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Training approaches for the deployment of a mechanical chest compression device: a randomised controlled manikin study

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Abstract

Objectives: To evaluate the effect of training strategy on team deployment of a mechanical chest compression device.

Design: Randomised controlled manikin trial.

Setting: Large teaching hospital in the UK

Participants: Twenty teams, each comprising three clinicians. Participating individuals were health professionals with intermediate or advanced resuscitation training.

Interventions: Teams were randomised in a 1:1 ratio to receive either standard mechanical chest compression device training or pit-crew device training. Training interventions lasted up to one hour. Performance was measured immediately after training in a standardised simulated cardiac arrest scenario in which teams were required to deploy a mechanical chest compression device.

Primary and secondary outcome measures: Primary outcome was chest compression flow-fraction in the minute preceding the first mechanical chest compression. Secondary outcomes included cardiopulmonary resuscitation quality and mechanical device deployment metrics, and non-technical skill performance. Outcomes were assessed using video recordings of the test scenario.

Results: In relation to the primary outcome of chest compression flow-fraction in the minute preceding the first mechanical chest compression, we found that pit-crew training was not superior to standard training (0.76 (95% CI 0.73 to 0.79) v 0.77 (95% CI 0.73 to 0.82), Mean difference -0.01 (95% CI -0.06 to 0.03), p=0.572). There was also no difference between groups in performance in relation to any secondary outcome.

Conclusions: Pit-crew training, compared with standard training, did not improve team deployment of a mechanical chest device in a simulated cardiac arrest scenario.

Trial registration: ISRCTN43049287, registration date 30/06/2016.

Keywords: Cardiac arrest, Cardiopulmonary Resuscitation, Advanced Cardiac Life Support, Pit-crew Training, Mechanical Chest Compression Device.

Strengths and limitations of the study

- This is the first randomised controlled study to investigate the effect of pit-crew training, compared with standard training, in the clinical area of cardiac arrest.
- This was a manikin study, such that it is unknown to what extent the findings can be reliably generalised to the clinical cardiac arrest setting.
- Outcomes were measured immediately after the training intervention, such that we did not investigate the long-term effect of each training intervention.

Background

Mechanical chest compression devices provide a method to deliver high-quality chest compressions to patients in cardiac arrest.[1] Despite evidence that manual chest compression delivery is often sub-optimal and that high-quality chest compression delivery is associated with improved survival, randomised controlled trials in out-of-hospital cardiac arrest (OHCA) have found that use of a mechanical chest compression device is not superior to manual chest compressions in relation to patient outcome.[2-5] In contrast, very low quality evidence from in-hospital cardiac arrest (IHCA) suggests use of devices may be associated with improved patient outcome.[6]

The key risk associated with use of mechanical chest compression devices is the pause in chest compressions associated with their deployment.[1] In the LINC randomised controlled trial of the use of mechanical chest compression devices in OHCA, a sub-study found that the median chest compression pause associated with device deployment was 36.0 seconds (interquartile range 19.5 to 45.5).[7] Such pauses are associated with a reduction in coronary pressure during the early part of a cardiac arrest and may therefore off-set the potential benefit of improved chest compression delivery associated with devices.[8]

Pit-crew resuscitation describes a concept where clinicians in a team act in a pre-determined way to undertake set tasks in a specific order, akin to a formula one motor racing team. In a clinical before-after quality improvement study, the use of this concept alongside other interventions was associated with a marked reduction in the pause associated with device deployment in OHCA.[9] However, the impact of the use of a pit-crew training approach has not, to date, been tested against other team training approaches in a randomised controlled trial.

Methods

We conducted a randomised controlled parallel group trial to evaluate the impact of pit-crew training, compared with standard training, on mechanical chest compression deployment in a simulated cardiac arrest. The mechanical chest compression device used was the LUCAS-2 mechanical chest compression device (Jolife AB/ Physio-Control, Lund, Sweden). Outcomes were evaluated through a video-recorded simulation test that was undertaken immediately after the training intervention.

All participants provided written informed consent prior to receiving any study intervention. The study was reviewed and approved by the University of Warwick Biomedical and Scientific Research Ethics Committee.

Participants

Teams of three clinicians were recruited to participate in the trial. To be eligible to participate, individual clinicians were required to be registered health professionals with current Immediate Life Support (ILS) or Advanced Life Support (ALS) certification, and to have completed the online manufacturer's device training package. Participants were not eligible if they had an injury or disability that prevented use or handling of the device, or if they had received practical training in the use of the device in the preceding six-months

Each team was required to be composed of three eligible clinicians, of which one was required to be an ALS certificated provider or instructor. As such, teams were broadly reflective of the standard required of in-hospital cardiac arrest teams in the UK.[10]

Study process

We advertised the study at the hospital site through posters in staff areas, emails to staff, and face-to-face discussions. Staff that consented to participate in the study were asked for their availability and allocated a training slot. As such, teams were created based on convenience, in that we established teams based on individual clinician's availability to attend training at a specified time.

On attendance at the training session, the team was randomised using a simple randomisation system provided by an internet-based randomisation service, which ensured allocation concealment (Sealed Envelope, London, UK). Teams were randomly allocated in a 1:1 ratio to receive either pit-crew training or standard training. After randomisation, a researcher (KC), with experience in teaching Advanced Life Support courses, immediately delivered the allocated training intervention. The team was not blinded to their allocated training intervention.

Following the training, the teams undertook a standardised manikin-based simulation test. The team acted as a hospital cardiac arrest team. The scenario, given in the SBAR format (Situation, Background, Assessment, Recommendation), described a 62-year old male who had undergone tracheal intubation due to hypoxia secondary to a probable pulmonary embolus and who had subsequently become haemodynamically unstable leading to cardiac arrest.[11] During the scenario, a mechanical chest compression device arrived during the second CPR cycle and the team was required to use the device. The length of the scenario was approximately eight minutes (four cycles of CPR).

The simulation test was video-recorded. Two digital video recorders were used to mitigate against the risk of data loss and possible obstruction of a camera by participants.

Study intervention

An overview of the two training approaches, based on the TIDieR (template for intervention description and replication) framework, is included as an electronic supplement (tables S1 and S2).[12] Both training approaches incorporated a presentation on device deployment and use, followed by an opportunity for the team to practice these skills. Skill practice was scenario-based, with feedback following each scenario. It was anticipated that training would last approximately 45-minutes, although teams were allowed to practice for as long as required.

The key difference between the training approaches was that teams randomised to pit-crew training received an overview of the concept and potential value of the pit-crew concept in the training presentation, together with guidance on how to operationalise pit-crew concepts in deploying the

mechanical chest compression device. These concepts were also highlighted during practice scenarios.

In both training approaches, teams were trained to deploy the device in two-stages, such that there was a pause for the deployment of the device back plate followed by the resumption of CPR and then a subsequent pause to enable deployment of the upper part of the mechanical device.

Outcome measures

The primary outcome was the chest compression flow-fraction in the minute preceding the first mechanical chest compression. Flow-fraction describes the proportion of time in which chest compressions are being delivered over a designated period. This specific outcome was selected as it enabled us to capture all pauses that may be attributable to device deployment.

There were a number of secondary outcome measures including chest compression flow-fraction (prior to the first mechanical chest compression, following the first mechanical chest compression, whole event), the duration of chest compression pauses associated with device deployment, and non-technical skills measured using the Team Emergency Assessment Measure (TEAM) tool.[13]

Data management

Videos were reviewed by two researchers (KC, RMV) independently. The first reviewer (KC) delivered the training intervention and so was not blinded to training allocation. The second reviewer (RMV) was blinded to training allocation. Videos were viewed using software that enabled timings to be derived to the nearest one-tenth of a second. We assessed agreement between video reviewers by computing the average difference and 95% confidence interval (CI) or median difference and interquartile range (IQR) for each outcome and plotting data using a Bland-Altman plot.[14] We used the mean value of the two reviewers in the analysis.

Statistical analysis

Our planned sample size of 20 teams (3 clinicians per team) was based on demonstrating an absolute increase in flow-fraction in the minute preceding the first mechanical chest compression of 0.15 (baseline 0.58, standard deviation 0.10) at 90% power with a p-value of 0.05. Due to the nature of the study, we did not increase the sample size to account for drop-outs. If a team member did not attend their allocated training session, then the team would not be eligible and so would not be randomised.

Data analysis was based on intention-to-treat principles. For baseline team and individual data, we report categorical variables as number and percentage, whilst continuous variables are described as mean (95% CI) or median (IQR), depending on the normality of the data.

All outcomes are assessed at the team level. For normally distributed continuous outcomes, we summarise team performance as mean (95% CI), and compare groups using an independent t-test and report the mean difference, 95% CI, and p-value. For non-normally distributed continuous

outcomes, we summarise group performance as median (IQR) and compare groups using a Mann-Whitney U test and report the p-value.

Results

Between June 2016 and September 2016, 77 clinicians consented to participate in the study (figure one). Of these, 60 participated in randomised teams. Four participants were excluded after giving consent to participate but prior to randomisation (one identified that their resuscitation certification had expired, one developed an injury that prevented use of the device, and two received previous practical mechanical device training). For the remaining 13 participants, we were unable to identify a convenient time for training prior to randomising the 20 teams required.

Demographic data at the team and individual level are shown in tables one and two respectively. Team characteristics were comparable between groups. There were some differences between groups at the individual participant level in relation to, for example, clinical experience and speciality.

For the primary outcome, the average difference between reviewers for the twenty cases was 0.01 (95% CI -0.01 to 0.02). Bland-Altman and average differences for other outcomes are included in the electronic supplement (table S3 and figure S1). Based on these data, outcome analyses are based on the average data from the two reviewers.

In relation to the primary outcome, we found no difference in the flow-fraction preceding the first mechanical chest compression between study groups (0.76 (95% CI 0.73 to 0.79) v 0.77 (95% CI 0.73 to 0.82), Mean difference -0.01 (95% CI -0.06 to 0.03), p=0.572) (table 3).

The chest compression pause associated with both the deployment of the back plate (3.80 seconds (95% CI 2.83 to 4.76) v 3.82 (95% CI 2.62 to 5.02), Mean difference -0.03 (95% CI -1.46 to 1.41), p=0.971) and upper part of the device (9.99 seconds (95% CI 8.84 to 11.14) v 9.67 (95% CI 8.02 to 11.32), mean difference 0.32 (95% CI -1.55 to 2.19), p=0.724) was similar. We observed no difference in relation to any other secondary outcome.

There were no study adverse events and all training interventions were delivered as planned. The time taken to deliver each training intervention was similar (49.0 minutes (95% CI 44.0 to 54.0) v 45.3 (95% CI 40.5 to 50.1), mean difference 3.1 (95% CI -2.7 to 10.1), p=0.244) (table three). During one simulation test (pit-crew training arm), the device battery failed as due to researcher error the device battery was not charged prior to training. This battery failure did not affect the primary outcome, but did marginally reduce flow-fraction across the whole scenario and following device deployment.

Discussion

In this randomised controlled manikin trial we found that the use of a pit-crew training approach, compared with a standard training approach, did not improve the deployment of a mechanical chest compression device in simulated IHCA. Similarly, the use of pit-crew training did not improve any other device deployment, CPR quality or non-technical skills metric.

Our study, in contrast to previous pit-crew cardiac arrest studies, directly compared pit-crew training with a standard training approach.[9, 15-19] Whilst not directly comparable, it is noteworthy that previous studies have typically reported an association between implementation of pit-crew principles and improvements in process and patient-focussed outcomes. For example, in a before/after OHCA clinical study, the implementation of pit-crew training alongside real-time feedback and post-event debriefing was associated with an improvement in neurologically intact survival following OHCA (odds ratio 2.3, 95% confidence interval 1.3 to 4.0).[18]

There are four possible explanations for this apparent contrast in findings. Firstly, previous studies have tended to implement pit-crew training alongside other interventions, such as real-time feedback, additional training, and cardiac arrest debriefing. As such, the findings of previous studies may reflect the impact of the overall package of interventions, such that pit-crew training either did not have an independent effect or complementary interventions enhanced its effect. Secondly, previous studies have adopted an observational design, such that the findings may be attributable to unmeasured confounders rather than the intervention that was implemented.

