RESUSCITATION 138 (2019) 273–281

Available online at www.sciencedirect.com

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Simulation and education

The effect of an International competitive leaderboard on self-motivated simulation-based CPR practice among healthcare professionals: A randomized control trial☆,☆☆

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☆ This manuscript was presented as a poster presentation at the International Pediatric Simulation Symposium & Workshops (Glasgow, UK) May 7, 2016, International Meeting on Simulation in Healthcare (Orlando, FL, USA) January 8, 2017, and at the Resuscitation Sciences / American Heart Association Conference (Chicago, IL, USA) November 11, 2018.

☆☆ This study was funded by the American Heart Association Western States Grant-in-Aid #15GRNT25030000 (PI: TPC).

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https://doi.org/10.1016/j.resuscitation.2019.02.050
Received 22 November 2018; Received in revised form 11 February 2019; Accepted 18 February 2019

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Abstract

Background: Little is known about how best to motivate healthcare professionals to engage in frequent cardiopulmonary resuscitation (CPR) refresher skills practice. A competitive leaderboard for simulated CPR can encourage self-directed practice on a small scale. The study aimed to determine if a large-scale, multi-center leaderboard improved simulated CPR practice frequency and CPR performance among healthcare professionals.

Methods: This was a multi-national, randomized cross-over study among 17 sites using a competitive online leaderboard to improve simulated practice frequency and CPR performance. All sites placed a Laerdal® ResusciAnne or ResusciBaby QCPR manikin in 1 or more clinical units – emergency department, ICU, etc. – in easy reach for 8 months. These simulators provide visual feedback during 2-minute compressions-only CPR and a performance score. Sites were randomly assigned to the intervention for the first 4-months or the second 4-months. Following any CPR practice by a healthcare professional, participants uploaded scores and an optional 'selfie' photo to the leaderboard. During the intervention phase, the leaderboard displayed ranked scores and high scores earned digital badges. The leaderboard did not display control phase participants. Outcomes included CPR practice frequency and mean compression score, using non-parametric statistics for analyses.

Results: Nine-hundred nineteen participants completed 1850 simulated CPR episodes. Exposure to the leaderboard yielded 1.94 episodes per person compared to 2.14 during the control phase ($p = 0.99$). Mean CPR performance participants did not differ between phases: 90.7 vs. 89.3 ($p = 0.19$).

Conclusion: A competitive leaderboard was not associated with an increase in self-directed simulated CPR practice or improved performance.

Keywords: Simulation, Resuscitation, Games, Experimental, Competitive behavior, CPR, Leaderboard

Introduction

Even among seasoned healthcare professionals, high-quality chest compressions – adequate rate and depth with complete chest recoil and minimal interruptions – do not occur in 36%–87% of cardiopulmonary resuscitation (CPR) events.[1–4] In fact, many healthcare professionals certified in CPR with Basic Life Support (BLS), Advanced Cardiac Life Support (ACLS), Pediatric Advanced Life Support (PALS) or Neonatal Resuscitation Program (NRP), are unable to demonstrate proper technique as recommended by the 2015 American Heart Association (AHA) guidelines.[1,5–7] The relative rarity of in-hospital cardiac arrests puts healthcare professionals at risk for skill decay and inadequate quality compressions.[3,4,8] Resuscitation skills have been shown to decay by 3 months post-training, which has prompted calls to use a frequent, low-dose 'rolling refresher' skills training approach such as the AHA Resuscitation Quality Improvement (RQI) methodology.[9–11] This is in contrast to the traditional 2-year certification cycles.

