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Effects of Practice on Competency In Single-Rescuer Cardiopulmonary Resuscitation

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This study demonstrated the effectiveness of brief practice on voice advisory manikins in improving skill retention by nursing students in single-rescuer cardiopulmonary resuscitation (CPR). Brief practice can assist nurses and other providers in maintaining their CPR skills and may lead to improved performance competency.

Cardiac arrests remain a significant health problem and leading cause of death both in and out of hospitals. Regardless of the setting, prompt initiation of quality cardiopulmonary resuscitation (CPR) improves patient survival and outcomes (Abella, Alvarado, Mykelbust, Edelson, & Barry, 2005; Aufderheide et al., 2010; Bobrow et al., 2013; Idris et al., 2012; Meaney et al., 2013; Thigpen et al., 2010; Wallace, Abella, & Becker, 2013). Nurses, other health care providers, and laypersons need to be trained effectively to develop and retain their CPR skills. This requires using or practicing skills frequently to avoid rapid decline.

Background

One problem with basic life support (BLS) and other types of training completed in one instructional session, with practice only at that time, is the performance skill may not be retained; when the skill is required later, individuals demonstrate a lower performance level (Luft & Buitrago, 2005). Basic life support training allows health care professionals and laypersons to perform CPR correctly in class, but skills need to be used or practiced to be retained.

Retention of skills is the result of performance persistence over time, and it requires practice (Niles et al., 2009; Sutton et al., 2011). By practicing a skill during its initial learning, individuals determine how to perform it. Clear instructions, specific and informative feedback from experts to guide movements, and practice with simulators and models are valuable strategies during this early cognitive learning phase. In the next phase of motor skill learning, the associative phase, practice enables individuals to continue to refine their performance and develop their expertise. With practice, they learn to perform the skill consistently and more quickly than during their initial learning. As they continue to practice, they gain proficiency and eventually can perform the skill without thinking about each step; performance in this phase becomes automatic (Schmidt & Lee, 2005). Spacing practice over a period of time is more effective than attempting to acquire a complex skill by practicing it all at one time (Luft & Buitrago, 2005).

Literature Review

Along with the need for prompt initiation of CPR during cardiac arrest, the need for high-quality CPR has been investigated extensively. Patient survival is related to the quality of the CPR (Meaney et al., 2013). When compressions are not deep enough and when rescuers compress too slowly, chances of survival decrease significantly (Abella et al., 2005; Stiell et al., 2012). Aufderheide and co-authors (2010) conducted a large-scale study of CPR adminis-

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tered by emergency medical services (EMS) providers (*n*=1,605) trained using the 2005 American Heart Association (AHA) CPR guidelines. Patient survival was compared to 1,641 CPR attempts by EMS providers trained under the 2010 guidelines, which increased the depth and rate of compressions. Investigators found a significant improvement in survival using the new guidelines (*p*=0.007). An additional systematic review and meta-analysis (Wallace et al., 2013) to measure the effect of CPR quality on cardiac arrest outcomes found deeper chest compressions and rates close to 85-100 compressions per minute were associated significantly with improved survival from cardiac arrest.

While research has indicated a clear need for properly administered CPR, evidence over the years has documented the lack of retention of CPR skills among nurses, other providers, and laypersons, thus affecting the quality of the CPR they are able to perform. De Regge, Calle, De Paepe, and Monsieurs (2008) investigated the difference between individual and group CPR training with noncritical care nurses (*n*=120). They found skill retention declined for both groups when reassessed after 9 months. In another study, Isbye and co-authors (2008) measured skill retention based on instructional method among second year medical students (*n*=43). The performance between an instructor-facilitated class and training with a voice advisory manikin (VAM) was not significantly different (*p*=0.12). The groups were reassessed after 3 months, and CPR skills declined to a level similar to pre-instruction.