A third explanation is that where treatment quality is already high, as observed in this study, pit-crew training provides no additional benefit. In Levy et al's before-after study, where the pit-crew training intervention was associated with a marked improvement in care delivery, the median pre-intervention pause between the final manual chest compression and first mechanical chest compression was 21 seconds (interquartile range 15 to 31).[9] In contrast, the mean total pause associated with device deployment in in the control group (standard training) in this study this study was about 14 seconds, with the upper end of the 95% confidence interval in both groups being less than 16.1 seconds.

Finally, it may be that pit-crew concepts provide more value in the clinical setting, compared to simulated cardiac arrest conditions. Replicating the real-life complexity of cardiac arrest management in the simulation laboratory is challenging.[20, 21] It is possible that pit-crew training provides most advantage in the unpredictable clinical setting, where the concepts provide a clear framework to direct effective team functioning.

Our study has several weakness. Firstly, we tested performance in a simulated cardiac arrest scenario that occurred immediately after the training intervention, such that we do not know how training interventions affected performance either in the longer-term or in the clinical setting. Secondly, participants were often experienced clinicians with frequent exposure to cardiac arrest, so it is unclear whether findings are generalisable to less experienced clinicians. Thirdly, we found that performance in both groups was markedly better than that estimated in our power calculation, so our study was underpowered to reliably detect a clinically important difference between groups. Fourthly, we did not capture participant views on the impact of training approaches on team functioning. Finally, whilst agreement between video reviewers was generally good, there was some variation in relation to the TEAM tool outcomes. However, analysis at an individual reviewer level produced similar results to our overall planned analysis (data not presented).

Conclusion

In this randomised controlled manikin trial, we found pit-crew training, compared with standard device training, did not improve the deployment of mechanical chest compression devices in a

simulated cardiac arrest. The time taken to deliver training was similar. Future controlled trials should examine the effect of pit-crew training in the clinical setting and on long-term performance.

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The funder had no role in the design of the study, data collection, data analysis and interpretation, or the writing of the manuscript.

Competing interests

KC, TQ, RL, JY, GDP report that their organisations have received funding from NIHR for clinical trials on the use of mechanical chest compression devices.

Author's contributions

KC conceived and designed the study, acquired the data, analysed the data, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, drafted the manuscript, and approved the final manuscript

RMV analysed the data, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

TQ conceived and designed the study, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

AD conceived and designed the study, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

RL conceived and designed the study, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

BO conceived and designed the study, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

JY contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

GDP conceived and designed the study, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

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Data sharing: The datasets generated and analysed during the current study are not publicly available to maintain participant confidentiality but are available from the corresponding author on reasonable request

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Figures and tables

List of figures

Figure one: study flow diagram

Table one: team characteristics

			Pit-crew training (10 teams)	Standard training (10 teams)
Teams with n doctors- n (%)				
	0		3 (30%)	3 (30%)
	1		5 (50%)	2 (20%)
	2		2 (20%)	3 (30%)
	3		0 (0%)	2 (20%)
Teams with n Advanced Life Support instructors- n (%)				
	0		4 (40%)	5 (50%)
	1		2 (20%)	4 (40%)
	2		3 (30%)	1 (10%)
	3		1 (10%)	0 (0%)
Teams with at least one member that has previously received device training- n (%)			5 (50%)	4 (40%)
Teams with at least one member with experience of using a device in clinical practice- n (%)			9 (90%)	10 (100%)

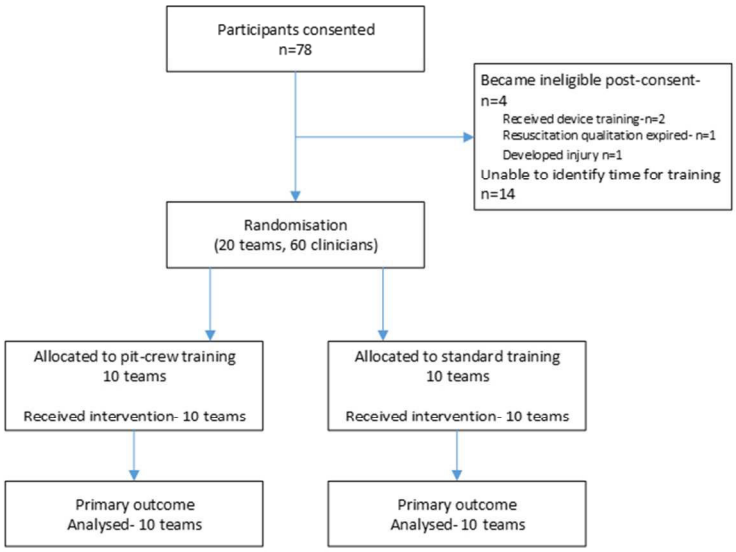
Table two: individual participant characteristics

	Pit-crew training (n=30)	Standard training (n= 30)
Gender- male- n (%)	12 (40.0%)	14 (46.7%)
Health profession- n (%)		
Doctor	9 (30%)	14 (46.7%)
Nurse	21 (70.0%)	12 (40.0%)
Operating department practitioner	-	1 (3.3%)
Paramedic	-	2 (6.7%)
Other	-	1 (3.3%)
Professional experience- years- median (IQR)	13.5 (6.3-21.3)	8.0 (3.8-13.5)
Grade- n (%)		
Band 5/ FY1	3 (10.0%)	5 (16.7%)
Band 6/ SHO	8 (26.7%)	11 (36.7%)
Band 7/ Registrar	14 (46.7%)	9 (30.0%)
Band 8+/ Consultant	5 (16.7%)	5 (16.7%)
Current speciality- n (%)		
Acute medicine	6 (20.0%)	5 (16.7%)
Critical care	11 (36.7%)	20 (66.7%)
Emergency medicine	6 (20.0%)	2 (6.7%)
Surgery	3 (10.0%)	2 (6.7%)
Other	4 (13.3%)	1 (3.3%)
Resuscitation qualification- n (%)		
Immediate Life Support provider	7 (23.3%)	7 (23.3%)
Advanced Life Support provider	12 (40.0%)	17 (56.7%)
Advanced Life Support instructor	11 (36.7%)	6 (20.0%)
Approximate number of cardiac arrests attended in last six months- median (IQR)	4.5 (2.0-10.0)	8.0 (1.8-15.8)
Previously received device training- Yes- n (%)	7 (23.3%)	4 (13.3%)
Previous use of a device in clinical practice- Yes- n (%)		
If yes, which device – n (%)	18 (60.0%)	17 (56.7%)
LUCAS	10 (55.6%)	8 (47.1%)
AUTOPULSE	11 (61.1%)	10 (58.8%)
THUMPER	2 (11.1%)	1 (5.9%)
If yes, how many times used- median (interquartile range)	2.5 (1.0-5.8)	3.0 (1.5-4.5)

Table three: Outcome measures (based on average from two videotape reviewers)

			Pit-crew training (n=10)	Standard training (n=10)	Mean difference (95% CI)	p-value†
Device deployment- mean (95% CI)						
	Flow-fraction in minute preceding first mechanical CC		0.76 (0.73 to 0.79)	0.77 (0.73 to 0.82)	-0.01 (-0.06 to 0.03)	0.572
	Time to deploy back-plate (secs)		3.80 (2.83 to 4.76)	3.82 (2.62 to 5.02)	-0.03 (-1.46 to 1.41)	0.971
	Time to deploy upper part of device (secs)		9.99 (8.84 to 11.14)	9.67 (8.02 to 11.32)	0.32 (-1.55 to 2.19)	0.724
	Total pause for mech device deployment (secs)		14.33 (12.62 to 16.03)	13.56 (11.05 to 16.06)	0.77 (-2.04 to 3.58)	0.572
	Time from device arrival to first mechanical CC (secs)- median (IQR)		55.25 (51.63 to 75.24)	60.43 (52.70 to 73.99)		0.912‡
Compliance with manufacturer's guidelines (out of eight)- median (IQR)			8 (8-8)	8 (8-8)		0.739‡
CPR quality						
	Flow-fraction- mean (95% CI)					
		Whole episode	0.94 (0.93 to 0.95)	0.94 (0.93 to 0.95)	0.00 (-0.01 to 0.01)	0.790
		Pre-device deployment	0.90 (0.89 to 0.92)	0.90 (0.88 to 0.91)	0.01 (-0.01 to 0.03)	0.538
		Post-device deployment	0.97(0.96 to 0.98)	0.97 (0.96 to 0.98)	0.00 (-0.01 to 0.01)	0.681
	Number of pauses > 5 seconds- median (IQR)		2.00 (1.75 to 3.00)	2.50 (1.00 to 4.13)		0.853‡
	Number of shocks delivered- median (IQR)		2 (2 to 2)	2 (2 to 2)		1.000 ‡
	Shocks delivered appropriately- median (IQR)		2 (2 to 2)	2 (2 to 2)		1.000 ‡
	Peri-shock pause (seconds)- median (IQR)					
		Pre-shock pause	0.00 (0.00 to 0.00)	0.00 (0.00 to 0.00)		1.000 ‡
		Post-shock pause	0.00 (0.00 to 0.00)	0.00 (0.00 to 0.00)		1.000 ‡
Non-technical skills- TEAM tool						
	TEAM tool- component score (out of 44)		38.0 (35.7 to 40.3)	37.6 (34.8 to 40.4)	0.40 (-2.94 to 3.74)	0.804
	TEAM tool- global (overall) score (out of ten)		8.1 (7.2 to 8.9)	7.9 (7.3 to 8.6)	0.15 (-0.87 to 1.17)	0.760
Training delivery						
	Duration of training- mean (95% CI)*		49.0 (44.0 to 54.0)	45.3 (40.5 to 50.1)	3.1 (-2.7 to 10.1)	0.244

† By independent t-test unless stated.
‡By Mann-Whitney U test.
* Data point measured directly during training intervention, so not based on assessment from two reviewers.



Study flow diagram

190x275mm (96 x 96 DPI)

Electronic supplement

Table S1: Descriptions of study intervention- standard training intervention- page 2

Table S2: Descriptions of study intervention- pit-crew training intervention- page 3

Table S3: Average differences between video reviewers- page 4

Figure S4: Bland-Altman plots- page 5

Table S1: Descriptions of study intervention- standard training intervention

Item	Description
BRIEF NAME	Standard training for the deployment of a mechanical chest compression device
WHY	Current evidence shows that deployment of mechanical chest compression devices in clinical practice may be associated with prolonged pauses in chest compressions. Such pauses can be harmful and reduce the likelihood of a successful outcome. In this training package, we will train clinicians to effectively deploy a mechanical chest compression device, using the training approach that is commonly used in NHS practice.
WHAT	**Materials**: Materials required include a mechanical chest compression device (LUCAS-2), powerpoint presentation, presentation projection facilities, manikin, hospital bed, defibrillator, ECG simulation pad, and airway equipment. **Procedures**: 1) Delivery of powerpoint presentation, which includes overview of how to deploy device (duration ~15-minutes) 2) Practical demonstration of process of deploying device (including which buttons should be pressed at relevant points) (duration ~5-minutes) 3) Opportunity for participants to practice deployment using simulation with feedback/ debriefing after each simulation (duration ~30-minutes) 4) Provide opportunity to ask questions and summarise key learning points (duration ~5-minutes)
WHO PROVIDED	The lead session instructor will be a Resuscitation Council (UK) Advanced Life Support with additional training in deployment of the LUCAS-2 mechanical chest compression device.
HOW	Training will be delivered face-to-face to three clinicians in each session.
WHERE	The training intervention will be delivered at a local hospital in a suitable training room (uninterrupted, adequate space) where required equipment is available.
WHEN and HOW MUCH	The training session will be delivered on one occasion. The duration is expected to be less than one hour.
TAILORING	This description of the intervention was developed following an initial run-through- no significant changes were required. The amount of practice required by each group will be determined on a group-by-group basis. This will be decided through discussion between the instructor and participants.
MODIFICATIONS	We do not anticipate making further modifications to the training package. If changes are deemed necessary, these will be recorded in any research output.
HOW WELL	The instructor at each session will record the duration of the session and any deviations from the training plan.

