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Simulation and education

A randomized education trial of spaced versus massed instruction to improve acquisition and retention of paediatric resuscitation skills in emergency medical service (EMS) providers

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Abstract

Aim: Resuscitation courses are typically taught in a massed format despite existing evidence suggesting skill decay as soon as 3 months after training. Our study explored the impact of spaced versus massed instruction on acquisition and long-term retention of provider paediatric resuscitation skills.

Methods: Providers were randomized to receive a paediatric resuscitation course in either a spaced (four weekly sessions) or massed format (two sequential days). Infant and adult chest compressions [CC], bag mask ventilation [BMV], and intraosseous insertion [IO] performance was measured using global rating scales.

Results: Forty-eight participants completed the study protocol. Skill performance improved from baseline in both groups immediately following training. 3-months post-training the infant and adult CC scores remained significantly improved from baseline testing in both the massed and spaced groups; however, the infant BMV and IO scores remained significantly improved from baseline testing in the spaced: BMV (pre, 1.8 ± 0.7 vs post-3-months, 2.2 ± 7; $P = 0.005$) IO (pre, 2.5 ± 1 vs post-3-months, 3.1 ± 0.5; $P = 0.04$) but not in the massed groups: BMV (pre, 1.6 ± 0.5 vs post-3-months, 1.8 ± 0.5; $P = 0.98$) IO (pre, 2.6 ± 1.1 vs post-3-months, 2.7 ± 0.2; $P = 0.98$).

Conclusion: 3-month retention of CC skills are similar regardless of training format; however, retention of other resuscitation skills may be better when taught in a spaced format.

Keywords: Cardiopulmonary resuscitation (CPR), Education, Training, Paediatric resuscitation

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Cardiopulmonary resuscitation (CPR) is a life-saving intervention in which the quality of resuscitation directly impacts survival.[1,2] Ensuring that cardiac arrest victims receive care consistent with current resuscitation guidelines[3,4] has the potential to save thousands of lives.[5] Healthcare providers (HCP) are typically taught and retrained on resuscitation skills every 12–24 months in formal Basic Life Support (BLS) and Advanced Life Support (ALS) courses at significant cost to the healthcare system. Although life support training leads to increases in knowledge, skills and attitudes,[6,7] HCP routinely show a significant decay in these domains as early as 3 months after training.[8–11] This is particularly significant for paediatric cardiopulmonary resuscitation, a rare but high-stakes event,[12] with existing studies suggesting that the quality of CPR provided in simulated[13,14] and real paediatric cardiac arrest events consistently falls short of guidelines.[15,16] Defining the optimal instructional design for resuscitation education may help to improve skill retention, which may subsequently improve outcomes from cardiac arrest.

Advanced life support courses have traditionally been taught using massed instruction, that is, instruction occurring over hours or days. Studies suggest spaced learning, which involves separating training into several discrete sessions over a prolonged period with measurable intervals between training sessions,[17] result in more efficient learning and improved retention of simple motor tasks,[18] surgical skills,[19] and emergency medicine procedural knowledge.[20] Studies in resuscitation education demonstrate improved HCP chest compressions with training sessions spaced monthly compared to training every 3, 6, or 12 months.[21,22] However, the effects of spaced training on long-term retention of other skills required for paediatric resuscitation, particularly among providers who are infrequently required to perform paediatric resuscitation, has not been explored.

In addition to knowledge and skills, HCP must be able to act within a resuscitation situation. This is particularly important for those involved in the initial response to a critically ill child such as emergency medical service (EMS) personnel. Self-efficacy, defined as a person's belief in his/her capability to organise and execute an action,[23,24] is a task-specific factor that is recognized as being important in the transfer of resuscitation training to clinical practice. Enhanced self-efficacy appears to be predictive of certain key behaviours such as choosing to intubate and inserting an intra-osseous device during a simulated resuscitation.[25] Studies have shown that immediately following massed paediatric resuscitation training, physician learners demonstrate enhanced self-efficacy in several key paediatric resuscitation skills.[25] However, self-efficacy in resuscitation, its long-term retention following training and the impact of instructional design has not been investigated in EMS personnel who may need to act in the absence of physicians.