Evidence to move to short, frequent ongoing practice sessions is growing. Achievement of CPR quality performance, including adequate chest compression rate and depth, compression fraction, and minimal leaning requires frequent practice to prevent skills decay, more regularly than the current 2-year recertification requirement.[9,12–15] Newer approaches include "booster training" with in situ simulation-based CPR sessions as short as 30 min.[13–16] This evidence is the root of the AHA RQI program which recognizes the benefits of feedback and frequent skills training every 3 months.[17]

This paradigm shift, however, opens a new problem: how to motivate learner activation among healthcare professionals to practice every 3 months. Mandated classroom training typically suffers from low learner activation.[18,19] Even for CPR, the inherent task-value of the activity is undervalued.[20] CPR training improves confidence and knowledge, but not always proportionately to performance[14,21,22], and this incongruence creates a barrier to motivating frequent practice. In addition, providers overestimate the quality of CPR during cardiac arrest.[8] Using simulation,[23] improving attitudes to CPR training,[21] allowing self-guided or self-directed learning,[24] and reducing barriers to CPR practice have been recommended, as these adhere to adult learning principles for successful learning and skills retention.[19–21,24] The AHA has made it a priority to 'optimize educational strategies' for CPR for this reason.[25,26] A *punitive* method to motivate frequent CPR practice among healthcare professionals is to mandate the traditional certification course for those neglecting frequent practice. However, no specific methods for *encouraging* frequent practice has been systematically implemented.

We propose that triggering learner activation among healthcare professionals is key to increase CPR practice frequency. In our single center pilot study in Manchester, England, both friendly competition and peer pressure were positive motivators for CPR practice.[27] This type of competition falls under the concept of *gamification*,[28,29] which can improve learner activation. Principles of gamification have been used in both entertainment and serious games to lengthen gameplay and learning activities.[28–31] We have already described the use of gamification in healthcare training,[32] and have developed an online mechanism to compare CPR performance scores between institutions and colleagues using game design elements, including points, badges, and leaderboards.[33] The purpose of this study was to examine the effect of this leaderboard on two germane outcomes in simulated CPR practice: first, the frequency of practice among healthcare professionals and second, their measured CPR performance. We hypothesized that exposure to a leaderboard during the intervention phase would increase both frequency of practice and CPR performance, and that this effect would carry over even when the leaderboard was not accessible.

Methods

Trial design & allocation

This was a randomized, crossover design study examining the effect of an open, online leaderboard on frequency of CPR practice and CPR performance that spanned from October 2015 to June 2016. Seventeen institutions within the International Network for Pediatric Innovation,

Research, and Education (INSPIRE) across 2 continents participated.[34] Each institution participated for 8 months, during which 4 consecutive months were spent in an intervention phase, and an additional 4 consecutive months were spent in a control phase. The order of the phases was randomized (Appendix 1) and allocation was not blindable – all institutions and subjects were aware of their randomization sequence. However, the actual timing of the phases differed across institutions as sites 'arrived' onto the leaderboard at predetermined times, in clusters called "waves" (Appendix 1). Randomization was done using *random.org* to approximate a 50-50 allocation for all institutions, and all subjects within one institutions shared the same allocation. Institutions that completed their 8 months had access to the leaderboard thereafter, but those data points were not collected for this study. All institutions received Ethics Board approval or exemption.

Participants

Eligible participants included any healthcare professional (e.g. physician, respiratory therapist, nurse, technician) working primarily at a participating institution, who would be expected to perform CPR on a patient. These included staff in the emergency department (ED), intensive care units (ICUs - pediatric, cardiac, medical, surgical, neonatal), inpatient wards, and in the operating rooms or post-anesthesia care units. Those in training, such as resident physicians were included. Participants were excluded from enrollment if they were only rotating through the participating institution temporarily, such as a medical or nursing student or rotating resident. Current BLS certification was not explicitly required for study inclusion, though all participants were healthcare staff who would otherwise be expected to clinically perform CPR. While the leaderboard was activated or de-activated for sites on the 1st day of the 4-month phase, participants could be enrolled at any time during the 8-month period, depending on local workflow and resources.