Table S2: Descriptions of study intervention- pit-crew training intervention

Item	Description
BRIEF NAME	Pit-crew training for the deployment of a mechanical chest compression device
WHY	Current evidence shows that deployment of mechanical chest compression devices in clinical practice may be associated with prolonged pauses in chest compressions. Such pauses can be harmful and reduce the likelihood of a successful outcome. In this training package, we will train clinicians using pit-crew principles to effectively deploy a mechanical chest compression device.
WHAT	**Materials**: Materials required include a mechanical chest compression device (LUCAS-2), powerpoint presentation, presentation projection facilities, manikin, hospital bed, defibrillator, ECG simulation pad, airway equipment, and pit-crew handout. The pit-crew handout will detail the process for pit-crew deployment of the device and the group will be encouraged to use it throughout the training session. **Procedures**: 1) Delivery of powerpoint presentation, which includes overview of how to deploy device and pit-crew concepts (duration ~15-minutes) 2) Practical demonstration of process of deploying device (including which buttons should be pressed at relevant points) (duration ~5-minutes) 3) Opportunity for participants to practice deployment using pit-crew principles in a simulation setting with feedback/ debriefing after each simulation (duration ~30-minutes) 4) Provide opportunity to ask questions and summarise key learning points (duration ~5-minutes)
WHO PROVIDED	The lead session instructor will be a Resuscitation Council (UK) Advanced Life Support with additional training in deployment of the LUCAS-2 mechanical chest compression device.
HOW	Training will be delivered face-to-face to three clinicians in each session.
WHERE	The training intervention will be delivered at a local hospital in a suitable training room (uninterrupted, adequate space) where required equipment is available.
WHEN and HOW MUCH	The training session will be delivered on one occasion. The duration is expected to be less than one hour.
TAILORING	This description of the intervention was developed following an initial run-through- no significant changes were required. The amount of practice required by each group will be determined on a group-by-group basis. This will be decided through discussion between the instructor and participants.
MODIFICATIONS	We do not anticipate making further modifications to the training package. If changes are deemed necessary, these will be recorded in any research output.
HOW WELL	The instructor at each session will record the duration of the session and any deviations from the training plan.

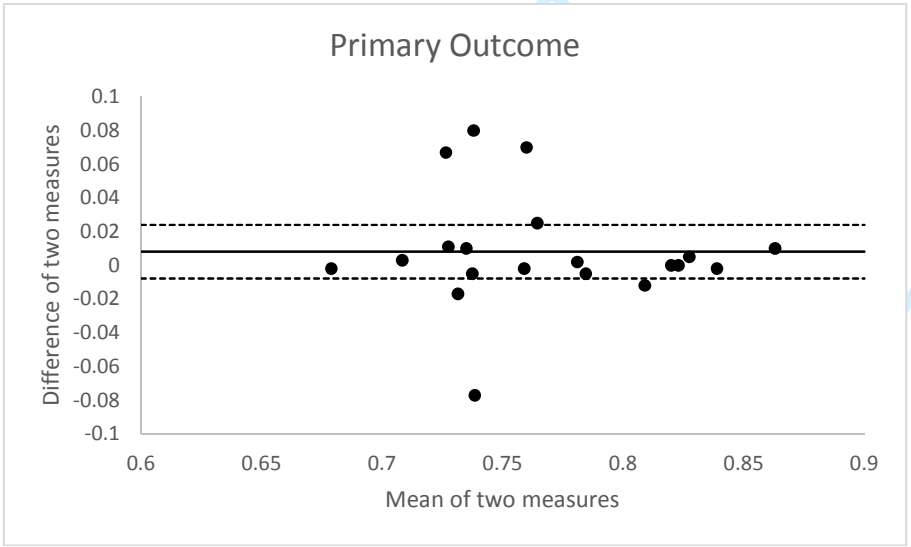
Table S3: Average differences between video reviewers

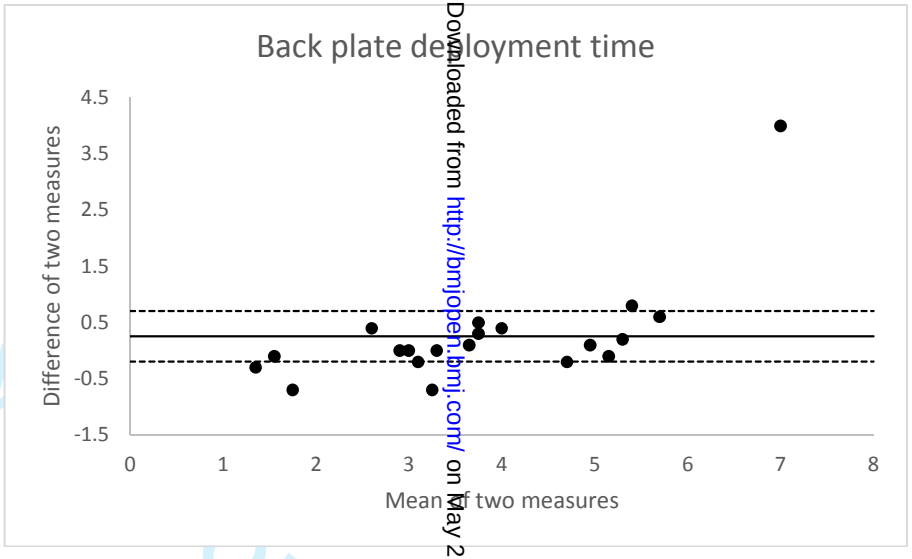
	Average difference (95% CI) between reviewers (unless stated)
Device deployment	
Flow-fraction in minute preceding first mechanical CC	0.008 (-0.008 to 0.024)
Time to deploy back-plate (secs)	0.050 (-0.175 to 0.400)†
Time to deploy upper part of device (secs)	0.000 (-0.100 to 0.300)†
Total pause for mech device deployment (secs)	-0.050 (-0.675 to 0.250)†
Time from device arrival to first mechanical CC (secs)	0.020 (-0.309 to 0.349)
Compliance with manufacturer's guidelines (out of eight)	0 (0 to 0)†
CPR quality	
Flow-fraction	
Whole episode	0.001 (-0.002 to 0.004)
Pre-device deployment	-0.000 (-0.010 to 0.009)
Post-device deployment	-0.000 (-0.002 to 0..001)
Number of pauses > 5 seconds	0 (0 to 0)†
Number of shocks delivered	0 (0 to 0)†
Shocks delivered appropriately	0 (0 to 0)†
Peri-shock pause (seconds)	
Pre-shock pause	0 (0 to 0)†
Post-shock pause	0 (0 to 0)†
Non-technical skills- TEAM tool	
TEAM tool- component score (out of 44)	-2.200 (-6.478 to 2.078)
TEAM tool- global (overall) score (out of ten)	-0.055 (-1.528 to 0.428)

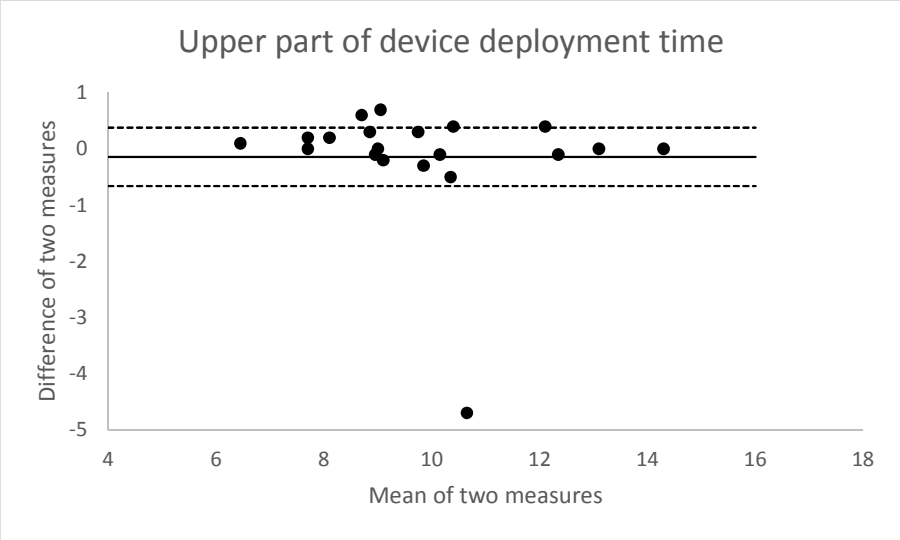
†- Reported as median difference (IQR)

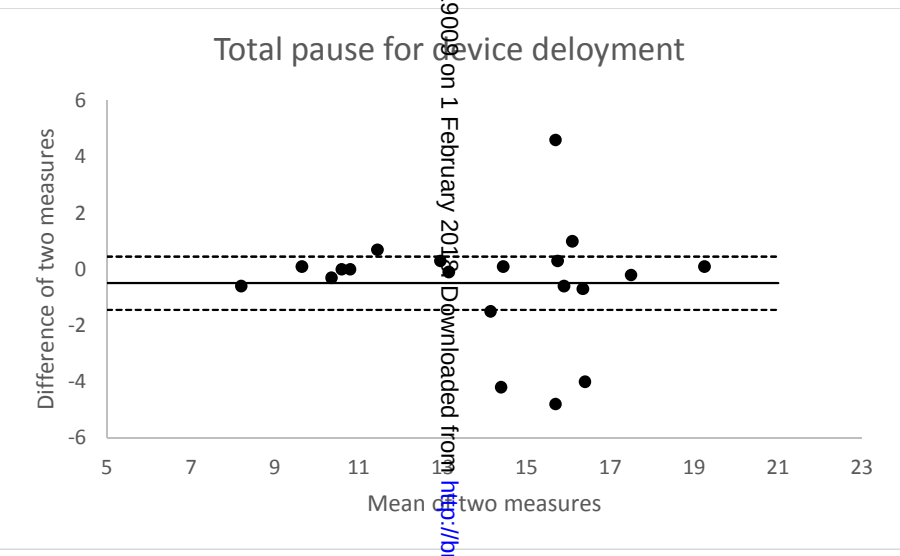
Figure S1: Bland-Altman plots

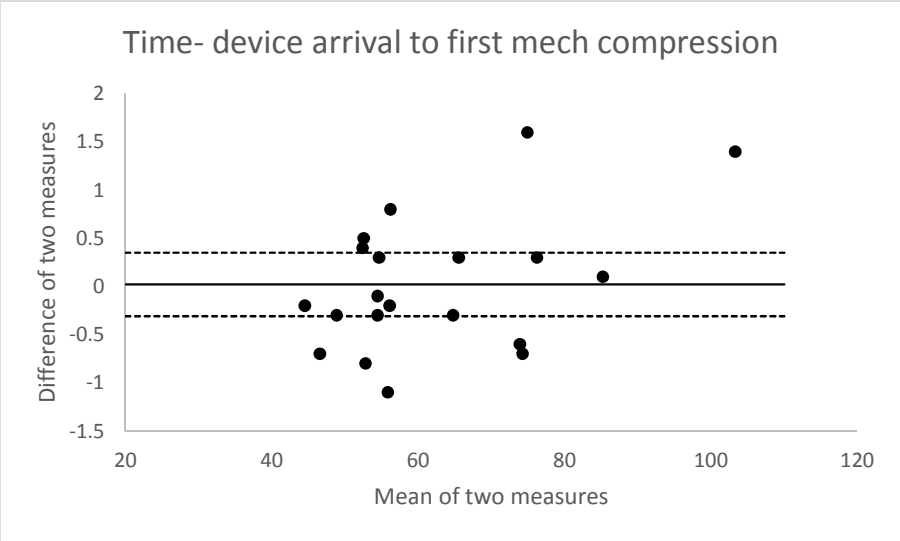
In each plot, the full line represents the mean difference between the two video reviewers and the dotted lines represent the upper and lower 95% confidence interval. Bland-Altman plots are not shown for number of shocks delivered, number of appropriate shocks delivered, pre-shock pause, and post-shock pause as there was perfect agreement for these outcomes. A plot is also not shown for manufacturer compliance, where there was perfect agreement for 19 groups and a difference of one in the other group.