Similarly, Smith, Gilcreast, and Pierce (2008) found 37% of the nurses studied (*n*=133) could not pass the BLS skills test 3 months after training, with further declines identified at 6 and 9 months. The authors recommended more frequent refresher training and practice of skills. Kromann, Bohnstedt, Jensen, and Ringsted (2010) compared medical students' CPR skill retention after 6 months between groups that either received a final skills test immediately after their instruction or were not tested at all. A decline in skill retention was found in both groups. The nonpost-test group retained 70.3% of skills while the tested group retained 75.9% of skills; differences in retention rates were not significant (*p*=0.06).

Other research on CPR skill retention continues to corroborate the decline of CPR skills over time. Nori, Saghafinia, Motamedi, and Hosseini (2012) tested nurses' (*n*=112) CPR skill retention after a 4-hour training course. They reassessed the skill retention of the participants after 10 weeks and after 2 years, and compared the results to the post-instruction assessment. Both knowledge and psychomotor skills declined significantly at 10 weeks and 2 years (*p*<0.001 each). Sankar, Vijayakanthi, Sankar, and Dubey (2013) investigated the differences between knowledge levels and skills of practicing nurses (*n*=28) compared to final semester nursing students (*n*=46). The two groups were trained in pediatric CPR via reading material distributed 3 weeks before instruction and then completed a 6-hour instructional session. Six weeks post-training, both groups experienced declines in CPR knowledge and skills.

Considering the rapid deterioration of CPR skills, frequent use or practice is critical to maintain competence. While the research has documented the loss of skills over time, few studies have examined the effects of practice on maintaining competence in CPR. In a two-part study, Oermann, Kardong-Edgren, and Odom-Maryon (2011) reported the benefits of brief CPR practice on skill retention. Nursing students (*n*=303) who practiced monthly on VAMs improved compression and ventilation skills with continued practice compared to a control group. The manikins guided performance of CPR skills by providing voice prompts, such as directing the student to "compress faster." Students in the control group had no practice beyond their initial BLS training. Their ability to ventilate with sufficient volume decreased after the 3rd month, and their ability to compress at a sufficient depth and rate decreased between 9 and 12 months (*p*=0.004). Brief practice enabled students to retain their CPR skills over a 1-year period.

Other researchers have documented the positive effects of brief practice of some type on retention of CPR skills. Niles and co-authors (2009) studied the skill retention benefit from practicing on manikins with automated feedback. Their study compared a group of nurses and other health care providers who practiced more than twice a month (frequent) to a group that practiced only once a month (infrequent). Over 15 weeks, the participants (*n*=420) practiced until they had achieved proficiency in CPR. The time for the frequent practice group to achieve proficiency was significantly less than the infrequent practice group (*p*<0.001). Sutton and others (2011) examined the effects of brief bedside CPR training using different educational methods for refreshing skills and improving retention. Pediatric in-hospital providers (*n*=89) were assigned randomly to a control group or to one of three types of booster training in CPR (instructor only, automated manikin practice that provided audiovisual feedback, or a combination of these methods). Participants had a pre-training evaluation (60 seconds) and booster training for 120 seconds. At the 6-month post-test, retention of skills was 2.9 times more likely after the provider had three brief training sessions (95% CI: 1.4-6.2; *p*=0.005). Instructor-led training was the most effective method.