All participants were instructed on how to use the simulator during recruitment by a research staff member. Immediately following enrollment, participants were asked to perform 2 min of single-rescuer CPR with real-time feedback. For adult manikins, this was hands-only CPR; for infant manikins, this required a single-rescuer CPR with a bag-valve mask provided according to the country's and unit's standard (30:2 – United States, 15:2– Europe/United Kingdom, 3:1– NRP Neonatal Intensive Care Units). The European Resuscitation Council uses 15:2 for single-rescuer CPR if they have healthcare training.[35] The real-time feedback enabled the participant to see if the rate, depth, and location of chest compressions and bag-mask ventilations were performed correctly. Participants were also briefed on how the leaderboard worked and how to upload and save CPR performance scores.[33]

Setting, simulator environment

The study protocol used either a Laerdal® ResusciAnne or ResusciBaby QCPR manikin (Stavenger, Norway) with either a SkillGuide or SkillReporter device attached. A "Q"CPR manikin can sense the "Q"uality of CPR being delivered for feedback. The choice of an adult or infant manikin was at the discretion and resources of each institution. For all sites, the manikin was placed in a clinical or clinical rest area (e.g. break room) openly accessible to clinical staff. Institutions with multiple departments participating placed a manikin at each department location, to ensure participants had accessibility without having to leave the clinical area. The simulators were either on mobile carts or fixed at the discretion of each site. Appendix 2 shows a sample cart from institution A.

The ResusciAnne simulator was required to be placed at 30 in. (75 cm) height with a 9 inch (23 cm) standard medical stool. One site used a platform at 22 in. (56 cm) without a stool. No mattress or soft surface was allowed.[36] No height or stool requirements existed for the ResusciBaby simulator, though a bag-valve mask was required to be with the infant QCPR simulator. The location and setup of the available simulator was verified at all 17 sites through site visits by the principal investigator. During these visits, participating local staff received standardized training and updates on the manikin and leaderboard.

Simulation event & feedback

The study allowed for voluntary CPR practice on the available QCPR simulator for all participants. CPR practice was considered 2 min of uninterrupted chest compressions on the adult QCPR simulator and 2 min of single-rescuer infant CPR on the infant simulator.

During all participants' 2-minute CPR practice sessions, real-time audiovisual feedback was provided by either the SkillGuide or SkillReporter software. Research and/or simulation staff were not allowed to provide any assistance *during* CPR performance. However, research and/or simulation staff were allowed to provide coaching *following* an individual's 2-minute practice session. After each CPR practice session, participants were asked to upload their scores onto the leaderboard as part of data collection. Each upload required a photograph that, at minimum, featured the score screen of the SkillGuide or SkillReporter. Participants included themselves in a 'selfie' photograph at their own discretion.

Intervention

The primary intervention for this study was the availability of the online leaderboard for the participant's institution. The online leaderboard was a real-time ranking of CPR performance based on the proprietary performance score provided by the SkillGuide or SkillReporter software. Institutions in the intervention phase could see their participant scores on the leaderboard which updated continuously. The leaderboard also contained scores from other institutions concurrently in the intervention phase (Fig. 1). During the control phase, any uploaded scores from the institution were blocked from being publicly visible. In other words, the leaderboard only displayed scores contributed from institutions who were in the intervention phase. Uploaded scores during the control phase were accessible to research staff only for analyses following completion of data collection. The development and implementation of the online leaderboard, selfie photographs, and badges / points system is described in detail in another publication.[33]

Research and education staff were prohibited from expressly changing their hours or availability between the two phases. In addition, sites were asked to limit larger-scale motivational activities that used the leaderboard (e.g. announced local competitions). Reminders or grand rounds regarding the leaderboard and CPR that would affect 6 or more people within an institution were recorded. As best as possible, the QCPR simulator and availability were customized to meet the needs of each institution, taking into account local security, available space, and familiarity of use by the participants.