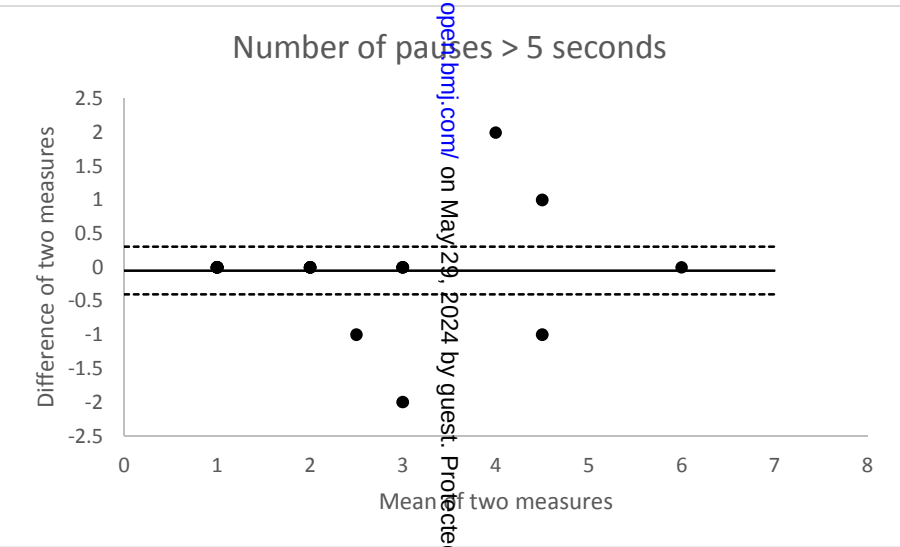


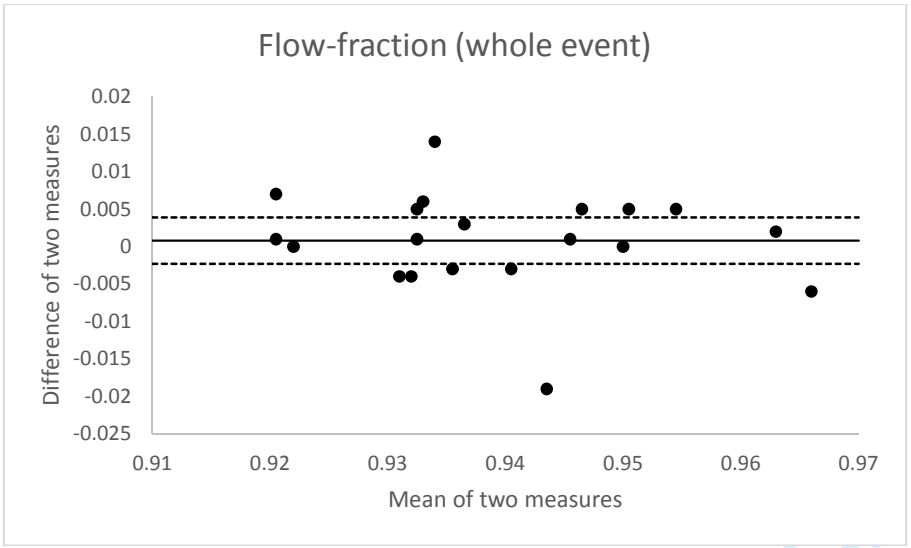


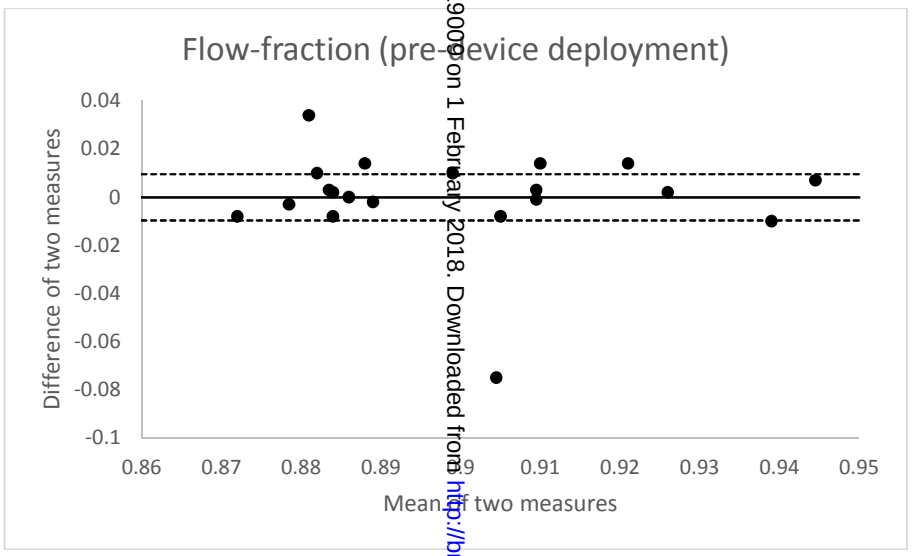


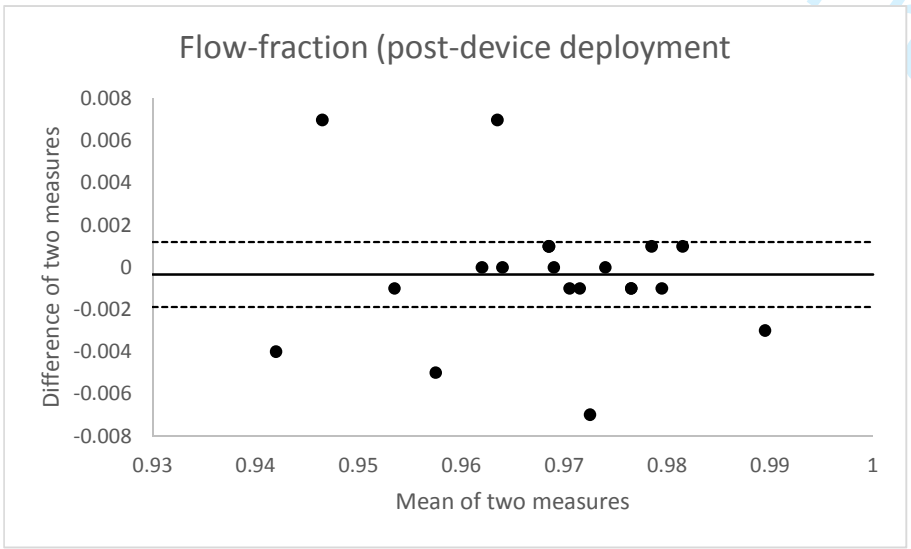


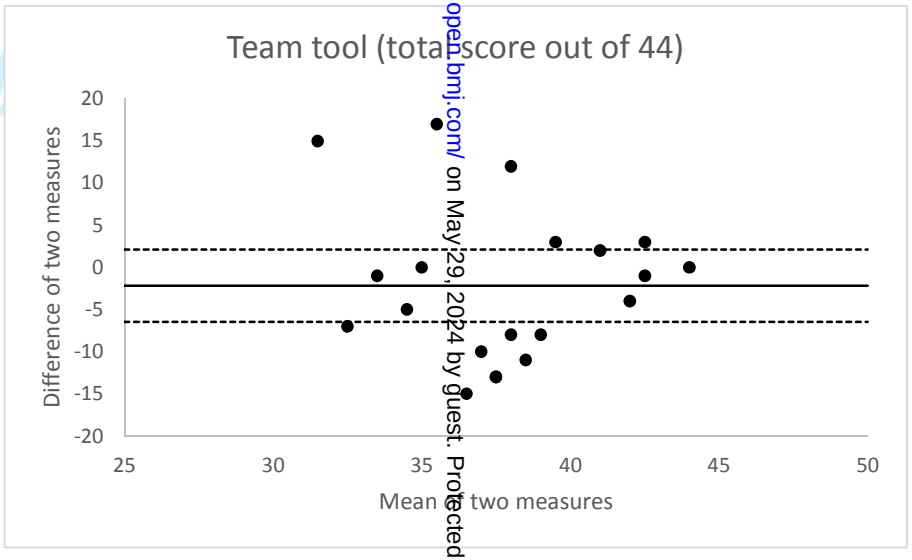


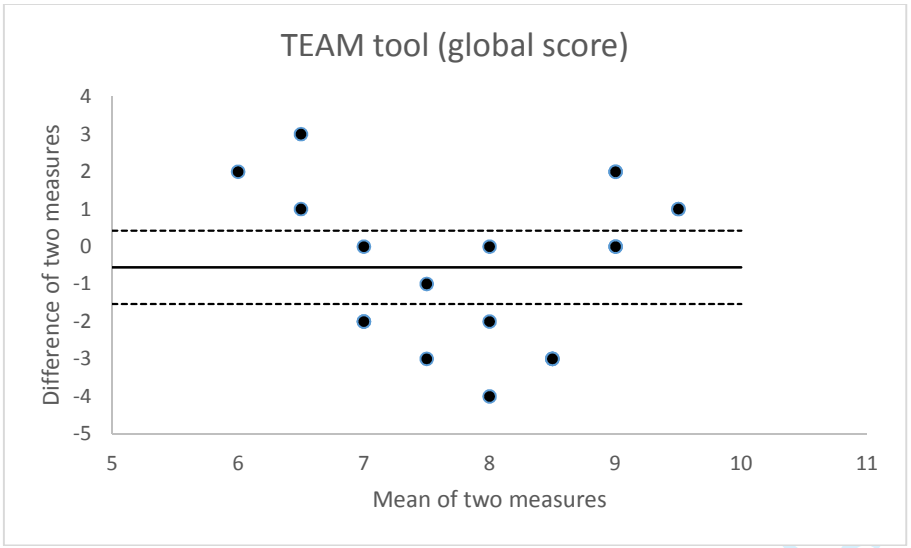












CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	4
	2b	Specific objectives or hypotheses	4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	4
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	N/A
Participants	4a	Eligibility criteria for participants	4
	4b	Settings and locations where the data were collected	5
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	5-6, electronic supplement
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	6
	6b	Any changes to trial outcomes after the trial commenced, with reasons	N/A
Sample size	7a	How sample size was determined	6
	7b	When applicable, explanation of any interim analyses and stopping guidelines	N/A
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	5
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	5
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	5
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	5
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	5,6

		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	N/A
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	6
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	6
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	Figure
	13b	For each group, losses and exclusions after randomisation, together with reasons	Figure
Recruitment	14a	Dates defining the periods of recruitment and follow-up	7
	14b	Why the trial ended or was stopped	7
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Table 1 &2
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	Figure
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	7
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	N/A
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	N/A
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	7
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	7-8
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	7-8
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	7-8
Other information			
Registration	23	Registration number and name of trial registry	2
Protocol	24	Where the full trial protocol can be accessed, if available	Provided
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	10

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

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Training approaches for the deployment of a mechanical chest compression device: a randomised controlled manikin study

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Training approaches for the deployment of a mechanical chest compression device: a randomised controlled manikin study

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Abstract

Objectives: To evaluate the effect of training strategy on team deployment of a mechanical chest compression device.

Design: Randomised controlled manikin trial.

Setting: Large teaching hospital in the UK

Participants: Twenty teams, each comprising three clinicians. Participating individuals were health professionals with intermediate or advanced resuscitation training.

Interventions: Teams were randomised in a 1:1 ratio to receive either standard mechanical chest compression device training or pit-crew device training. Training interventions lasted up to one hour. Performance was measured immediately after training in a standardised simulated cardiac arrest scenario in which teams were required to deploy a mechanical chest compression device.

Primary and secondary outcome measures: Primary outcome was chest compression flow-fraction in the minute preceding the first mechanical chest compression. Secondary outcomes included cardiopulmonary resuscitation quality and mechanical device deployment metrics, and non-technical skill performance. Outcomes were assessed using video recordings of the test scenario.

Results: In relation to the primary outcome of chest compression flow-fraction in the minute preceding the first mechanical chest compression, we found that pit-crew training was not superior to standard training (0.76 (95% CI 0.73 to 0.79) v 0.77 (95% CI 0.73 to 0.82), Mean difference -0.01 (95% CI -0.06 to 0.03), p=0.572). There was also no difference between groups in performance in relation to any secondary outcome.

Conclusions: Pit-crew training, compared with standard training, did not improve team deployment of a mechanical chest device in a simulated cardiac arrest scenario.

Trial registration: ISRCTN43049287, registration date 30/06/2016.

Keywords: Cardiac arrest, Cardiopulmonary Resuscitation, Advanced Cardiac Life Support, Pit-crew Training, Mechanical Chest Compression Device.