The primary objective of this study was to evaluate whether a Paediatric Advanced Life Support (PALS) course taught using spaced training conditions compared with the same PALS course taught using standard massed training conditions has an impact on EMS providers' long-term (3-month) retention of paediatric resuscitation skills (infant and adult chest compressions [CC], infant bag mask ventilation [BMV], and intraosseous insertion [IO]). Secondary objectives were to assess the 3-month retention of paediatric resuscitation knowledge and self-efficacy.

Material and methods

We conducted a prospective single-blinded randomized educational trial with 2 parallel arms. University of Calgary Conjoint Health Research Ethics Board (CHREB) approval and written consent from all participants was obtained. Participants were recruited from Calgary metro and surrounding areas EMS and block randomized to receive a PALS course in either a spaced format (four 3.5 -h weekly sessions over 1 month) or a massed format (two sequential 7-h days; Fig. 1) The study took place between September 2015 and June 2016.

Study participants

Currently employed EMS providers (paramedics or emergency medical technicians) were recruited to participate. Potential participants were excluded if they had completed a PALS course in the past year or if they were unable to complete at least 3 out of 4-sessions in the spaced instruction arm.

Randomization

Upon enrolment, individual participants were block randomized to one of the 2 parallel training conditions through the use of numbered cards inserted into opaque envelopes. Odd numbered cards were assigned to the massed training condition while even numbered cards were assigned to the spaced training condition. It was impossible to blind participants to their training condition. Outcomes raters were blinded to the training condition.

Intervention

Spaced and massed courses were based on the American Health Association/Heart and Stroke Foundation of Canada 2010 PALS curriculum and were identical in content, format and time allotted (Supplementary methods).

Outcome measures

The primary outcome measure was global rating scale (GRS) score for the four individual procedural skills (adult and infant CC, infant BMV and IO). Secondary outcome measures included quantitative metrics of CPR, a multiple-choice question (MCQ) test, and visual analogue scale (VAS) scores for self-efficacy.

Procedural skills

Skills were assessed on video recordings of the participants pre-, post-, and 3-months post-course. The authors developed GRS tools for each skill based on the Criteria for good assessment Consensus Statement.[26] Each tool consisted of a rubric of items followed by an overall 4-point Likert scale (1 = very poor and 4 = excellent) (Appendix A).

Quantitative measures of CPR skills

CC and infant BMV quality were measured using Laerdal Resusci Anne™, Laerdal Resusci Baby™ and Laerdal SimPad SkillReporter™. Performance was scored from 0 to 100%.

MCQ test

The 33-question standardized Heart and Stroke Foundation of Canada PALS MCQ test was used post-training and 3-months post-course.

