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Title: e-learning in Advanced Life Support - What factors influence assessment outcome?

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Abstract: Aim
To establish variables which are associated with favourable Advanced Life Support (ALS) course assessment outcomes, maximising learning effect.

Method
Between 1 January 2013 and 30 June 2014, 8,218 individuals participated in a Resuscitation Council (UK) e-learning Advanced Life Support (e-ALS) course. Participants completed 5-8 hours of online e-learning prior to attending a one day face-to-face course. e-learning access data were collected through the Learning Management System (LMS). All participants were assessed by a multiple choice questionnaire (MCQ) before and after the face-to-face aspect alongside a practical cardiac arrest simulation (CAS-Test). Participant demographics and assessment outcomes were analysed.

Results
The mean post e-learning MCQ score was 83.7 (SD 7.3) and the mean post-course MCQ score was 87.7 (SD 7.9). The first attempt CAS-Test pass rate was 84.6% and overall pass rate 96.6%. Participants with previous ALS experience, ILS experience, or who were a core member of the resuscitation team performed better in the post-course MCQ, CAS-Test and overall assessment. Median time spent on the e-learning was 5.2 hours (IQR 3.7-7.1). There was a large range in the degree of access to e-learning content. Increased time spent accessing e-learning had no effect on the overall result (OR 0.98, P=0.367) on simulated learning outcome.

Conclusion
Clinical experience through core membership of cardiac arrest teams and previous ILS or ALS training were independent predictors of performance on the ALS course whilst time spent accessing e-learning materials did not affect course outcomes. This supports the blended approach to e-ALS which allows participants to tailor their e-learning experience to their specific needs.

e-learning in Advanced Life Support – What factors influence assessment outcome?

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ABSTRACT

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Between 1 January 2013 and 30 June 2014, 8,218 individuals participated in a Resuscitation Council (UK) e-learning Advanced Life Support (e-ALS) course. Participants completed 5-8 hours of online e-learning prior to attending a one day face-to-face course. e-learning access data were collected through the Learning Management System (LMS). All participants were assessed by a multiple choice questionnaire (MCQ) before and after the face-to-face aspect alongside a practical cardiac arrest simulation (CAS-Test). Participant demographics and assessment outcomes were analysed.

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The mean post e-learning MCQ score was 83.7 (SD 7.3) and the mean post-course MCQ score was 87.7 (SD 7.9). The first attempt CAS-Test pass rate was 84.6% and overall pass rate 96.6%. Participants with previous ALS experience, ILS experience, or who were a core member of the resuscitation team performed better in the post-course MCQ, CAS-Test and overall assessment. Median time spent on the e-learning was 5.2 hours (IQR 3.7-7.1). There was a large range in the degree of access to e-learning content. Increased time spent accessing e-learning had no effect on the overall result (OR 0.98, P=0.367) on simulated learning outcome.

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Clinical experience through core membership of cardiac arrest teams and previous ILS or ALS training were independent predictors of performance on the ALS course whilst time spent accessing e-learning materials did not affect course outcomes. This supports the blended approach to e-ALS which allows participants to tailor their e-learning experience to their specific needs.

INTRODUCTION

The Formula for Survival[1] identifies three factors that influence survival from cardiac arrest: high-quality research, efficient education of patient caregivers and an effective chain of survival from the early recognition of cardiac arrest through to post resuscitation care.[2] Advanced Life Support (ALS) courses, which address both the second and third aspects of this formula, are used internationally to train healthcare personnel how to manage patients in cardiac arrest. Previous studies have linked participation on ALS courses to improved outcomes from cardiac arrest.[3–5] Courses use multimodal delivery methods to equip participants with background scientific knowledge, targeted clinical skills and non-technical skill development. This blended learning approach is from course manuals, online e-learning material, didactic lectures, hands-on skill stations and formative assessment. In the United Kingdom (UK) and many other countries, successful completion of an ALS course (or similar) is required for healthcare professionals who manage acutely unwell patients on a regular basis.