Variables

The primary independent variable of interest was access to one's own scores on the leaderboard– either fully visible during the intervention phase or blocked during the control phase. The 2 primary outcome

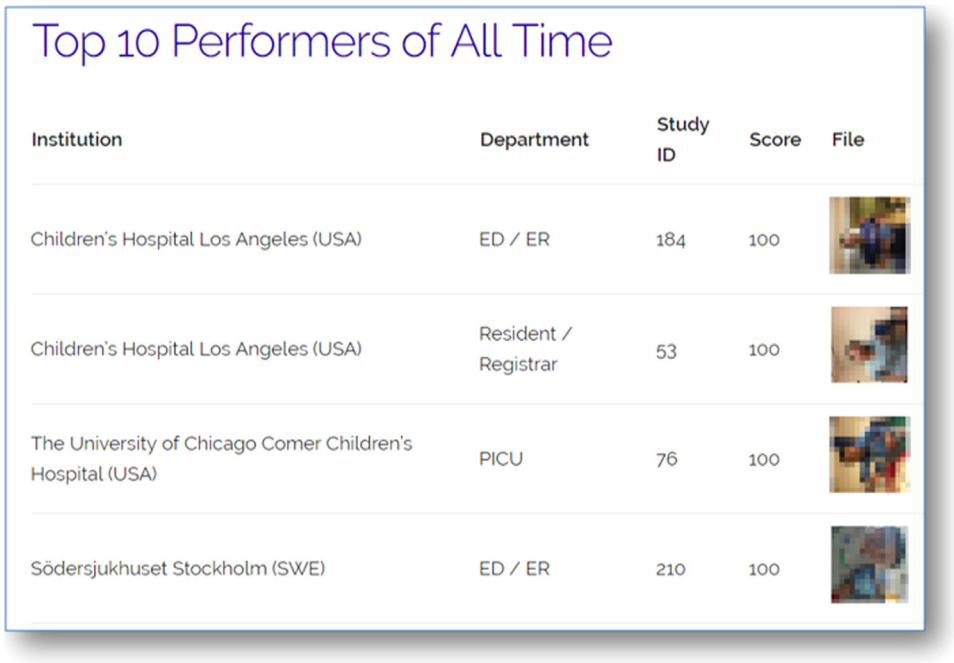

Fig. 1 – A screenshot of the online leaderboard.

variables were *frequency of practice*, defined as the total times that a participant voluntarily uploaded their performance onto the leaderboard, and CPR performance as measured by *CPR Score*, a percent (%) value generated by the Laerdal SkillReporter or SkillGuide software that correlated to adherence to 2010 AHA or European Resuscitation Council (ERC) guidelines. The 2015 guidelines came into effect midway through the study. To maintain consistency, we opted not to change the software to 2015 settings. All data came from the leaderboard uploads and provided date/time stamps for all activities. All uploads were accompanied by a photo of the score displayed on the Laerdal SkillReporter or SkillGuide to verify authenticity.

Sample size considerations

Because the study question centered around stimulating competitive behavior through gamification, subjects were allowed to recruit other potential subjects ad lib – e.g. asking a colleague to join to compare scores – as long as a research staff at the institution facilitated enrollment without coercion. Therefore, no maximum sample size ceiling was set for this study. A minimum sample size was estimated based on the targeted RQI reference of every 3 months. This translates to 2.67 CPR episodes during the 8-month block. We used an alpha of 0.05, Power of 0.9 with 1-to-1 allocation. An increase from 2 +/- 2 CPR episodes (once per phase) to 2.67 roughly yields a Cohen's $d = 0.25$, estimating a minimum sample size of 198 per group or 396 total (G*Power 3.1, Dusseldorf, Germany).

Analyses

Descriptive statistics were used to summarize demographic information and overall CPR frequency over time for all participants, divided by simulator type. We conducted independent T-tests for normal continuous data, and Wilcoxon-Mann-Whitney U tests for nonparametric data. In order to estimate the crossover effect, a linear mixed effects (LME) model using a restricted maximum likelihood (REML) method was employed, which accounted for participants nested within departments within institutions. Frequency of practice and CPR score were the 2 dependent variables in two separate models. The crossover effect was modeled in the LME model as a random effect as the interaction between assignment arm and sequence and reported as the estimate of covariance with 95% confidence intervals (CIs). The level of significance was set at $p = 0.05$ for all analyses without correction. Analyses were done using SPSS (v. 22.0, IBM Corp., Armonk, NY, USA), and figures were generated using Prism Software (v. 7.0a, GraphPad Software Inc.).