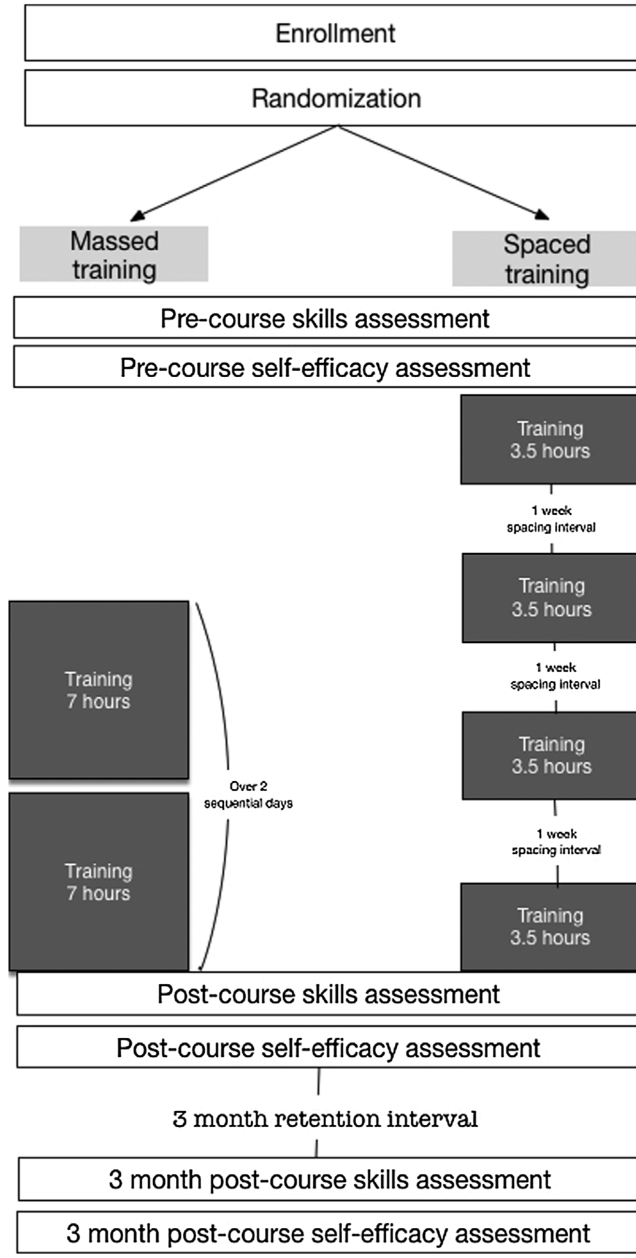

Fig. 1 – Study outline.

Self-efficacy

Participants completed a VAS questionnaire pre-, post-, and 3-months post-course. The questionnaire consisted of four questions evaluating self-efficacy in overall paediatric resuscitation, CC, BMV, and insertion of an IO device on a linear 100 mm scale. Work by Turner et al. has demonstrated good correlation between standard self-efficacy questionnaires and the VAS for self-efficacy for specific well-defined resuscitation tasks.[27]

Other paediatric resuscitation experiences

In order to ascertain whether participants engaged in paediatric resuscitation during the spacing or retention intervals, participants completed a follow-up questionnaire addressing any other paediatric resuscitation clinical or learning experiences. Participants in both groups completed the questionnaire 3-months post-course while participants in the spaced group also completed the questionnaire prior to their weekly training session.

Statistical analysis

For the primary outcome of skill performance as measured on the GRS, with an alpha level of 0.05, an assumed power of 0.8, and a predicted effect size of 0.85 (based on a previously determined effect sizes of 0.96, 1.01 and 1.6)[28–30] 26 participants per group would be necessary. This estimate of 52 subjects was similar to the sample sizes in the studies in medical education that reported differences between massed and spaced learning groups.[19,31] We aimed for 30 participants per group due to expected loss to follow-up.

All data analysis was performed using statistical software SPSS® Statistics Version 25 (IBM® Armonk, NY), with significance designated as $p < 0.05$. Summary statistics are described with mean, percentage and standard deviation. For skills scores where two ratings were available, average score of the two raters was used. Intraclass correlation (ICC) coefficient was calculated for interrater reliability (IRR). To account for baseline differences as well as dropouts, a generalized linear model was constructed with participants as repeated measures and separate fixed factors for training condition and an interaction of training condition*time point. Cohen's d was used to calculate effect size. A Cohen's d of 0.2, 0.5 and 0.8 are considered small, medium and large effect sizes respectively.

Results

Study population

Seventy-two potential participants were recruited and randomized between August 1, 2015 and February 6, 2016. Thirty-eight participants were randomized to spaced training; however, ten participants withdrew prior to participating in the intervention (due to scheduling conflicts), one participant completed three of the four spaced sessions but could not complete the remaining sessions or the follow-up. One participant completed the intervention but was lost to follow-up. Thirty-four participants were randomized to the massed training condition; however, twelve participants withdrew prior to participating in the intervention, two withdrew because they were unable to complete their basic life support (BLS) certification prior to the PALS course (a prerequisite to obtain PALS Heart and Stroke Foundation certification) and the other ten withdrew due to scheduling conflicts. A total of 11 PALS courses (5 spaced and 6 massed were run over the study period). Forty-eight participants (26 in the spaced group and 22 in the massed group) completed the study and follow-up (Fig. 2).