The Resuscitation Council (UK) has a 25 year history in delivering ALS courses.[6] A total of 20,268 individuals participated in an ALS course between January 2015 and December 2015.[6,7] In 2011, a strategic decision was taken to meet increasing demand, and to increase the flexibility of learning for participants. The Resuscitation Council (UK) launched a novel e-learning ALS course (e-ALS), as an alternative to the conventional two day face-to-face (c-ALS) course, valuing this key educational approach of blended learning. This constitutes 5-8 hours of pre-course online e-learning, followed by a condensed, focussed one day face-to-face element. A multi-centre randomised control trial (RCT) in 2012[8] and a large observational study of 27,170 participants in 2015[9] demonstrated almost identical assessment outcomes for participants enrolled upon either c-ALS or e-ALS. The findings of these two studies consolidated the emerging role of the Resuscitation Council (UK) e-ALS course. Whilst outcome data were comparable in the observational study,[9] it did not assess the extent to which those participants enrolled on the e-ALS course actually accessed the e-learning material, or its effect on assessment outcomes.

Previous studies investigating the utility of e-learning all display a common limitation, whereby participants often do not fully access the e-learning material.[10,11] Jensen et al. investigated e-learning as a means for retaining ALS competency but found that only 57.5% of candidates accessed all of the stipulated modules.[10] Similarly Perkins et al. found that only 64% of candidates accessed pre-course e-learning via a CD prior to attending an ALS course.[11] This limitation was acknowledged by the authors, who postulated that any true difference between the control and

intervention groups may not have been detected because the intervention had not been implemented effectively. Secondly, it provides challenges for ALS course organisers to establish exactly what extent of e-learning has been undertaken by the participants prior to attending a face-to-face course. Whilst this allows personalisation of the learning experience, it also reduces the standardisation of content delivered to those on an ALS course. Consequently, it is unknown whether making e-learning non-compulsory adversely affects candidate outcome.

This study was designed to access the aforementioned observational study data set,[9] analysing the extent to which participants access pre-requisite e-learning material, establishing the effect on candidate ALS assessment outcome. In doing this, study authors intend to highlight independent predictors of successful ALS course outcome.

METHODS

Setting and Participants

ALS participants voluntarily enrolled on a one-day e-ALS course at one of 94 national training centres. Each candidate registered on the Resuscitation Council (UK) Learning Management System (LMS) prior to attending the course. Participants were from a wide range of healthcare professions and stages of training.

The e-ALS Course

The e-ALS course consists of 5-8 hours of e-learning content covering essential ALS topics. Each candidate is given access to the LMS 8 weeks prior to their course and is asked to complete the 12 electronic learning modules. Additionally, participants receive a physical copy of the ALS course manual at least four weeks before the course date. e-learning progress is monitored by the course centres. Participants are free to choose to personalise their learning experience – undertaking as little or as much of the e-learning preparation as they feel necessary although there are three compulsory modules: ALS in perspective; advanced life support algorithm; non-technical skills (progress data are not routinely collected on the LMS for this module as it was only introduced in 2013).

There are nine non-compulsory modules: causes and prevention of cardiac arrest; acute coronary syndromes; monitoring, rhythm recognition and 12 lead ECG; bradycardia, pacing and drugs; tachycardia, cardioversion and drugs; special circumstances; post resuscitation care; arterial blood gas analysis; and decisions relating to resuscitation.

On completion of the e-learning, participants undertake a compulsory multiple choice questionnaire (MCQ), although their results in this do not affect the participants' post-course outcome. After completing the one-day face to face aspect, each candidate undertakes a post-course MCQ and a practical cardiac arrest management simulation test (CAS-Test). In order to achieve ALS competency participants need to pass both of these aspects. Participants are permitted two attempts at the MCQ and three attempts at the CAS-Test. The pre and post-course MCQs comprise 30 different stem questions, with each having four true/false answers, creating a total of 120 questions. The pass mark is 75%. The CAS-Test simulations are criterion based and are well validated.[12,13] They assess participants' abilities in patient assessment, formulating a treatment plan and leadership of the cardiac arrest team. Overall scores and pass/fail data are recorded.