Results

One thousand fourteen eligible participants were approached among participating institutions. One hundred twelve were enrolled outside of the participating institutions' 8-month block, leaving 920 enrolled; of these, 319 participants (34.7%) were recruited during the control period (white boxes in Fig. 2) and 601 participants were recruited during the intervention period (65.3%, gray boxes in Fig. 2). The CONSORT diagram is presented in Fig. 2. The demographics of the subjects involved are presented in Table 1.

There were 685 CPR episodes that were logged onto the leaderboard during the control period and 1165 during the intervention period. These are summarized in Table 2. This represented 2.14 episodes per participant during the control phase and 1.94 episodes per participant during the intervention, though only a small number of participants practiced more than once. This included participants who only practiced once.

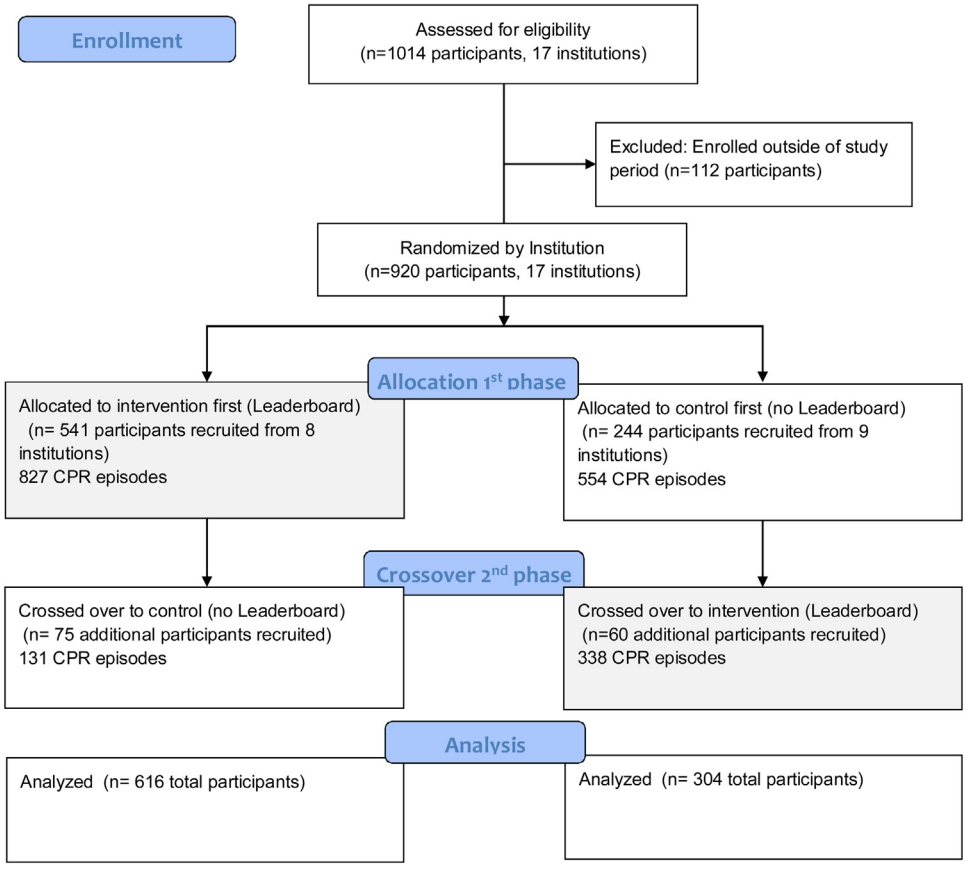

Fig. 2 – CONSORT Diagram by Participant and CPR episodes.

Fig. 3 demonstrates the distribution of frequency of practice and CPR scores. Table 3 illustrates the progression of *frequency of practice* separated by institutions who started in the control phase first, versus those who started in reverse. In either allocation, no difference due to the intervention was seen ($p > 0.58$), and no crossover effect was seen (95% CI 1.0–26.5, $p = 0.236$).