The demographic characteristics of the 48 participants who completed the pre-, post-, and 3-month post skills and self-efficacy assessment are shown in Table 1. None of the participants were involved in other paediatric resuscitation clinical or educational experiences over the instructional or follow-up period.

Skills

GRS scores are shown in Fig. 3. Skills scores for infant CC improved immediately following the course in both the massed (pre, 1.3 ± 0.7 vs post, $3.1 \pm 0.1.2$; $P < 0.0001$) (Cohen's d = 1.8) and spaced groups (pre, 1.6 ± 1.1 vs post, 2.9 ± 1.2; $P < 0.0001$) (Cohen's d = 1.1). 3-months post-course the infant CC scores remained significantly improved from baseline testing in both the massed (pre, 1.3 ± 0.7 vs post-3-months, 2.5 ± 1.5; $P = 0.01$) (Cohen's d = 1) and spaced groups (pre, 1.6 ± 1.1 vs post-3-months, 2.5 ± 1.3; $P = 0.01$) (Cohen's d = 0.7).

Skills scores for adult CC improved immediately following the course in both the massed (pre, 1.3 ± 0.6 vs post, 2.3 ± 1.1; $P = 0.004$) (Cohen's d = 1.1) and spaced groups (pre, 1.1 ± 0.6 vs post, 2.6 ± 1.3; $P < 0.0001$) (Cohen's d = 1.5). 3-months post-course the adult CC scores remained significantly improved from baseline testing in both the massed (pre, 1.3 ± 0.6 vs post-3-months, 2.2 ± 1.3; $P = 0.04$) (Cohen's d = 0.9) and spaced groups (pre, 1.1 ± 0.6 vs post-3-months, 2.3 ± 1.1; $P < 0.0001$) (Cohen's d = 1.4).

Skills scores for infant BMV improved immediately following the course in both the massed (pre, 1.6 ± 0.5 vs post, 2.2 ± 0.6; $P = 0.001$) (Cohen's d = 1.1) and spaced groups (pre, 1.8 ± 0.7 vs post, 2.3 ± 0.1; $P = 0.008$) (Cohen's d = 0.6). 3-months post-course the infant BMV scores remained significantly improved from baseline testing in the spaced (pre, 1.8 ± 0.7 vs post-3-months, 2.2 ± 0.7; $P = 0.005$) (Cohen's d = 0.6) but not in the massed groups (pre, 1.6 ± 0.5 vs post-3-months, 1.8 ± 0.5; $P = 0.98$)

Skills scores for infant IO improved immediately following the course in both the massed (pre, 2.6 ± 1.1 vs post, 3.3 ± 0.5; $P = 0.04$) (Cohen's d = 0.6) and spaced groups (pre, 2.5 ± 1 vs post, 3.2 ± 0.6; $P = 0.04$) (Cohen's d = 0.8). 3-months post-course the infant IO scores remained significantly improved from baseline testing in the spaced

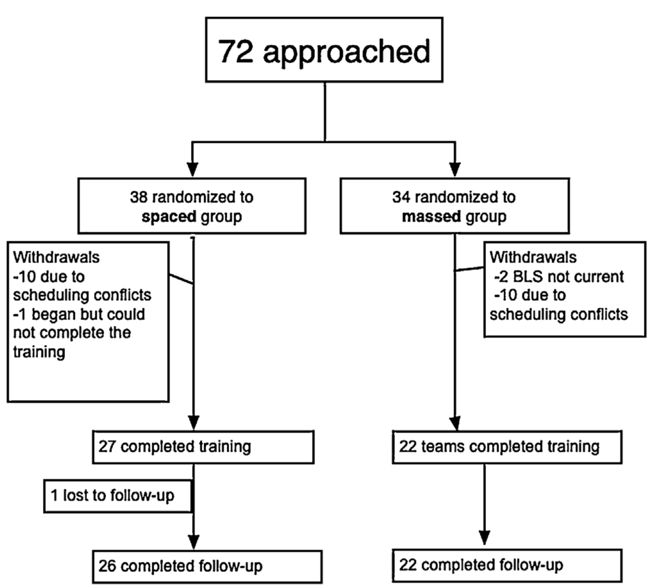

Fig. 2 – Overview of participants enrolment (BLS denotes basic life support).