Statistical analysis

Demographic data were collected on the LMS. Anonymised data were transferred to Microsoft Excel *(Microsoft Corporation, Redmond, USA)* and analysed using SPSS 23 *(IBM, Armonk, USA)* and R statistical program Version 3.3.1.[14] Categorical baseline characteristics were summarised using counts and percentages while continuous baseline characteristics were summarised using mean, median (IQR, interquartile range) and ranges. Independent t-tests, one-way ANOVAs and linear regression models were utilised to determine differences between continuous variables. Logistic regression was used for dichotomous outcome variables.

A multivariable logistic regression model was fitted to assess which variables predict whether a trainee passes the CAS-Test on the first attempt. Trainees attending the same course session tend to have similar outcomes[8] and so the multivariable logistic regression model included a random effects term for course session. A similar model was fitted to assess which variables predict whether a trainee passes the overall test. Odds ratios (OR), 95% confidence intervals and p-values from the multivariable random effects logistic regression models were reported. To assess which variables predict the MCQ score of a trainee in the first attempt, MCQ scores were analysed by fitting a linear mixed model with a random effects term for course session. Mean difference in MCQ scores, 95% confidence intervals and p-values from the linear missed model were reported. An analysis of standard residuals was carried out and outliers removed. Co-linearity was assessed by independently entering each independent variable into a logistic regression with the remaining variables entered as dependent variables. Collinearity diagnostics were calculated and

160 the variance inflation factor (VIF) in all instances was <1. In all models, missing data were excluded from the
161 complete case analysis by a listwise deletion. Statistical significance was set at P-values of <0.05.
162
163 **RESULTS**
164 ***Demographics***
165 8,218 participants were enrolled on one of 450 e-ALS courses during the study period. Mean age was 32.0 years (SD
166 8.2). 15 participants started but failed to complete the course. 1.8% of the total participants had a degree of missing
167 data and these were excluded from the analysis. Any missing data occurred due to incomplete data entry by
168 participants or local course facilitators on the LMS. Stratified participant demographics are displayed below in table 1
169 in addition to time spent accessing the e-learning and corresponding pass rates.

Table 1: Participant demographics on the e-ALS course and time spent on e-learning

Characteristics/outcomes	n, (%)	Hours spent on compulsory modules	Hours spent on non-compulsory modules	Total hours spent on e-Learning	Overall pass rate (%)
Healthcare background					
Doctor	6236				6095
Range	(75.9)	0-13.2	0-21.0	0-24.0	(97.8)
Mean (SD)		1.1 (0.8)	4.1 (2.5)	5.3 (3.0)	
Median (IQR)		0.9 (0.7-1.4)	3.8 (2.6-5.3)	4.9 (3.4-6.7)	
Nurse	1244				1122
Range	(15.1)	0-8.9	0-17.2	0-24.0	(90.9)
Mean (SD)		1.3 (0.9)	5.4 (3.4)	6.9 (3.9)	
Median (IQR)		1.1 (0.8-1.6)	4.8 (3.4-6.6)	6.2 (4.5-8.5)	
Medical student	534				525 (98.3)
Range	(6.5)	0-4.7	0-16.0	0-17.6	
Mean (SD)		1.1 (0.7)	4.4 (2.2)	5.6 (2.6)	
Median (IQR)		0.9 (0.7-1.3)	4.1 (2.9-5.6)	5.3 (4.0-6.9)	
Operating Department Practitioner	73 (0.9)				67 (93.1)
Range		0-6.9	0-11.5	0.2-21.4	
Mean (SD)		1.3 (1.1)	5.3 (2.7)	7.0 (3.7)	
Median (IQR)		1.0 (0.8-1.4)	5.2 (3.5-7.2)	6.4 (4.8-8.8)	
Ambulance staff/ Paramedic	40 (0.5)				39 (97.5)
Range		0-6.4	0-18.7	0-22.7	
Mean (SD)		1.3 (1.2)	4.7 (3.1)	6.5 (4.0)	
Median (IQR)		1.1 (0.7-1.9)	4.8 (3.3-5.7)	6.4 (4.4-8.0)	
Resuscitation Officer	15				15 (100.0)
Range	(0.2)	0.6-3.0	4.3-9.5	5.1-10.4	
Mean (SD)		1.3 (0.7)	6.1 (1.5)	7.5 (1.7)	
Median (IQR)		1.0 (0.8-2.1)	6.1 (4.8-7.1)	7.5 (5.7-9.2)	
Other	74				62 (84.9)
Range	(0.9)	0-5.5	0-18.0	0-20.6	
Mean (SD)		1.4 (0.9)	6.0 (3.4)	7.8 (4.1)	