When the institution experienced a control phase followed by an intervention phase, the CPR performance minimally increased ($p = 0.006$). No such difference was found when institutions went in reverse allocation order. There was no crossover effect (95% CI 1.5–51.8, $p = 0.270$).

Discussion

This is one of largest international studies that implemented an online competitive leaderboard for self-directed CPR practice. Our data do not show any lasting improvements in either frequency of CPR practice or CPR performance scores in the presence of such a leaderboard. Although most participants enjoyed the concept of the leaderboard, we found that it was not sustainable beyond the short-term and did not reliably motivate independent practice every 3 months.

The use of competition and leaderboards to engage audience participation is not new and has been used effectively in health education. Examples include increasing participation in medical school lectures[37], inducing competition for quality improvement, and using points as a gamification technique for medical boards preparation.[38] While gamification using leaderboards, points, and badges, as we did for CPR, had prior evidence of success, it predicated on a short-term effect. The single-center study on which we based our multi-center trial, lasted less than 1 year in a local context.[27] Even the most popular game as measured by total participants, Pokemon Go™, peaked in its overall phenomenon in less than a few months. The Ice Bucket Challenge, whose selfie feature we borrowed for the CPR leaderboard, also had only a few months of longevity.[39] While the evidence for gamification to change behavior exists, the

Table 1 – Demographics of the participants in the Two Randomized Arms.

	Intervention → Control Arm			Control → Intervention Arm		
Institutions	A	142	25%	I	44	13%
coded by letter	B	60	10%	J	1	<1%
	C	204	35%	K	30	9%
	D	41	7%	L	44	13%
	E	7	1%	M	46	14%
	F	36	6%	N	32	10%
	G	65	11%	O	22	7%
	H	32	5%	P	102	30%
				Q	12	4%
Locations	Emergency Dept / Accident & Emergency	266	46%		103	31%
	Pediatric Intensive / Critical Care Unit	116	20%		176	53%
	Neonatal Intensive / Critical Care Unit	78	13%		0	
	Ward / Floor	32	5%		0	
	Residency (no fixed location)	59	10%		40	12%
	Cardiac Intensive / Critical Care Unit	36	6%		14	4%
Role	Physician	126	21%		69	20%
	Nurse	232	40%		109	33%
	Ancillary Services	53	9%		19	6%
	Pre-hospital	2	<1%		33	10%
	Other	10	2%		10	3%
	[Missing]	164	28%		93	28%
Gender	Male	109	19%		70	21%
	Female	310	53%		169	51%
	[Missing]	168	28%		94	28%
Age (years)	Mean+/− Std Dev	34.3 +/−9.0			34.2 +/−9.3	
Height (cm)		167.2 +/−15.6			74.8 +/−20.1	
Weight (kg)		70.4 +/−18.5				
Total		587			333	

longevity of such a technique appears to be lacking, which is consistent with our own frequency data. It is likely that we triggered an *overjustification effect*, where the gimmick of the game element superceded the importance of the training (CPR) itself.[32]

There are several explanations for our finding of low frequency of practice. First, compressions-only CPR has a ceiling effect– once the AHA guidelines for depth, rate, and minimizing lean are met, there is no further improvement. Given that overall scores for our participants in simulated CPR were quite high (90% and higher), there was minimal 'room for improvement.' For both games and gamification, *incremental challenge* or the ability to provide an individualized level of challenge to progress, is a required element to engage participants.

Table 2 – List of institutions, randomization order, and frequency of CPR practice episodes per phase.