Table 1 – Participant demographics.

Variable	Massed group (n = 22)	Spaced group (n = 26)
Years of EMS service	9.6 (±4.1)	9.1 (±4.9)
Female gender (%)	10 (46)	13 (50)
Provider type (%)		
Advanced care paramedic (EMT-P)	16 (73)	21 (81)
Primary care paramedic (EMT-A)	6 (27)	5 (19)
Previously completed PALS (%)	17 (77)	22 (85)
Timing of previous pediatric resuscitation (months)	47 ± 43	46 ± 43
Motivation to learn pediatric resuscitation		
(1) Not at all motivated	0	0
(2) Slightly motivated	0	0
(3) Moderately motivated	1	1
(4) Very motivated	10	10
(5) Extremely motivated	11	15

EMS — Emergency Medical Services, EMT — Emergency Medical Technician, PALS — Pediatric Advanced Life Support.

(pre, 2.5 ± 1 vs post-3-months, 3.1 ± 0.5; $P = 0.04$) (Cohen's d = 0.8) but not in the massed groups (pre, 2.6 ± 1.1 vs post-3-months, 2.7 ± 0.2; $P = 0.98$).

Quantitative skills scores

Quantitative skills scores are shown in Table 2. Quantitative skills scores for infant and adult CC improved immediately following the course in both the massed and spaced groups. 3-months post-course the infant CC scores remained significantly improved from baseline testing in both the massed and spaced groups.

Quantitative skills scores for infant BMV improved immediately following the course in the spaced group but not in the massed group. 3-months post-course the infant BMV scores remained significantly improved from baseline testing in the spaced but not in the massed group.

Knowledge (MCQ test)

In the spaced group there was no decay in the mean MCQ score 3-months post course compared to the immediate post-course score (post, 30.3 + 0.5 vs post-3-months 29.7 ± 0.5; $P = 0.39$) however there was a statistically significant decay in the MCQ scores in the massed training condition (post, 31.1 ± 0.5 vs post-3-months 29.6 ± 0.5; $P = 0.04$) (Cohen's d = 0.6).

Self-efficacy

Self-efficacy scores for overall paediatric resuscitation improved immediately following the course in both the massed and spaced groups, however 3-months post-course only the spaced group's self-efficacy scores remained significantly above baseline scores with self-efficacy scores in the massed group not significantly different from baseline scores. An identical trend was seen in self-efficacy of cardiac massage and intraosseous insertion (Table 3). Self-efficacy scores for bag mask ventilation improved immediately following the course in both the massed and spaced groups, however 3-months post-course self-efficacy was no longer significantly different from baseline in both groups.

Discussion

Our study demonstrates that spaced instruction results in long-term (3-month) retention of more skills than massed training. Although participants in both training formats retained CC performance, those in the spaced group also retained BMV and IO insertion skills. Recent studies have demonstrated that spaced practice improves chest compression quality among in-hospital healthcare providers (HCP) [21,22]; however, existing evidence related to the effect of spaced training on skills other than chest compressions are heterogenous with respect to how spacing is introduced (during initial training versus booster or just-in-time training)[30,32–34] and what skills are assessed. Ours is the first study to look at spaced instruction in the context of paediatric resuscitation skills taught during a PALS course among experienced providers.

