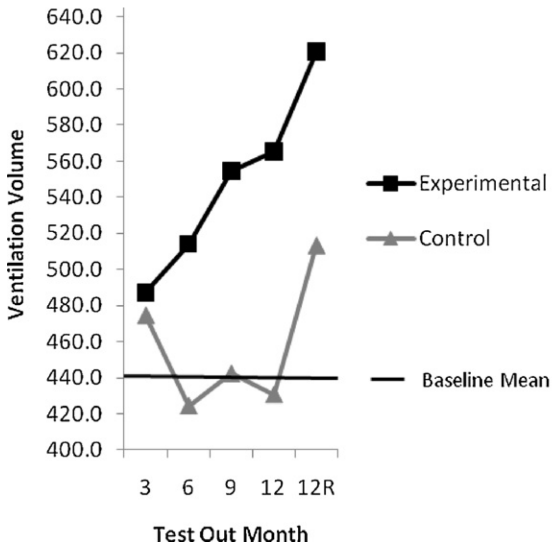

Fig. 4. Mean ventilation volume (ml) by group and test out month. Mean ventilation volume (ml) for experimental (6 min monthly practice) and control (no practice) groups at each reassessment time. Baseline mean is average ventilation volume for both groups combined immediately after CPR training.

ventilation volumes were similar (experimental group $M = 487.0$, SD = 210.3 ml; control group $M = 474.7$, SD = 228.2 ml; $p = 0.71$), but with practice students in the experimental group improved steadily in their ability to ventilate with an adequate volume, and by 6 months, their mean ventilation volume was 514.0 (SD = 208.4) ml, within an acceptable range of 500–800 ml. These volumes continued to increase with practice. At 12 months the mean ventilation volume was 565.4 (SD = 147.8) ml and with retraining 620.7 (SD = 211.0) ml (Table 1). In the control group, the mean ventilation volumes remained less than the recommended minimum throughout the 12 months (Fig. 4). With retraining the mean volume increased to 513.6 (SD = 259.1) ml.

Students who completed short practice sessions had a significantly higher percent of ventilations with adequate volume than the control group, $F = 20.0$ (1, 592), $p < 0.0001$. These differences were statistically significant at all reassessments except for 3 months where the percent of ventilations with adequate volume was only between 38.1% (experimental group) and 39.2% (control group) even though all participants had been certified in BLS only a few months earlier. With short practices, however, students improved in this skill: the percent of ventilations with adequate volume increased steadily to 52.2 (SD = 30.9) at 12 months and 56.9 (SD = 30.3) following retraining (Fig. 5). In the control group, at 6 months fewer ventilations had adequate volume (37.2%, SD = 33.8) than at the 3-month testing point, and the ability to ventilate remained low (approximately 38%) at the 9- and 12-month reassessment (Table 1). With retraining students in the control group improved only slightly, with 42.7% (SD = 34.3) of the ventilations having adequate volume.

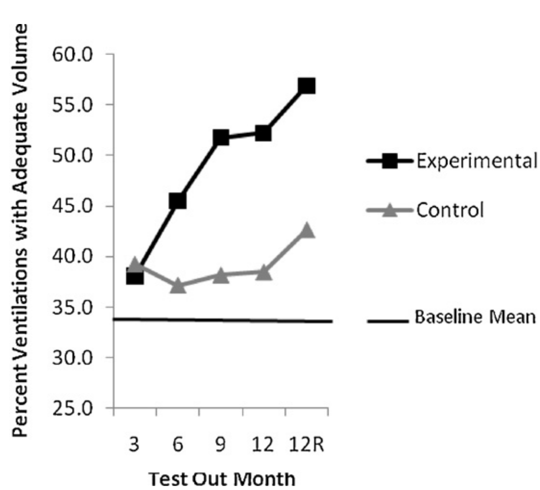

Fig. 5. Percent of ventilations with adequate volume by group and test out month. Percent of ventilations with adequate volume for experimental (6 min monthly practice) and control (no practice) groups at each reassessment time. Adequate volume between 500 and 800 ml. Baseline mean is average percent of ventilations with adequate volume for both groups combined immediately after CPR training.

3. Discussion

Many studies over the years have shown that BLS knowledge and skills are not retained.[7–10,14,24–26] While skills may be performed adequately during initial training, they degrade rapidly without practice or use. Short practice sessions with VAMs are a strategy for enhancing learning of CPR psychomotor skills during training and with repeated practice, for improving their performance and retention.