Institution	Geographic Location	Units Involved	1st Phase → 2nd Phase	Intervention CPR frequency	Control CPR frequency
A	Western USA	ED PICU	Int → Ctrl	152	29
B	Northeastern USA	ED	Int → Ctrl	59	12
C	Southern USA	ED PICU NICU	Int → Ctrl	268	32
D	Southern USA	PICU NICU	Int → Ctrl	56	0
E	United Kingdom	PICU OR	Int → Ctrl	2	5
F	Southern USA	PICU CICU	Int → Ctrl	113	28
G	Sweden	ED	Int → Ctrl	124	11
H	United Kingdom	Ward	Int → Ctrl	24	14
I	Northeastern USA	ED	Ctrl → Int	2	46
J	Midwestern USA	ED	Ctrl → Int	2	0
K	Northeastern USA	PICU	Ctrl → Int	41	14
L	Midwestern USA	PICU	Ctrl → Int	76	0
M	Sweden	PICU OR	Ctrl → Int	193	313
N	Canada	ED	Ctrl → Int	6	27
O	Northeastern USA	PICU	Ctrl → Int	24	35
P	Midwestern USA	ED PICU	Ctrl → Int	10	119
Q	Midwestern USA	ED PICU	Ctrl → Int	13	0
Total				1165	685

USA– United States of America. ED– Emergency Department / Accident & Emergency. PICU– Pediatric Intensive Care Unit. NICU– Neonatal Intensive Care Unit. CICU– Cardiovascular Intensive Care Unit (Pediatric). OR– Operating Room / Operating Theatre. Int– Intervention. Ctrl– Control.

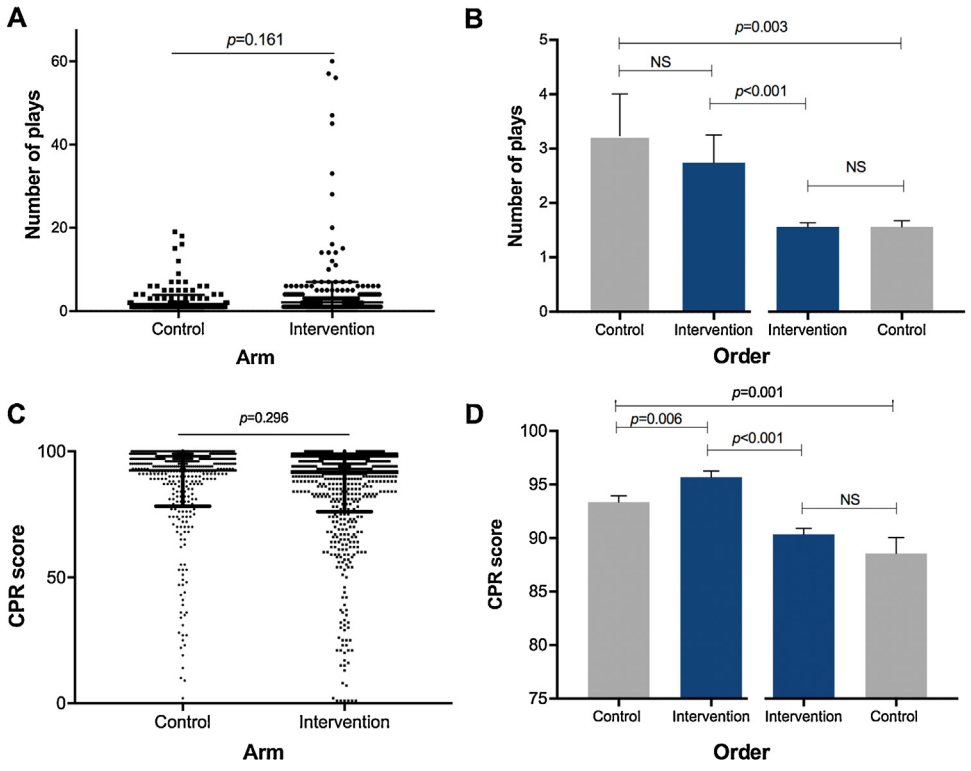

Fig. 3 – CPR scores and frequency of practice by randomization arm. (A–B) Frequency of practice by control or intervention. (A) shows frequency of practice by control or intervention arm and (B) shows frequency of practice by order of crossover. (C–D) CPR scores by control or intervention. (C) shows total CPR scores by control or intervention arm and (D) shows CPR scores by order of crossover. Error bars represent SEMs.