The fact that long-term retention of performance was maintained in all four skills within the spaced group suggests that the spacing effect persists despite varying task complexity and associated motor response.[28] We hypothesize that this differential retention of skills may be related to the nature of motor response required for the included skills with CC being a more continuous (cyclic movement

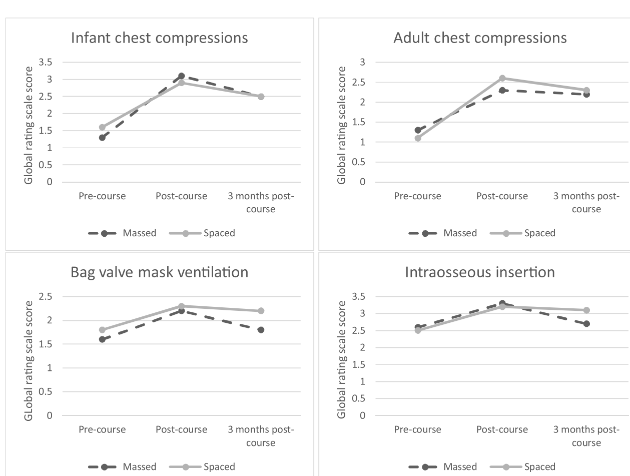

Fig. 3 – Mean global rating scale (GRS) skills assessment scores between (1) pre-course to post-course, (2) pre-course to 3 months post-course.

Table 2 – Differences in quantitative skills assessment scores between (1) pre-course to post-course (2) pre-course to 3 months post-course.

Skill	Massed (n = 22) Pre-course	Post-course	P-value	Effect size Cohen's D	Spaced (n = 26) Pre-course	Post-course	P-value	Effect size Cohen's D
Infant chest compressions	35.7 ± 27.9	90 ± 13.5	<0.0001	2.5	45.8 ± 35.8	94.6 ± 4.6	<0.0001	1.9
Adult chest compressions	40.3 ± 30	93 ± 8.6	<0.0001	2.4	49.3 ± 31.1	91.6 ± 13.2	<0.0001	2.4
Bag mask ventilation	48 ± 30.5	61.2 ± 27.7	0.490		30.9 ± 30.4	56.5 ± 21.3	<0.0001	1.0
	Pre-course	3 months post-course	P-value	Effect size Cohen's D	Pre-course	3 months post-course	P-value	Effect size Cohen's D
Infant chest compressions	35.7 ± 27.9	77.3 ± 25.7	<0.0001	1.6	45.8 ± 35.8	77.8 ± 26.9	<0.0001	1.0
Adult chest compressions	40.3 ± 30	90 ± 8.6	<0.0001	2.2	49.3 ± 31.1	85.7 ± 4.2	<0.0001	2.2
Bag mask ventilation	48 ± 30.5	48.1 ± 30.6	1.0		30.9 ± 30.4	53.9 ± 24.1	0.005	0.8

Table 3 – Differences in mean self-efficacy scores between (1) pre-course to post-course (2) pre-course to 3 months post-course.

VAS self-efficacy question	Massed Pre-course	Post-course	P-value	Effect size Cohen's D	Spaced Pre-course	Post-course	P-value	Effect size Cohen's D
Pediatric resuscitation	57.4 ± 17.2	79.5 ± 10.1	<0.0001	1.6	53.1 ± 14.4	83.9 ± 7.3	<0.0001	2.7
Cardiac massage	43.4 ± 31.1	61.2 ± 33.6	0.002	0.6	62.4 ± 30.9	82.2 ± 9.6	<0.0001	0.9
Bag mask ventilation	76.8 ± 14.8	87.1 ± 7.9	0.001	0.9	79.4 ± 10.2	87.8 ± 1.5	0.001	1.0
Insertion of an intraosseous device	66.3 ± 21.5	82 ± 11.1	<0.0001	0.9	59.5 ± 26	86.2 ± 9.8	<0.0001	1.4
	Pre-course	3 months post-course	P-value	Effect size Cohen's D	Pre-course	3 months post-course	P-value	Effect size Cohen's D
Pediatric resuscitation	57.4 ± 17.2	63 ± 14.6	0.34		53 ± 14.4	71.8 ± 9.1	<0.0001	1.6
Cardiac massage	43.4 ± 31.1	57.2 ± 31.2	0.06		62.3 ± 4.9	82.2 ± 9.6	<0.0001	2.6
Bag mask ventilation	76.8 ± 14.8	76.6 ± 9.7	1		79.4 ± 10.2	81.8 ± 9.3	0.74	
Insertion of an intraosseous device	66.3 ± 21.5	77.1 ± 11.1	0.05	0.6	59.5 ± 26	81.9 ± 12.4	<0.0001	1.1