Strengths and limitations of the study

- This is the first randomised controlled study to investigate the effect of pit-crew training, compared with standard training, in the clinical area of cardiac arrest.
- This was a manikin study, such that it is unknown to what extent the findings can be reliably generalised to the clinical cardiac arrest setting.
- Outcomes were measured immediately after the training intervention, such that we did not investigate the long-term effect of each training intervention.

Background

Mechanical chest compression devices provide a method to deliver high-quality chest compressions to patients in cardiac arrest.[1] Despite evidence that manual chest compression delivery is often sub-optimal and that high-quality chest compression delivery is associated with improved survival, randomised controlled trials in out-of-hospital cardiac arrest (OHCA) have found that use of a mechanical chest compression device is not superior to manual chest compressions in relation to patient outcome.[2-5] In contrast, very low quality evidence from in-hospital cardiac arrest (IHCA) suggests use of devices may be associated with improved patient outcome.[6]

The key risk associated with use of mechanical chest compression devices is the pause in chest compressions associated with their deployment.[1] In the LINC randomised controlled trial of the use of mechanical chest compression devices in OHCA, a sub-study found that the median chest compression pause associated with device deployment was 36.0 seconds (interquartile range 19.5 to 45.5).[7] Such pauses are associated with a reduction in coronary pressure during the early part of a cardiac arrest and may therefore off-set the potential benefit of improved chest compression delivery associated with devices.[8]

Training as a team may be an effective strategy to optimise the delivery of care that is usually provided by a clinical team.[9] Pit-crew resuscitation describes a concept where clinicians in a team act in a pre-determined way to undertake set tasks in a specific order, akin to a formula one motor racing team. In a clinical before-after quality improvement study, the use of this concept alongside other interventions was associated with a marked reduction in the pause associated with device deployment in OHCA.[10] However, the impact of the use of a pit-crew training approach has not, to date, been tested against other team training approaches in a randomised controlled trial.

Methods

We conducted a randomised controlled parallel group trial to evaluate the impact of pit-crew training, compared with standard training, on mechanical chest compression deployment in a simulated cardiac arrest. The mechanical chest compression device used was the LUCAS-2 mechanical chest compression device (Jolife AB/ Physio-Control, Lund, Sweden). Outcomes were evaluated through a video-recorded simulation test that was undertaken immediately after the training intervention.

All participants provided written informed consent prior to receiving any study intervention. The study was reviewed and approved by the University of Warwick Biomedical and Scientific Research Ethics Committee.

Participants

Teams of three clinicians were recruited to participate in the trial. To be eligible to participate, individual clinicians were required to be registered health professionals with current Immediate Life Support (ILS) or Advanced Life Support (ALS) certification, and to have completed the online manufacturer's device training package. Participants were not eligible if they had an injury or disability that prevented use or handling of the device, or if they had received practical training in the use of the device in the preceding six-months

Each team was required to be composed of three eligible clinicians, of which one was required to be an ALS certificated provider or instructor. As such, teams were broadly reflective of the standard required of in-hospital cardiac arrest teams in the UK.[11]

Study process

We advertised the study at the hospital site through posters in staff areas, emails to staff, and face-to-face discussions. Staff that consented to participate in the study were asked for their availability and allocated a training slot. As such, teams were created based on convenience, in that we established teams based on individual clinician's availability to attend training at a specified time. This broadly reflects how hospital cardiac arrest teams are created in clinical practice, in that the designated team will be drawn from clinicians who have been scheduled to work a particular shift.

On attendance at the training session, the team was randomised using a simple randomisation system provided by an internet-based randomisation service, which ensured allocation concealment (Sealed Envelope, London, UK). Teams were randomly allocated in a 1:1 ratio to receive either pit-crew training or standard training. After randomisation, a researcher (KC), with experience in teaching Advanced Life Support courses, immediately delivered the allocated training intervention. The team was not blinded to their allocated training intervention.

Following the training, the teams undertook a standardised manikin-based simulation test. The team acted as a hospital cardiac arrest team. The scenario, given in the SBAR format (Situation, Background, Assessment, Recommendation), described a 62-year old male who had undergone tracheal intubation due to hypoxia secondary to a probable pulmonary embolus and who had subsequently become haemodynamically unstable leading to cardiac arrest.[12] During the scenario, a mechanical chest compression device arrived during the second CPR cycle and the team was required to use the device. The length of the scenario was approximately eight minutes (four cycles of CPR).

The simulation test was video-recorded. Two digital video recorders were used to mitigate against the risk of data loss and possible obstruction of a camera by participants.

Study intervention

An overview of the two training approaches, based on the TIDieR (template for intervention description and replication) framework, is included as an electronic supplement (tables S1 and S2).[13] Both training approaches incorporated a presentation on device deployment and use, followed by an opportunity for the team to practice these skills. Skill practice was scenario-based, with feedback following each scenario. It was anticipated that training would last approximately 45-minutes, although teams were allowed to practice for as long as required.

The key difference between the training approaches was that teams randomised to pit-crew training received an overview of the concept and potential value of the pit-crew system in the training

presentation, together with guidance on how to operationalise the pit-crew system in deploying the mechanical chest compression device. This pit-crew training system requires team members to adopt a nominated role that is associated with specific tasks, with team members trained to perform tasks in a co-ordinated manner. These concepts were also highlighted in feedback during practice scenarios.

In both training approaches, teams were trained to deploy the device in two-stages, such that there was a pause for the deployment of the device back plate followed by the resumption of CPR and then a subsequent pause to enable deployment of the upper part of the mechanical device.

Outcome measures

The primary outcome was the chest compression flow-fraction in the minute preceding the first mechanical chest compression. Flow-fraction describes the proportion of time in which chest compressions are being delivered over a designated period. This specific outcome was selected as it enabled us to capture all pauses that may be attributable to device deployment.

There were a number of secondary outcome measures including chest compression flow-fraction (prior to the first mechanical chest compression, following the first mechanical chest compression, whole event), the duration of chest compression pauses associated with device deployment, and non-technical skills measured using the Team Emergency Assessment Measure (TEAM) tool.[14]

Participating teams were not routinely informed as to the precise outcome measures being collected. However, a key focus of training interventions was the minimisation of pauses during deployment and outcomes were recorded in the study entry on the trial registration website.

Data management

Videos were reviewed by two researchers (KC, RMV) independently. The first reviewer (KC) delivered the training intervention and so was not blinded to training allocation. The second reviewer (RMV) was blinded to training allocation. Videos were viewed using software that enabled timings to be derived to the nearest one-tenth of a second.

We assessed agreement between video reviewers by computing the average difference and 95% confidence interval (CI) or median difference and interquartile range (IQR) for each outcome and plotting data using a Bland-Altman plot.[15] Bland-Altman plots visually depict the level of agreement between two reviewers, with good agreement represented by a small difference between the upper and lower limit of agreement and the majority of measurements falling between the limits of agreement. We used the mean value of the two reviewers in the analysis.

Statistical analysis

Our planned sample size of 20 teams (3 clinicians per team) was based on demonstrating an absolute increase in flow-fraction in the minute preceding the first mechanical chest compression of 0.15 (baseline 0.58, standard deviation 0.10) at 90% power with a p-value of 0.05. Due to the nature

of the study, we did not increase the sample size to account for drop-outs. If a team member did not attend their allocated training session, then the team would not be eligible and so would not be randomised.

Data analysis was based on intention-to-treat principles. For baseline team and individual data, we report categorical variables as number and percentage, whilst continuous variables are described as mean (95% CI) or median (IQR), depending on the normality of the data.

All outcomes are assessed at the team level. For normally distributed continuous outcomes, we summarise team performance as mean (95% CI), and compare groups using an independent t-test and report the mean difference, 95% CI, and p-value. For non-normally distributed continuous outcomes, we summarise group performance as median (IQR) and compare groups using a Mann-Whitney U test and report the p-value.

Results

Between June 2016 and September 2016, 78 clinicians consented to participate in the study (figure one). Of these, 60 participated in randomised teams. Four participants were excluded after giving consent to participate but prior to randomisation (one identified that their resuscitation certification had expired, one developed an injury that prevented use of the device, and two received previous practical mechanical device training). For the remaining 13 participants, we were unable to identify a convenient time for training prior to randomising the 20 teams required.

Demographic data at the team and individual level are shown in tables one and two respectively. Team characteristics were comparable between groups. There were some differences between groups at the individual participant level in relation to, for example, clinical experience and speciality.

For the primary outcome, the average difference between reviewers for the twenty cases was 0.01 (95% CI -0.01 to 0.02). Bland-Altman and average differences for other outcomes are included in the electronic supplement (table S3 and figure S1). Based on these data, outcome analyses are based on the average data from the two reviewers.

In relation to the primary outcome, we found no difference in the flow-fraction preceding the first mechanical chest compression between study groups (0.76 (95% CI 0.73 to 0.79) v 0.77 (95% CI 0.73 to 0.82), Mean difference -0.01 (95% CI -0.06 to 0.03), p=0.572) (table 3).

The chest compression pause associated with the deployment time of both the back plate and upper part of the device being similar between groups. We also observed no difference between groups in relation to any other secondary outcome.

There were no study adverse events and all training interventions were delivered as planned, with te time taken to deliver training interventions being similar between groups (table three). During one simulation test (pit-crew training arm), the device battery failed as due to researcher error the device battery was not charged prior to training. This battery failure did not affect the primary outcome, but did marginally reduce flow-fraction across the whole scenario and following device deployment.

Discussion

In this randomised controlled manikin trial we found that the use of a pit-crew training approach, compared with a standard training approach, did not affect the deployment of a mechanical chest compression device in simulated IHCA. Similarly, the use of pit-crew training did not affect any other device deployment, CPR quality or non-technical skills metric.

Our study, in contrast to previous pit-crew cardiac arrest studies, directly compared pit-crew training with a standard training approach.[10, 16-20] Whilst not directly comparable, it is noteworthy that previous studies have typically reported an association between implementation of pit-crew principles and improvements in process and patient-focussed outcomes. For example, in a before/after OHCA clinical study, the implementation of pit-crew training alongside real-time feedback and post-event debriefing was associated with an improvement in neurologically intact survival following OHCA (odds ratio 2.3, 95% confidence interval 1.3 to 4.0).[19]

There are four possible explanations for this apparent contrast in findings. Firstly, previous studies have tended to implement pit-crew training alongside other interventions, such as real-time feedback, additional training, and cardiac arrest debriefing. As such, the findings of previous studies may reflect the impact of the overall package of interventions, such that pit-crew training either did not have an independent effect or complementary interventions enhanced its effect. Secondly, previous studies have adopted an observational design, such that the findings may be attributable to unmeasured confounders rather than the intervention that was implemented.

A third explanation is that where team performance is high, as observed in this study, pit-crew training provides no additional benefit. In Levy et al's before-after study, where the pit-crew training intervention was associated with a marked improvement in care delivery, the median pre-intervention pause between the final manual chest compression and first mechanical chest compression prior to implementation of pit-crew training was 21 seconds (interquartile range 15 to 31).[10] In contrast, the mean total pause associated with device deployment in in the standard training group in this study this study was about 14 seconds, such that the opportunity for pit-crew training to have a measurable effect on team performance may have been limited.

Finally, it may be that pit-crew concepts provide more value in the clinical setting, compared to simulated cardiac arrest conditions. Replicating the real-life complexity of cardiac arrest management in the simulation laboratory is challenging.[21, 22] It is possible that pit-crew training provides most advantage in the unpredictable clinical setting, where the system provides a clear framework to direct effective team functioning.

Our study has several weakness. Firstly, we tested performance in a simulated cardiac arrest scenario that occurred immediately after the training intervention, such that we do not know how training interventions affected performance either in the longer-term or in the clinical setting. Secondly, participants were often experienced clinicians with frequent exposure to cardiac arrest, so it is unclear whether findings are generalisable to less experienced clinicians. Thirdly, we found that performance in both groups was markedly better than that estimated in our power calculation, so our study was underpowered to reliably detect a clinically important difference between groups. Fourthly, we did not capture participant views on the impact of training approaches on team functioning. Such information may have captured the personal learning style of individuals within

the team and how receptive they were to the different training approaches. Finally, whilst agreement between video reviewers was generally good, there was some variation in relation to the TEAM tool outcomes. However, analysis at an individual reviewer level produced similar results to our overall planned analysis (data not presented).