Other factors affecting CPR have been studied as well. Verplancke and co-authors (2008) examined the effects of confidence and gender on BLS skills among 296 nurses from noncritical care units. They found confidence with skills (*p*<0.03), shorter time since the last training (*p*=0.01), shorter time since the last CPR experience (*p*<0.01), and the male sex (*p*<0.001) correlated with higher-quality skills. They also found the mean compression depth achieved by the nurses was only within guidelines among 24% of the nurses. Mpotos and colleagues (2011) hypothesized that training students to compress to a depth of greater than 50 mm would mitigate the loss of depth during compressions that is seen. The control group was trained to achieve a compression depth of 40-50 mm while the experimental group was trained to a depth of more than 50 mm. After 6 months, the retest found the control group only achieved a depth greater than 50 mm 6% of the time, but the experimental group achieved the appropriate depth 49% of the time ($p<0.001$). Fatigue was a major contribution to the lack of high-quality CPR in a study of 20 healthy female participants by Trowbridge and associates (2009). Investigators compared hands-only CPR to 30:2 CPR. They found the average rate, depth, and force were significantly lower ($p<0.001$, $p<0.004$, $p=0.001$, respectively) during hands-only CPR. Most of the decline in quality was experienced in the first 2 of 10 minutes studied. During hands-only CPR, only seven subjects were able to finish the full 10 minutes.

Considering the rapid loss of CPR skills, frequent use or practice is critical to maintain competence. The studies reported in this literature review document the loss of skills. Only a few studies have examined the use of practice to maintain competence, and none explored the outcomes of brief practice of CPR over an extended period of time.

Purpose

The purpose of this study was to examine the effectiveness of brief practice of single rescuer CPR on VAMs in retaining skills compared to a control group with no practice beyond their initial training.

Method

This study was a randomized, controlled trial with 606 students in 10 schools of nursing. At baseline, students were trained and certified in BLS either through the AHA HeartCode™ BLS course (using VAMs) or instructor-led training (using traditional manikins). Differences in methods of BLS training are reported elsewhere (Kardong-Edgren, Oermann, Odom-Maryon, & Ha, 2010; Oermann et al., 2010). The 10 schools were assigned randomly to train using one of the two BLS courses. After student participants were certified, they were assigned randomly to an experimental group (brief practice of compressions, ventilations, and single-rescuer CPR, each for 2 minutes once a month) or a control group with no further practice. The brief practice sessions to refresh students' CPR skills were done using sensored Resusci Anne™ adult manikins (Laerdal Medical, Stavanger, Norway) in the learning laboratory of their schools. Every 3 months, 20% of the students then were selected randomly from both groups to assess retention of CPR skills and exit the study. A complete description of these methods has been reported elsewhere (Oermann et al., 2011).

Subjects

Subjects were nursing students in pre-licensure programs. Most were female ($n=460$), with mean age of 28. A few students ($n=37$) had performed CPR prior to the study. No significant differences existed in demographics between the experimental and control groups. The institutional review board at the primary author's university provided approval as a multi-site study.

Outcome Measures

To assess the quality of CPR skills, students performed compressions, ventilations, and single-rescuer CPR for 3 minutes each on a Laerdal Resusci Anne Skill Reporter™ manikin. Using the data from the Skill Reporter manikin, researchers evaluated the following:

1. Quality of compressions during single-rescuer CPR: compression rate (avg/minute), compression depth (mm), and percentage of compressions with adequate depth.
2. Percentage of compressions with correct hand placement.
3. Quality of the ventilations: ventilation rate (avg/minute), ventilation volume (ml), and percentage of ventilations with adequate volume.

Other outcomes of this study not related to single-rescuer CPR have been reported elsewhere (Oermann et al., 2011). Data were collected electronically by the Skill Reporter manikin.

Data Analysis

Data were summarized as means (standard deviations) for experimental and control groups, and by month of retesting (3, 6, 9, or 12). Each outcome measure was analyzed using a linear mixed model to examine the influence of monthly practice, the month of the retesting, and the two-way interaction. The initial type of training (HeartCode or instructor-led) and baseline CPR skill measures were included in the model as covariates to control for differences between groups at baseline (Kardong-Edgren et al., 2010; Oermann et al., 2010). A complete description of the data analysis is provided elsewhere (Oermann et al., 2011). SAS software (version 9.1) was used, and significance testing was set at the 0.05 level.