By practicing only 6 min a month on VAMs, students maintained their ability to compress with an adequate depth throughout the entire 12 months, with no loss of this skill. In a study by Wik et al.,[13] when laypersons received VAM feedback 12 months after their initial training, their CPR skills were the same as immediately after training and 6 months post-training. Without practice, students' ability to compress with adequate depth decreased significantly between months 9 and 12. The final group of students ($n = 49$) who retrained in BLS were not able to improve their skill in compression even with this additional training. Completion of a BLS course may be effective for training nursing students and other providers how to compress, but in this study without practice the ability to perform that skill was only retained for somewhere between 9 and 12 months. It is important to note that students' compression depths throughout the study were less than the new recommended AHA guidelines; further practice of this skill is indicated.

The positive effects of brief monthly practice were evident most clearly in students' ventilation skills. At baseline students had completed successfully their BLS training, but 3 months later neither group was able to ventilate with a volume in the recommended range of 500–800 ml. With practice, by 6 months students had ventilation volumes over 500 ml, which continued to increase over the length of the study. In contrast to compression skills, which were lost between months 9 and 12 if not practiced, the ventilation skills of students in the control group deteriorated by 3 months after the initial BLS training and continued to degrade. This is consistent with findings of a study by Madden[25] in which nursing students were unable to pass a CPR skill assessment shortly after completing their BLS course: the poorest performed skill was ventilating with an adequate volume.

Theories of skill acquisition suggest that in the initial learning of a new skill, the primary goal is to perform the skill at an acceptable level.[27,28] The focus in this early learning phase is on accuracy of performance rather than speed. With experience performance becomes smoother, learners do not need to concentrate on how to perform the skill at an acceptable level, and eventually performance becomes automated.[29] BLS training provides sufficient practice for students to accurately perform CPR psychomotor skills at the time but not enough for sustained learning or improvement in performance. Consistent improvement in skill performance requires deliberate practice in which learners are guided to improve some aspect of performance for a well-defined skill, receive immediate feedback on their performance, and have opportunities to perform the same tasks repeatedly.[29–32] Monthly practice of CPR skills on VAMs provided repetitive performance of well-defined skills, assessment of skills, and specific, informative feedback about one's own performance.

Few other studies have examined the outcomes of frequent, brief practices on CPR skill performance and retention, but it is clear from our research that practicing only 6 min a month was effective for maintaining and even improving CPR psychomotor skills. In the PAD Trial, volunteers were retrained back to a proficiency level through brief, one-on-one interactive sessions that focused on their specific learning needs.[8] Further study should examine the frequency of practice because it may be that practice every 2 or 3 months is sufficient, but for now, we recommend short practices on manikins with some form of automated feedback for students and health care providers who use CPR skills infrequently in their work settings.

3.1. Limitations

Selection bias may have played a factor in the study results. Students volunteered for participation in the project, and those students may have been more motivated to learn than others in the nursing program. Site coordinators implemented the protocol at their own schools of nursing and were not to provide any feedback or prompts as students practiced their CPR skills on the VAMs. However, we had no way of monitoring if coordinators inadvertently prompted students during their practice sessions.

As anticipated, the rate of attrition increased as the study progressed and was highest for the 12-month reassessment groups. Students in the 12R group who had the online HeartCode™ BLS course at baseline repeated this same course. However, students in the IL courses may have had different instructors when they repeated their BLS training.

4. Conclusions

The findings of this study not only confirmed the importance of practicing CPR psychomotor skills to retain them but also revealed that short monthly practices could improve skills over baseline. Students who practiced their psychomotor skills on VAMs for only 6 min monthly either maintained or improved their skills over the 12-month period. In contrast students who did not practice beyond their initial training experienced a significant loss of compression skills between months 9 and 12 and ability to ventilate adequately by 3 months. The results also demonstrated that self-directed CPR skill practice on a manikin with some form of automated feedback was a viable option for delivering frequent practice sessions to nursing students and, potentially, to practicing nursing staff and other health care providers.

Conflict of interest statement

We acknowledge the following potential conflict of interest: The American Heart Association (AHA) and Laerdal Medical Corporation supplied the materials and equipment for the study at no cost to the schools of nursing that served as training sites and funded the entire study through a grant to the National League for Nursing (NLN). The project was coordinated through the NLN with funding provided by them to the Principal Investigator (MO) and research team. Representatives from the NLN, AHA, and Laerdal Medical Corporation served on the team with the investigators that designed the study. The NLN, AHA, and Laerdal Medical Corporation were not involved in the collection, analysis, and interpretation of data; in the writing of the manuscript; nor in the decision to submit the manuscript for publication. The investigators and site coordinators had sole responsibility for implementing the study and collecting and uploading the data. The investigators had sole responsibility for data analysis and interpretation, and for writing and submitting the manuscript. There were no restrictions by the NLN, AHA, or Laerdal Medical Corporation on the statistical analysis or publication of the findings.

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