Conclusion

In this randomised controlled manikin trial, we found pit-crew training, compared with standard device training, did not improve the deployment of mechanical chest compression devices in a simulated cardiac arrest. The time taken to deliver training was similar. Future controlled trials should examine the effect of pit-crew training in the clinical setting and on long-term performance.

Funding

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Competing interests

KC, TQ, RL, JY, GDP report that their organisations have received funding from NIHR for clinical trials on the use of mechanical chest compression devices.

Author's contributions

KC conceived and designed the study, acquired the data, analysed the data, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, drafted the manuscript, and approved the final manuscript

RMV analysed the data, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

TQ conceived and designed the study, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

AD conceived and designed the study, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

RL conceived and designed the study, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

BO conceived and designed the study, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

JY contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

GDP conceived and designed the study, contributed to interpretation of the data, critically revised the manuscript for important intellectual content, and approved the final manuscript

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Data sharing: The datasets generated and analysed during the current study are not publicly available to maintain participant confidentiality but are available from the corresponding author on reasonable request

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Figures and tables

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Table one: team characteristics

			Pit-crew training (10 teams)	Standard training (10 teams)
Teams with n doctors- n (%)				
	0		3 (30%)	3 (30%)
	1		5 (50%)	2 (20%)
	2		2 (20%)	3 (30%)
	3		0 (0%)	2 (20%)
Teams with n Advanced Life Support instructors- n (%)				
	0		4 (40%)	5 (50%)
	1		2 (20%)	4 (40%)
	2		3 (30%)	1 (10%)
	3		1 (10%)	0 (0%)
Teams with at least one member that has previously received device training- n (%)			5 (50%)	4 (40%)
Teams with at least one member with experience of using a device in clinical practice- n (%)			9 (90%)	10 (100%)

Table two: individual participant characteristics

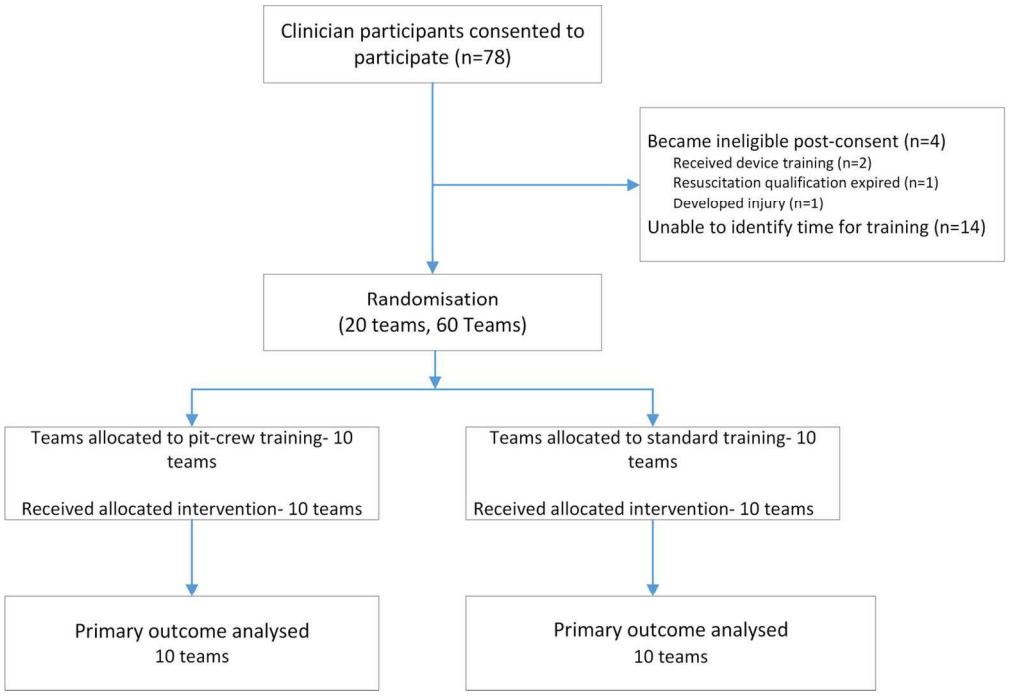
			Pit-crew training (n=30)	Standard training (n= 30)
Gender- male- n (%)			12 (40.0%)	14 (46.7%)
Health profession- n (%)				
	Doctor		9 (30%)	14 (46.7%)
	Nurse		21 (70.0%)	12 (40.0%)
	Operating department practitioner		-	1 (3.3%)
	Paramedic		-	2 (6.7%)
	Other		-	1 (3.3%)
Professional experience- years- median (IQR)			13.5 (6.3-21.3)	8.0 (3.8-13.5)
Grade- n (%)				
	Band 5/ FY1		3 (10.0%)	5 (16.7%)
	Band 6/ SHO		8 (26.7%)	11 (36.7%)
	Band 7/ Registrar		14 (46.7%)	9 (30.0%)
	Band 8+/ Consultant		5 (16.7%)	5 (16.7%)
Current speciality- n (%)				
	Acute medicine		6 (20.0%)	5 (16.7%)
	Critical care		11 (36.7%)	20 (66.7%)
	Emergency medicine		6 (20.0%)	2 (6.7%)
	Surgery		3 (10.0%)	2 (6.7%)
	Other		4 (13.3%)	1 (3.3%)
Resuscitation qualification- n (%)				
		Immediate Life Support provider	7 (23.3%)	7 (23.3%)
		Advanced Life Support provider	12 (40.0%)	17 (56.7%)
		Advanced Life Support instructor	11 (36.7%)	6 (20.0%)

			Pit-crew training (n=30)	Standard training (n= 30)
Approximate number of cardiac arrests attended in last six months- median (IQR)			4.5 (2.0-10.0)	8.0 (1.8-15.8)
Previously received device training- Yes- n (%)			7 (23.3%)	4 (13.3%)
Previous use of a device in clinical practice- Yes- n (%)				
	If yes, which device – n (%)		18 (60.0%)	17 (56.7%)
		LUCAS	10 (55.6%)	8 (47.1%)
		AUTOPULSE	11 (61.1%)	10 (58.8%)
		THUMPER	2 (11.1%)	1 (5.9%)
	If yes, how many times used- median (interquartile range)		2.5 (1.0-5.8)	3.0 (1.5-4.5)

Table three: Outcome measures (based on average from two videotape reviewers)

	Pit-crew training (n=10)	Standard training (n=10)	Mean difference (95% CI)	p-value†
Device deployment- mean (95% CI)				
Flow-fraction in minute preceding first mechanical CC	0.76 (0.73 to 0.79)	0.77 (0.73 to 0.82)	-0.01 (-0.06 to 0.03)	0.572
Time to deploy back-plate (secs)	3.80 (2.83 to 4.76)	3.82 (2.62 to 5.02)	-0.03 (-1.46 to 1.41)	0.971
Time to deploy upper part of device (secs)	9.99 (8.84 to 11.14)	9.67 (8.02 to 11.32)	0.32 (-1.55 to 2.19)	0.724
Total pause for mech device deployment (secs)	14.33 (12.62 to 16.03)	13.56 (11.05 to 16.06)	0.77 (-2.04 to 3.58)	0.572
Time from device arrival to first mechanical CC (secs)- median (IQR)	55.25 (51.63 to 75.24)	60.43 (52.70 to 73.99)		0.912‡
Compliance with manufacturer's guidelines (out of eight)- median (IQR)	8 (8-8)	8 (8-8)		0.739‡
CPR quality				
Flow-fraction- mean (95% CI)				
Whole episode	0.94 (0.93 to 0.95)	0.94 (0.93 to 0.95)	0.00 (-0.01 to 0.01)	0.790
Pre-device deployment	0.90 (0.89 to 0.92)	0.90 (0.88 to 0.91)	0.01 (-0.01 to 0.03)	0.538
Post-device deployment	0.97(0.96 to 0.98)	0.97 (0.96 to 0.98)	0.00 (-0.01 to 0.01)	0.681
Number of pauses > 5 seconds- median (IQR)	2.00 (1.75 to 3.00)	2.50 (1.00 to 4.13)		0.853‡
Number of shocks delivered- median (IQR)	2 (2 to 2)	2 (2 to 2)		1.000 ‡
Shocks delivered appropriately- median (IQR)	2 (2 to 2)	2 (2 to 2)		1.000 ‡
Peri-shock pause (seconds)- median (IQR)				
Pre-shock pause	0.00 (0.00 to 0.00)	0.00 (0.00 to 0.00)		1.000 ‡
Post-shock pause	0.00 (0.00 to 0.00)	0.00 (0.00 to 0.00)		1.000 ‡
Non-technical skills- TEAM tool				
TEAM tool- component score (out of 44)	38.0 (35.7 to 40.3)	37.6 (34.8 to 40.4)	0.40 (-2.94 to 3.74)	0.804
TEAM tool- global (overall) score (out of ten)	8.1 (7.2 to 8.9)	7.9 (7.3 to 8.6)	0.15 (-0.87 to 1.17)	0.760
Training delivery				
Duration of training- mean (95% CI)*	49.0 (44.0 to 54.0)	45.3 (40.5 to 50.1)	3.1 (-2.7 to 10.1)	0.244

† By independent t-test unless stated.
‡By Mann-Whitney U test.
* Data point measured directly during training intervention, so not based on assessment from two reviewers.



Study flow diagram

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Electronic supplement

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Table S3: Average differences between video reviewers- page 4

Figure S1: Bland-Altman plots- page 5

Table S1: Descriptions of study intervention- standard training intervention

Item	Description
BRIEF NAME	Standard training for the deployment of a mechanical chest compression device
WHY	Current evidence shows that deployment of mechanical chest compression devices in clinical practice may be associated with prolonged pauses in chest compressions. Such pauses can be harmful and reduce the likelihood of a successful outcome. In this training package, we will train clinicians to effectively deploy a mechanical chest compression device, using the training approach that is commonly used in NHS practice.
WHAT	**Materials**: Materials required include a mechanical chest compression device (LUCAS-2), powerpoint presentation, presentation projection facilities, manikin, hospital bed, defibrillator, ECG simulation pad, and airway equipment. **Procedures**: 1) Delivery of powerpoint presentation, which includes overview of how to deploy device (duration ~15-minutes) 2) Practical demonstration of process of deploying device (including which buttons should be pressed at relevant points) (duration ~5-minutes) 3) Opportunity for participants to practice deployment using simulation with feedback/ debriefing after each simulation (duration ~30-minutes) 4) Provide opportunity to ask questions and summarise key learning points (duration ~5-minutes)
WHO PROVIDED	The lead session instructor will be a Resuscitation Council (UK) Advanced Life Support with additional training in deployment of the LUCAS-2 mechanical chest compression device.
HOW	Training will be delivered face-to-face to three clinicians in each session.
WHERE	The training intervention will be delivered at a local hospital in a suitable training room (uninterrupted, adequate space) where required equipment is available.
WHEN and HOW MUCH	The training session will be delivered on one occasion. The duration is expected to be less than one hour.
TAILORING	This description of the intervention was developed following an initial run-through- no significant changes were required. The amount of practice required by each group will be determined on a group-by-group basis. This will be decided through discussion between the instructor and participants.
MODIFICATIONS	We do not anticipate making further modifications to the training package. If changes are deemed necessary, these will be recorded in any research output.
HOW WELL	The instructor at each session will record the duration of the session and any deviations from the training plan.