Results

Quality of Compressions

No significant differences were identified in the compression rates and depths between the groups when students performed single-rescuer CPR (see Table 1). The average number of compressions per minute was more than 100 throughout the 12 months; students retained this skill even without practice. Compression depths ranged from 41.9 ($SD=7.6$) mm at 3 months to 42.3 ($SD=6.6$) mm at 12 months in the group that practiced CPR. In the control group, depths were lower but not significantly so; at 3 months the mean depth was 40.6 ($SD=10.2$) and at 12 months 39.7 ($SD=9.5$) mm. Although no significant differences were found between the groups in mean compression depths, a higher percentage of compressions performed by students in the experimental group were within the range of 38-51 mm, as recommended in the AHA (2005) guidelines, and this was maintained with brief practice

TABLE 1.
Single-Rescuer CPR Skill Comparisons by Group and Test Month

CPR Skill	Test Month	Experimental Group Result Mean	Experimental Group Result *SD*	Control Group Result Mean	Control Group Result *SD*	Mixed Linear Model[a] Effect	F (df1, df2)	*p* Value
Compression Rate (avg/minute)	3	104.2	14.7	105.0	17.3	Group	0.73 (1, 593)	0.39
	6	103.1	12.2	106.2	14.0	Test Month	4.35 (4, 593)	0.002
	9	105.4	14.0	105.1	18.8	Group*Test	0.60 (4, 593)	0.66
	12	106.0	11.4	107.1	16.1			
Compression Depth (mm)	3	41.9	7.6	40.6	10.2	Group	3.66 (1, 593)	0.06
	6	42.0	6.6	41.4	8.9	Test Month	1.34 (4, 593)	0.26
	9	42.2	6.2	42.4	8.0	Group*Test	1.66 (4, 593)	0.16
	12	42.3	6.6	39.7	9.5			
Compression Depth (percentage with adequate depth)	3	58.1	33.1	47.7	34.3	Group	15.37 (1, 593)	<0.0001
	6	62.0	32.1	50.9	36.1	Test Month	1.97 (4, 593)	0.10
	9	66.3	32.3	53.5	33.5	Group*Test	0.19 (4, 593)	0.94
	12	57.8	33.1	48.3	36.9			
Hand Placement (percentage correct)	3	88.2	24.7	88.3	22.3	Group	3.30 (1, 593)	0.07
	6	91.7	16.0	83.1	30.1	Test Month	0.48 (4, 593)	0.75
	9	87.5	20.3	83.6	29.1	Group*Test	0.17 (4, 593)	0.95
	12	88.3	18.6	86.1	23.1			
Compressions Performed Correctly (percentage correct)	3	52.3	33.6	46.0	33.6	Group	18.81 (1, 593)	0.0001
	6	58.7	32.6	43.7	36.8	Test Month	2.27 (4, 593)	0.06
	9	62.1	32.8	48.1	35.7	Group*Test	0.19 (4, 593)	0.94
	12	53.4	33.4	41.7	35.1			
Ventilation Rate (avg/minute)	3	4.3	3.2	4.1	3.4	Group	11.22 (1, 593)	0.0009
	6	3.9	1.5	3.8	1.8	Test Month	1.42 (4, 593)	0.23
	9	4.0	1.6	3.4	2.3	Group*Test	0.54 (4, 593)	0.71
	12	4.5	1.4	3.7	1.9			
Ventilation Volume (ml)	3	583.7	265.2	576.4	280.3	Group	13.78 (1, 593)	0.0002
	6	600.1	213.0	571.0	314.6	Test Month	1.41 (4, 593)	0.23
	9	593.7	186.9	546.2	289.6	Group*Test	0.72 (4, 593)	0.58
	12	619.1	208.4	550.0	273.8			
Ventilation Volume (percentage with adequate volume)	3	33.4	30.5	30.2	27.6	Group	9.80 (1, 593)	0.002
	6	41.1	27.6	39.3	31.1	Test Month	2.12 (4, 593)	0.08
	9	43.0	30.3	33.0	30.0	Group*Test	0.94 (4, 593)	0.44
	12	41.1	32.2	35.1	28.4			
Ventilations Performed Correctly (percentage correct)	3	33.5	29.9	31.0	28.1	Group	8.84 (1, 593)	0.003
	6	40.5	27.9	37.4	29.5	Test Month	1.61 (4, 593)	0.17
	9	41.1	30.2	31.8	28.9	Group*Test	0.53 (4, 593)	0.71
	12	40.1	31.4	35.0	29.7			