VAS — visual analogue scale.

pattern) response compared to BMV and IO which are discrete (having a definite beginning and end) responses.[35] Studies consistently demonstrate that continuous movements are generally retained better than discrete movements.[35]

The results related to CC and BMV performance are strengthened by the quantitative secondary outcome measures. Within the spaced group the quantitative measure results mirror the GRS results whereas in the massed group, the statistical significance of the GRS and quantitative results of BMV performance differ slightly. Despite these differences, the overall trends in this data are similar and likely clinically meaningful.

Although there was a statistically significant difference in knowledge retention at 3 months, both groups maintained mean exam scores beyond the acceptable passing standard (84%) for the course. This is not surprising given that other studies have demonstrated a dichotomy between theoretical and practical skill retention with theoretical knowledge frequently maintained for months (rather than weeks) following training.[36,37]

Self-efficacy improved in both training conditions, a finding that is consistent with previous studies evaluating self-efficacy following paediatric resuscitation training.[38] At the 3-month retention interval there was an important decay in self-efficacy following the course taught in a massed format such that self-efficacy was no longer significantly different from baseline in 3 out of the 4 domains. This decay was less prominent when taught in a spaced format as self-efficacy remained significantly above baseline levels in 3 out of 4 domains measured. This is an important finding that is consistent with our previous data suggesting that in spaced training, self-efficacy has a slower decay compared to massed training[39] but contrasts the findings of Turner et al. who demonstrated maintained self-efficacy among physicians up to 6 months post-paediatric resuscitation training.[38] A significant proportion of participants (>50%) in Turner's study had the opportunity to use their resuscitations skills at least once during the retention interval, whereas in our study none of the participants were involved in the resuscitation of children during the retention interval. Given that self-efficacy can be derived from personal experience,[40] it is possible that participants in the study by Turner et al. maintained their self-efficacy because of their opportunity to use their skills. The benefits of alternative instructional designs such as spacing may be particularly relevant for those providers such as EMS who have limited opportunities to be involved in paediatric resuscitation on a regular basis but need to preserve behaviours consistent with an increased likelihood of responding and performing in the rare times that they are involved.

A common argument in favor of massed training is the perceived logistical advantage with regards to participant and instructor scheduling, educational material availability and attendance compared to spaced conditions. Our experience does not support these perceptions as there was a similar withdrawal rate in both groups (the majority of which occurred prior to any training). Our previous work also suggests that learners prefer spaced instruction.[32]

Important limitations of our study include a small sample size and uncertain reliability/validity of our assessments. We would have ideally had 26 participants per study group but due to participant drop out prior to training we had only 22 participants in the massed group. Despite this limitation, we were able to demonstrate statistically significant differences at 3 months and the total numbers are similar to samples sizes in prior medical education studies that report differences between massed and spaced learning groups.[19,31]. With regards to the assessment tools, there were none available in the literature with reported validity evidence. We developed our own assessment tools through review of the literature using expert consensus to guide our decisions. We sought to optimize reliability of our tools through the use of dedicated assessment rubrics for each skill and assessor training prior to conducting assessments. Furthermore, for three out of the four skills, we also used quantitative measures of skill performance. The trends within the data were similar adding further validity evidence to our approach.

In summary, our study adds to this growing evidence in favor of spaced instruction for procedural skills by demonstrating that spaced practice over a 3-week period within the initial phase of learning among experienced EMS providers results in long-term retention of more skills compared to traditional massed format. Furthermore, it supports recent recommendations that resuscitation training should be replaced or supplemented with spaced practice.[17] Given that HCP completing resuscitation courses routinely show a significant decay in their skills after training,[8,11] optimizing the long-term retention of a greater number of paediatric resuscitation skills among pre-hospital providers is particularly important given that they are often performing these skills both infrequently and in the absence of other HCPs.

Conflict of interest

The authors do not perceive any potential sources of conflict of interest

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resuscitation.2019.06.010.

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