Table S2: Descriptions of study intervention- pit-crew training intervention

Item	Description
BRIEF NAME	Pit-crew training for the deployment of a mechanical chest compression device
WHY	Current evidence shows that deployment of mechanical chest compression devices in clinical practice may be associated with prolonged pauses in chest compressions. Such pauses can be harmful and reduce the likelihood of a successful outcome. In this training package, we will train clinicians using pit-crew principles to effectively deploy a mechanical chest compression device.
WHAT	**Materials**: Materials required include a mechanical chest compression device (LUCAS-2), powerpoint presentation, presentation projection facilities, manikin, hospital bed, defibrillator, ECG simulation pad, airway equipment, and pit-crew handout. The pit-crew handout will detail the process for pit-crew deployment of the device and the group will be encouraged to use it throughout the training session. **Procedures**: 1) Delivery of powerpoint presentation, which includes overview of how to deploy device and pit-crew concepts (duration ~15-minutes) 2) Practical demonstration of process of deploying device (including which buttons should be pressed at relevant points) (duration ~5-minutes) 3) Opportunity for participants to practice deployment using pit-crew principles in a simulation setting with feedback/ debriefing after each simulation (duration ~30-minutes) 4) Provide opportunity to ask questions and summarise key learning points (duration ~5-minutes) A key focus of the training is the requirement for team members to adopt a nominated role that is associated with specific tasks, with team members trained to perform tasks in a co-ordinated manner. These concepts are highlighted in feedback during practice scenarios.
WHO PROVIDED	The lead session instructor will be a Resuscitation Council (UK) Advanced Life Support with additional training in deployment of the LUCAS-2 mechanical chest compression device.
HOW	Training will be delivered face-to-face to three clinicians in each session.
WHERE	The training intervention will be delivered at a local hospital in a suitable training room (uninterrupted, adequate space) where required equipment is available.
WHEN and HOW MUCH	The training session will be delivered on one occasion. The duration is expected to be less than one hour.
TAILORING	This description of the intervention was developed following an initial run-through- no significant changes were required. The amount of practice required by each group will be determined on a group-by-group basis. This will be decided through discussion between the instructor and participants.
MODIFICATIONS	We do not anticipate making further modifications to the training package. If changes are deemed necessary, these will be recorded in any research output.
HOW WELL	The instructor at each session will record the duration of the session and any deviations from the training plan.

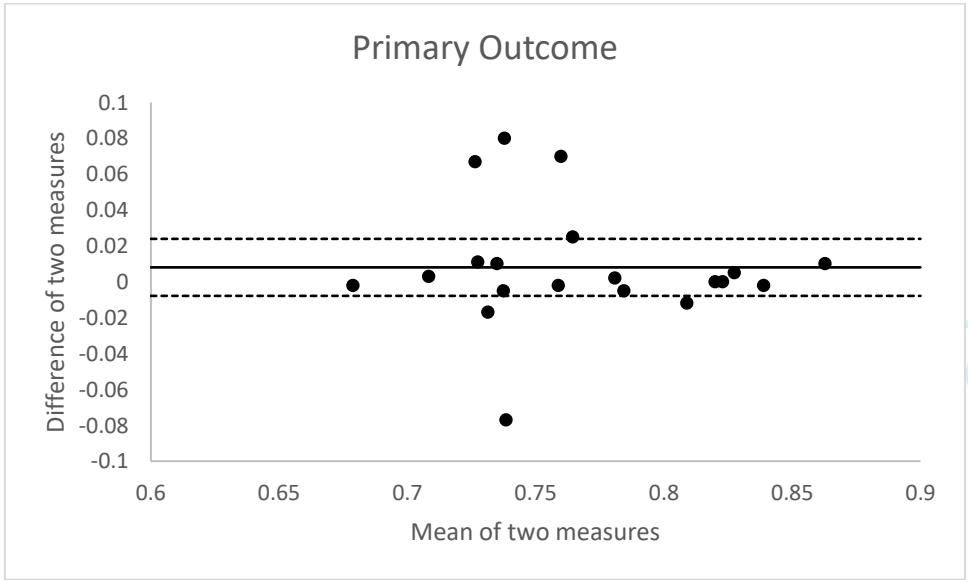
Table S3: Average differences between video reviewers

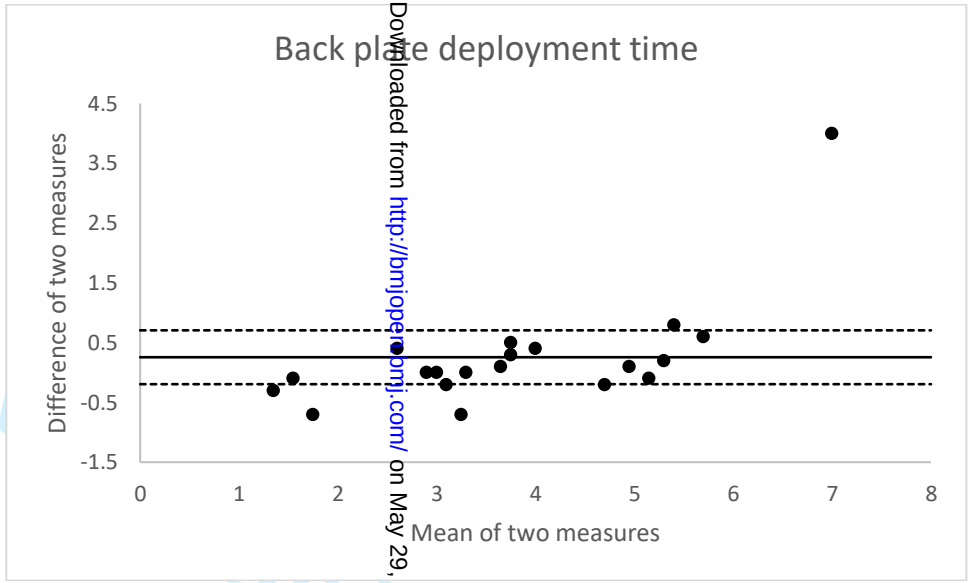
	Average difference (95% CI) between reviewers (unless stated)
Device deployment	
Flow-fraction in minute preceding first mechanical CC	0.008 (-0.008 to 0.024)
Time to deploy back-plate (secs)	0.050 (-0.175 to 0.400)†
Time to deploy upper part of device (secs)	0.000 (-0.100 to 0.300)†
Total pause for mech device deployment (secs)	-0.050 (-0.675 to 0.250)†
Time from device arrival to first mechanical CC (secs)	0.020 (-0.309 to 0.349)
Compliance with manufacturer's guidelines (out of eight)	0 (0 to 0)†
CPR quality	
Flow-fraction	
Whole episode	0.001 (-0.002 to 0.004)
Pre-device deployment	-0.000 (-0.010 to 0.009)
Post-device deployment	-0.000 (-0.002 to 0..001)
Number of pauses > 5 seconds	0 (0 to 0)†
Number of shocks delivered	0 (0 to 0)†
Shocks delivered appropriately	0 (0 to 0)†
Peri-shock pause (seconds)	
Pre-shock pause	0 (0 to 0)†
Post-shock pause	0 (0 to 0)†
Non-technical skills- TEAM tool	
TEAM tool- component score (out of 44)	-2.200 (-6.478 to 2.078)
TEAM tool- global (overall) score (out of ten)	-0.055 (-1.528 to 0.428)

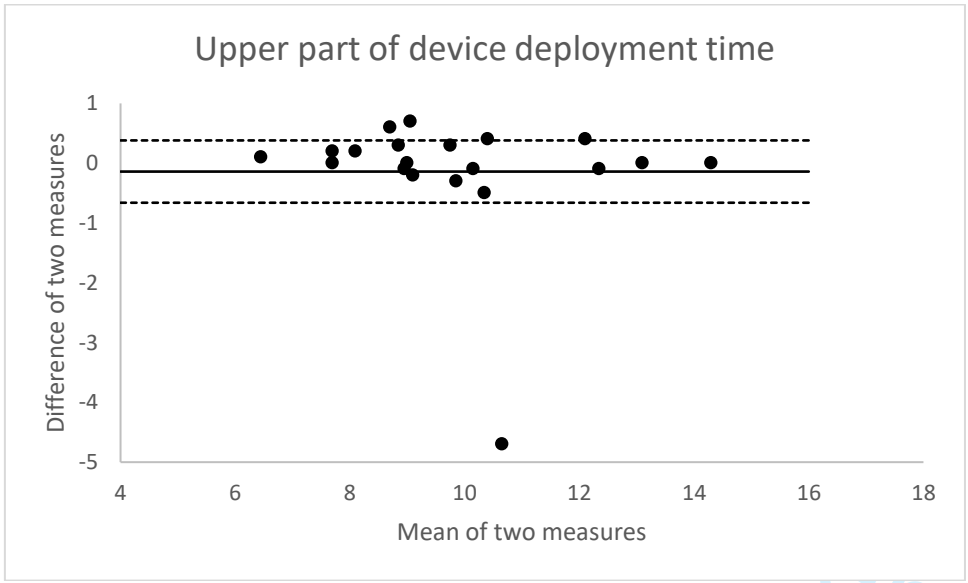
†- Reported as median difference (IQR)

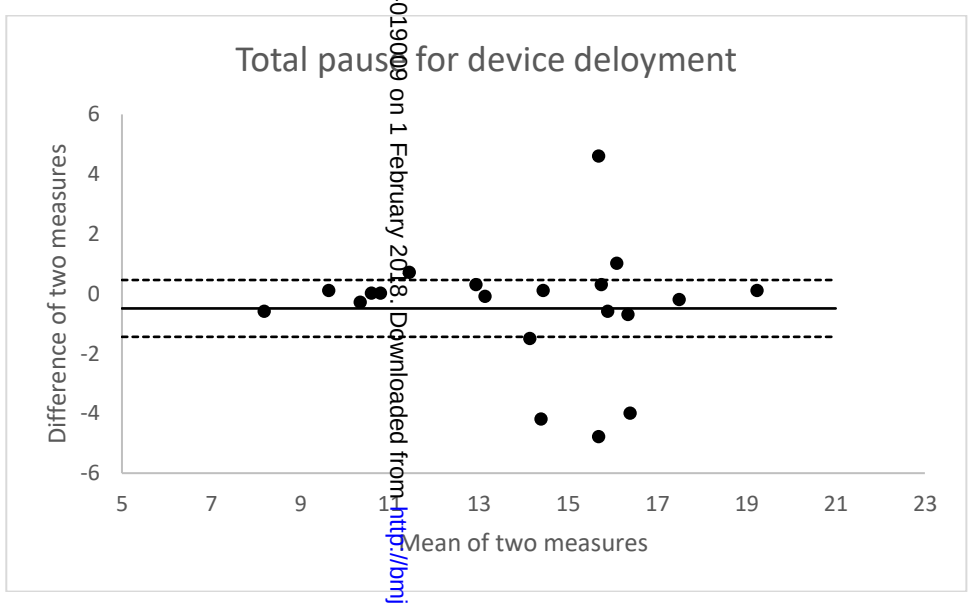
Figure S1: Bland-Altman plots

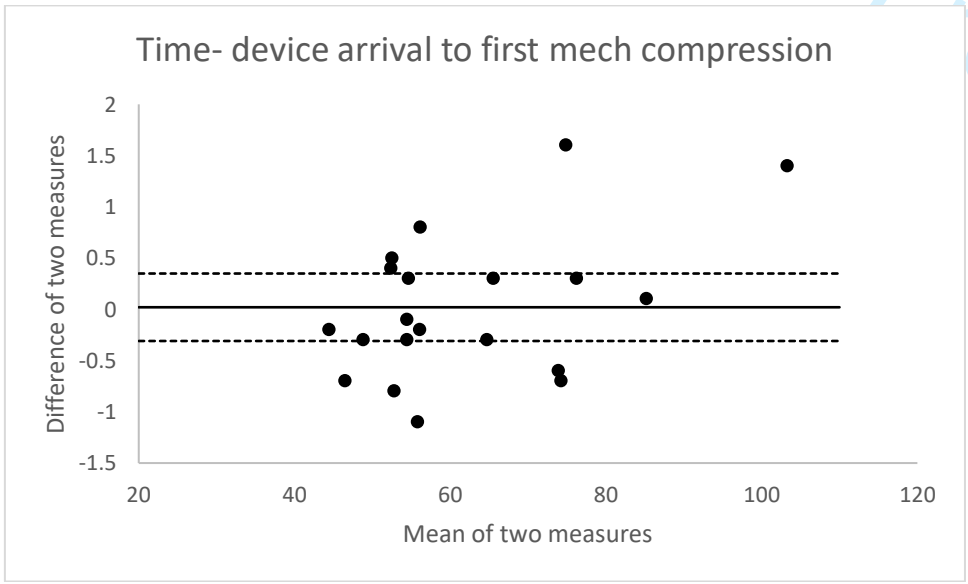
In each plot, the full line represents the mean difference between the two video reviewers and the dotted lines represent the upper and lower 95% confidence interval. Bland-Altman plots are not shown for number of shocks delivered, number of appropriate shocks delivered, pre-shock pause, and post-shock pause as there was perfect agreement for these outcomes. A plot is also not shown for manufacturer compliance, where there was perfect agreement for 19 groups and a difference of one in the other group.