[a] Mixed Linear Model using post-CPR skill as outcome, Group (Experimental or Control) and Test Out Month (3, 9, or 12) as main effects, a Group*Test Out Month interaction term, and including pre-CPR skill and Teaching Method (HeartCode, Instructor-led Manikin A or Instructor-led Manikin B) as covariates.

over the year of the study (F=15.37 [1,593], $p < 0.0001$) (see Table 1).

The AHA 2010 guidelines indicated providers should compress to a depth of at least 2 inches (51 mm) in adults (Berg et al., 2010). To explore if students would have met the 2010 guidelines, authors re-examined the baseline data, that were collected immediately after students passed their BLS course. Only 66 (11%) students compressed to a depth of 51 mm or more.

Hand Placement

Students in both groups placed their hands correctly on the manikins during single-rescuer CPR (p=0.07). The percentage of compressions with the correct hand position ranged from a low of 83.1% in the control group at 6 months to 91.7% in the experimental group at 6 months. The Skill Reporter software provides the number of compressions performed correctly during single-rescuer CPR. These are defined as compressions with a depth of 38-51 mm and complete release and correct hand placement on the manikin. The experimental group performed significantly better than the control, with more than half their compressions at all retesting points meeting these criteria and no loss of their skills demonstrated over the 12 months (F=18.81 [1,593], p<0.0001).

Quality of Ventilations

Significant differences were found in ventilation skills between the experimental and control groups. Ventilation rates were lower in the control group, and they decreased over the 12 months (p=0.0009). Students who refreshed their CPR skills with monthly practice had no loss of ability to ventilate with an adequate volume; their mean ventilation volumes ranged from 583.7 ml (*SD*=265.2) at the 3-month retesting to 619.1 ml (*SD*=208.4) at the end of the year. Over this same period in the control group, ventilation volumes decreased from 576.4 ml (*SD*=280.3) to 550.0 ml (*SD*=273.8) (see Table 1). These differences were significant (F=13.78 [1,593], p= 0.0002). Students who practiced also had a higher percentage of ventilations with an adequate volume, ranging from a low of 33.4% at 3 months after they were trained in BLS to 41.1% following a year of monthly practice (p=0.002). Although some differences existed between the groups, ventilation volumes were within the 500-800 ml range used for the study.

The Skill-Reporter software provides the number of ventilations performed without errors; these are defined as ventilations with volumes of 500-800 ml with the airway open and an inflation flow rate of less than 800 ml/second. Students in the experimental group had a higher percentage of ventilations that met these criteria at all the retesting points than the control group (F=8.84, [1,593], p=0.003).

The authors re-examined the ventilation data at baseline (immediately following training in BLS) using the 2010 guidelines, which recommended volumes of 500-600 ml (Berg et al., 2010). Only 90 (15%) students ventilated within that range; their mean ventilation volume during single-rescuer CPR was 552.0 ml (*SD*=29.7). After completing BLS training, almost half (n=277, 46%) of the students had volumes less than 500 ml (lower than recommended minimum in either set of guidelines). Results for the remaining students (n=239, 39%) were above 600, with mean volume of 822.6 ml (*SD*=187.6). Only 133 (22%) participants had a compression-to-ventilation ratio of 30:2.