Without increasing 'levels,' 'difficulties' or challenges, this motivation to improve was removed, and thereafter the effect of any points or leaderboard rank was reduced. It is possible that increasing the duration of CPR could have created an incremental challenge component, but this would have physical and exertional constraints not suitable for the goals of training all providers.

The ceiling effect may also be a halo effect. The performance score algorithm proprietary to Laerdal® is relatively forgiving for small deviations from the AHA guidelines. This provides psychologically favorable benefits of increasing confidence, which also may reduce the motivation to practice further.

Lastly, part of the leaderboard's purpose was to spur competition as a motivator for CPR practice. However, competition is known to not motivate all types of healthcare providers and learners and can alienate some, particularly lower performers.[32] Compared with the extant medical literature, the competition intended by the online

Table 3 – Frequency of practice and CPR performance as outcomes per group and randomization order, with crossover effect estimates.

Outcome 1: Frequency of CPR Practice	Order					
	Control > Intervention			Intervention > Control		
	Control	Intervention	p-value	Intervention	Control	p-value
Total frequency of practice, mean (SEM)	3.2 (0.8)	2.7 (0.5)	0.583	1.6 (0.1)	1.6 (0.1)	0.982
Crossover effect (estimate of covariance) (95% CI)	5.1 (1.0, 26.5)					
p-value	0.236					
Outcome 2: CPR performance	**Order**					
	Control > Intervention			Intervention > Control		
	Control	Intervention	p-value	Intervention	Control	p-value
CPR performance score, mean (SEM)	93.4 (0.5)	95.7 (0.6)	**0.006**	90.4 (0.6)	88.6 (1.5)	0.253
Crossover effect (estimate of covariance) (95% CI)	8.8 (1.5, 51.8)					
p-value	0.270					

leaderboard was in a different, larger setting. Competition certainly has an effect in a small, local setting[27] such as a single operating theatre or classrooms; however, it is probable that competing against unknown healthcare workers across countries was not as motivational as competing against known colleagues or rival departments. In fact, although the study duration went through both the World Cup and Olympics in 2016, no increase in CPR practice was seen during those phases where national competitive pride was otherwise natural.

An anecdotal phenomenon observed at multiple institutions deserves mention here. More than half of the sites reported observing a participant refusing to upload a low score, and either giving up or retrying for a higher score. These events were not captured by our data collection protocol and the exact prevalence of this behavior is unknown. This may explain the relatively high scores in our existing data. While the behavior of trying for a higher score is exactly the behavior the leaderboard intended to harness, we were unfortunately not able to comment systematically on these behaviors.

The study does have some limitations. First, although researchers and research staff across sites were instructed not to change enrollment practices between the intervention and control phases, it was ultimately not possible to blind participants or staff, and a higher enrollment did occur during the intervention phase. Whether that was a research staff bias or a phenomenon of the leaderboard (e.g. other interested participants crowding around) is unknown. While this led to a much higher sample size than the minimum required, we still did not find a significant and meaningful difference in practice frequency nor performance. Second, we observed at multiple sites the habit of participants deleting low or unsatisfactory scores in favor of a better score to upload. This is a similar phenomenon to normal 'selfies,' to put the best image forward. Because the study was designed to be self-motivated, we were unable to prevent lower scores from being deleted. While their pursuit of a higher score was in line with the AHA intent for increased CPR practice, it may have artificially lowered the recorded practice frequency and inflated the mean performance scores. It is unknown how many attempts were not logged or deleted. Finally, the institutions involved were almost all pediatric institutions or pediatric units. While the motions of CPR practice are not necessarily different, the staff experience with CPR – given that cardiac arrest is rarer in children– may have influenced the perceived need for frequent training.

Conclusion

An online gamification technique using leaderboards, points, badges, and a selfie feature does not increase self-motivated simulated CPR practice among healthcare staff over the long-term. Further strategies or a set of evolving strategies are needed to motivate healthcare staff to repeatedly practice CPR.

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.2019.02.050.

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