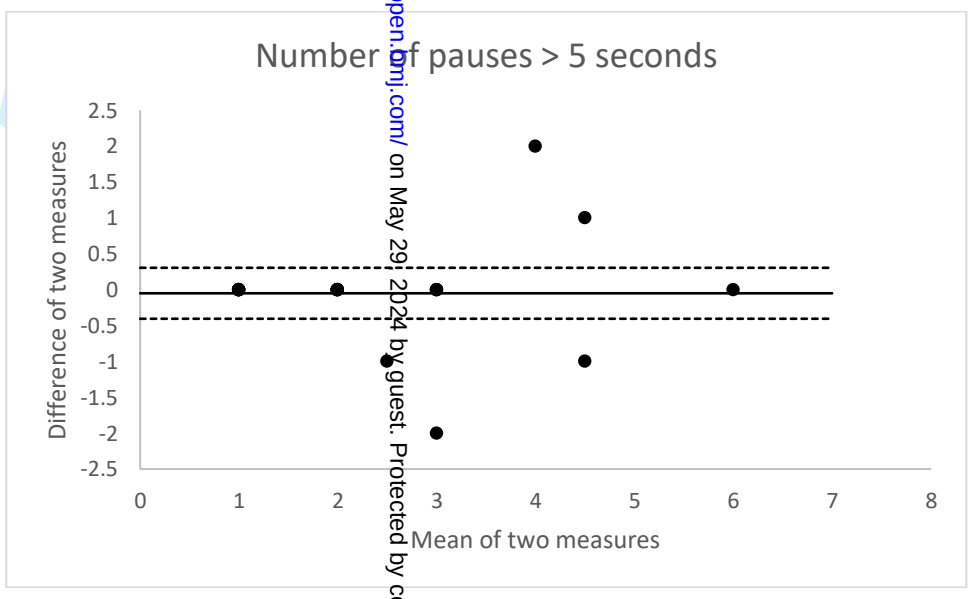


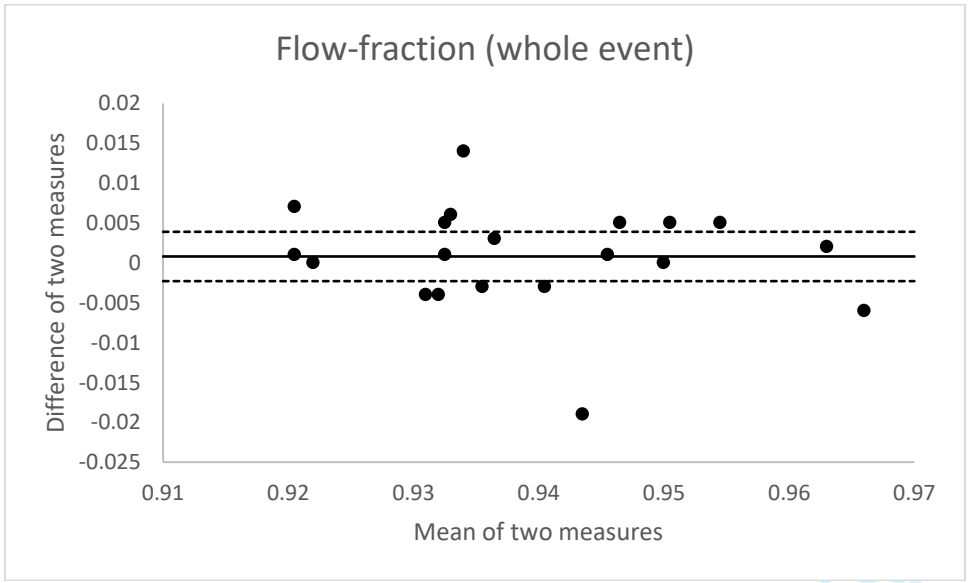


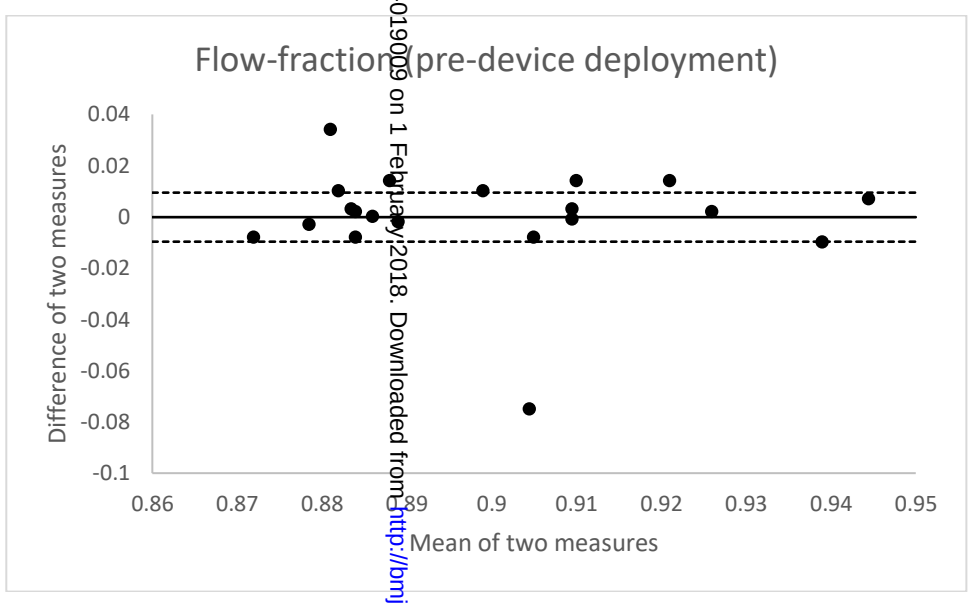


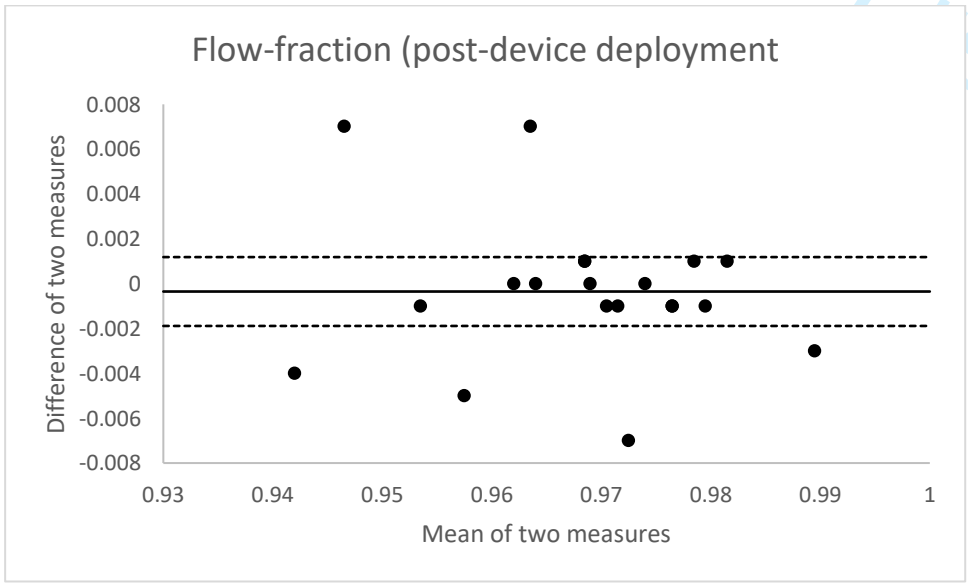


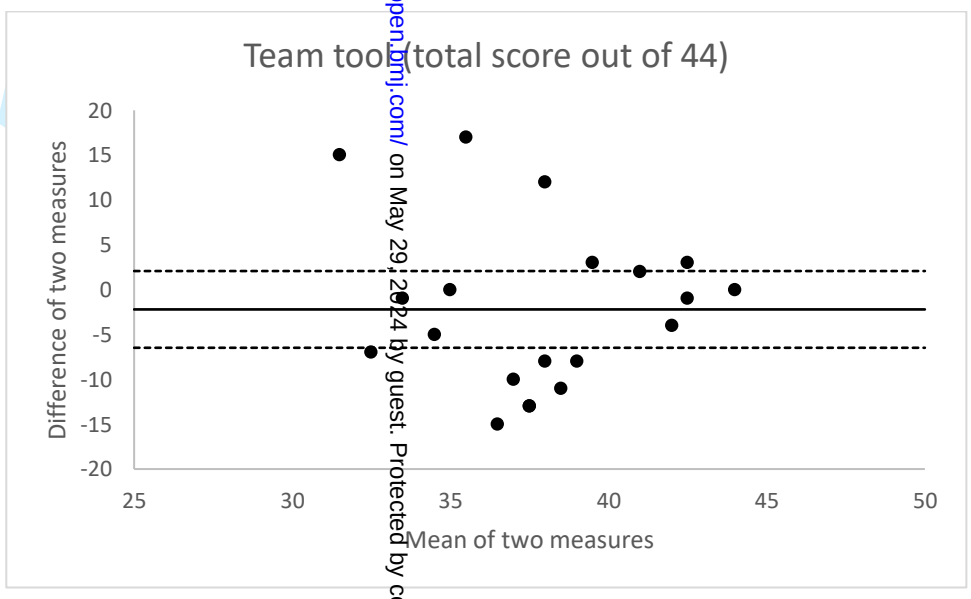


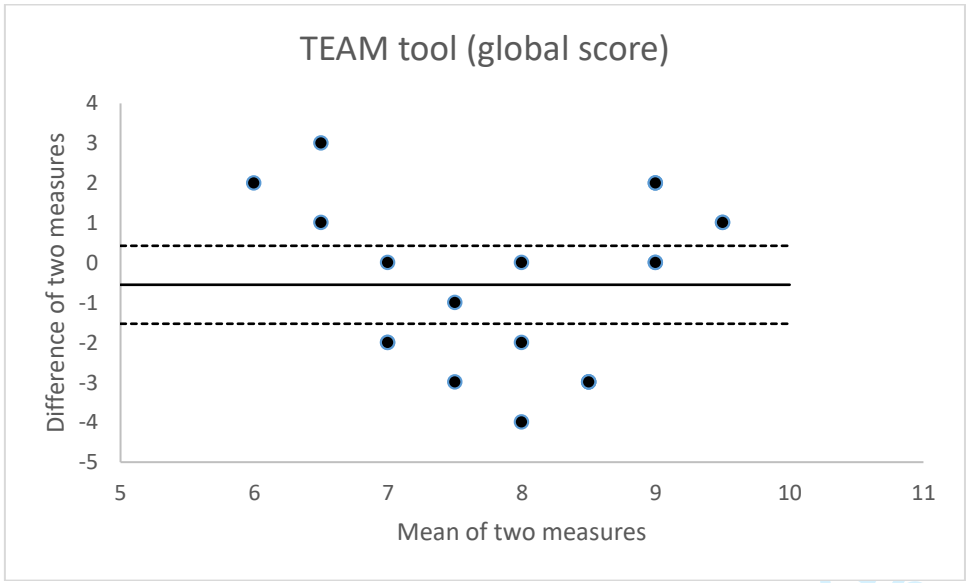












CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	4
	2b	Specific objectives or hypotheses	4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	4
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	N/A
Participants	4a	Eligibility criteria for participants	4
	4b	Settings and locations where the data were collected	5
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	5-6, electronic supplement
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	6
	6b	Any changes to trial outcomes after the trial commenced, with reasons	N/A
Sample size	7a	How sample size was determined	6
	7b	When applicable, explanation of any interim analyses and stopping guidelines	N/A
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	5
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	5
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	5
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	5
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	5,6

		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	N/A
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	6
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	6
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	Figure
	13b	For each group, losses and exclusions after randomisation, together with reasons	Figure
Recruitment	14a	Dates defining the periods of recruitment and follow-up	7
	14b	Why the trial ended or was stopped	7
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Table 1 &2
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	Figure
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	7
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	N/A
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	N/A
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	7
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	7-8
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	7-8
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	7-8
Other information			
Registration	23	Registration number and name of trial registry	2
Protocol	24	Where the full trial protocol can be accessed, if available	Provided
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	10

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.