Discussion

Brief practice of CPR skills and other refreshers may maintain practitioner competence. While no statistically significant differences were found in compression rates and depths between experimental and control groups during single-rescuer CPR, students who practiced CPR skills each month performed more of their compressions with an adequate depth and retained this skill over the 12-month study period. They also performed more compressions correctly. These findings are consistent with a related study (Oermann et al., 2011). However, results of that study indicated students who practiced had higher compression rates and better compression depths than students in the control group, and students in the control lost their ability to compress between 9 and 12 months (p=0.004).

Students who practiced CPR retained their ventilation skills when performing single-rescuer CPR. In contrast, students who had no further CPR practice after initial training had lower ventilation rates and volumes that decreased over time. Volumes for the control group, however, were still within the 500-800 ml range used for the study.

Brief but frequent practice on manikins with automated feedback appeared to be an effective strategy for maintaining skills in single-rescuer CPR. Independent practice on VAMs and other types of manikins that guide performance, along with brief refreshers with an instructor, allow nurses and other providers to maintain competence in CPR performance and avoid skill decline associated with lack of use or practice. By practicing a skill repeatedly and receiving specific and instructional feedback on performance, learners retain skills and develop their expertise (Ericsson, 2004).

Many studies have documented the deterioration of CPR skills, but research is limited concerning how to promote maximum skill retention. This study and other research (Niles et al., 2009; Sutton et al., 2011) suggest brief practices, including those done at the bedside, are effective for maintaining competence in CPR. Although students who practiced performed better than those in the control group, their compression depths were low, and few students (11%) would meet AHA 2010 guidelines. Compressing deep enough may be difficult for some nurses and other providers (Abella et al., 2005; Mpotos et al., 2011; Verplancke et al., 2008). Because deeper chest compressions and compression rates close to a range of 85-100 compressions per minute improve the chances of survival from cardiac arrest (Wallace et al., 2013), nurses, other providers, and laypersons need to develop the ability to compress deep and fast.

Fatigue also may have influenced the compression depths reached by students in our study. When students' skills were assessed, they first performed 3 minutes of compressions, followed by 3 minutes of ventilations, and then 3 minutes of single-rescuer CPR. This finding is consistent with the study by Trowbridge and co-authors (2009), who found compression skills decreased from the beginning to the end of CPR when performed for 10 minutes, with most of the loss in the initial 2 minutes.

Limitations

This study was completed with nursing students; nurses who have had more training in CPR may not need the same amount of practice as students. In addition, students volunteered for participation. Thus selection bias may have influenced the findings.

Recommendations for Future Research

This study should be replicated in multiple settings with nurses and other providers who have a range of experience in performing CPR. As the extent of practice for maintaining competence in CPR is not known, studies should examine the relationship of varying amounts of practice and proficiency in CPR skill. Studies should include measurements of compression depth and rate as well as ventilation volumes with a goal to improve the quality of nurses' skills.

Nursing Implications

Based on the findings of this study and previous evidence on the rapid decline of CPR skills, the authors recommend nurses and other providers practice their CPR skills frequently; practice will enable them to maintain their competence. Although students in the study practiced for 6 minutes a month, it is likely the extent of practice needed to maintain competence can be less frequent and shorter for nurses and other providers who have been trained multiple times in BLS. Nurses need to assume responsibility for maintaining their competence in CPR. The availability of manikins on a patient care unit would allow nurses to practice their CPR skills at a convenient time and place. Short practice sessions on the unit or in the simulation laboratory can be done independently. In addition to practicing skills to retain them, the quality of nurses' CPR skills should be assessed and gaps in performance identified. With this information, nurses can focus their practice on skills they need to improve.

Conclusion

Brief practice on manikins with automated feedback allowed nursing students in this study to perform a higher percentage of compressions with adequate depth during single-rescuer CPR with no decline of ability over the 12-month study period. Students who practiced CPR also improved ventilation skills in comparison to the control group. Study findings documented the benefits of short practice sessions on ability to perform single-rescuer CPR. MSN

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