Median (IQR)		1.2 (0.9-1.5)	4.8 (3.7-7.5)	6.7 (5.0-9.7)	
Not available	2				
Stage of training					
Medical Student Range Mean (SD) Median (IQR)	537 (6.5)	 0-4.7 1.1 (0.7) 0.9 (0.7-1.3)	 0-16.0 4.4 (2.2) 4.1 (2.9-5.6)	 0-17.6 5.6 (2.6) 5.3 (4.0-6.9)	526 (98.0)
Foundation Year 1 Doctor Range Mean (SD) Median (IQR)	1650 (20.1)	 0-7.0 1.1 (0.7) 0.9 (0.7-1.3)	 0-21.0 4.0 (2.2) 3.8 (2.7-5.2)	 0-21.7 5.2 (2.6) 4.9 (3.6-6.5)	1624 (98.4)
Foundation Year 2 Doctor Range Mean (SD) Median (IQR)	1663 (20.2)	 0-10.0 1.1 (0.8) 0.9 (0.7-1.3)	 0-18.4 4.1 (2.3) 3.9 (2.7-5.2)	 0-20.8 5.3 (2.8) 5.0 (3.6-6.6)	1639 (98.6)
Junior Grade Doctor (ST1/ST2) Range Mean (SD) Median (IQR)	794 (9.7)	 0-9.4 1.2 (0.8) 1.0 (0.7-1.5)	 0-20.6 4.3 (2.7) 3.7 (2.6-5.4)	 0-24.0 5.5 (3.3) 4.9 (3.5-7.0)	768 (96.8)
Middle Grade Doctor[#] Range Mean (SD) Median (IQR)	1465 (17.8)	 0-13.2 1.1 (0.8) 0.9 (0.7-1.4)	 0-20.8 3.9 (2.5) 3.5 (2.3-5.0)	 0-23.5 5.1 (2.9) 4.7 (3.2-6.5)	1434 (97.9)
Senior Grade Doctor[$] Range Mean (SD) Median (IQR)	488 (5.9)	 0-5.1 1.2 (0.9) 1.0 (0.8-1.5)	 0-17.7 4.1 (2.7) 3.7 (2.5-5.3)	 0-21.2 5.4 (3.4) 4.9 (3.3-7.1)	469 (96.1)
Junior Nurse (Band 4-6) Range Mean (SD) Median (IQR)	1002 (12.2)	 0-8.9 1.3 (0.9) 1.1 (0.8-1.6)	 0-17.2 5.0 (3.2) 4.9 (3.5-6.7)	 0-23.1 7.1 (3.9) 6.4 (4.7-8.7)	886 (88.4)
Senior Nurse (Band 7-9) Range Mean (SD) Median (IQR)	395 (4.8)	 0-6.8 1.3 (0.9) 1.1 (0.8-1.6)	 0-15.4 5.0 (3.2) 4.5 (3.1-6.5)	 0-24.0 6.6 (3.8) 5.9 (4.2-8.1)	378 (95.5)
Other Range Mean (SD) Median (IQR)	223 (2.7)	 0-8.3 1.6 (1.2) 1.2 (0.9-1.9)	 0-18.7 5.9 (3.3) 5.3 (3.5-7.7)	 0-22.7 7.6 (4.2) 6.9 (4.9-9.5)	202 (90.2)
Not available	1				
Previous ALS experience					
No Range Mean (SD) Median (IQR)	4615 (56.2)	 0-10.0 1.2 (0.8) 1.0 (0.7-1.4)	 0-21.0 4.5 (2.7) 4.1 (3.9-7.2)	 0-24.0 5.8 (3.2) 5.3 (3.8-7.2)	4411 (95.6)
Yes Range Mean (SD) Median (IQR)	3593 (43.8)	 0-13.2 1.2 (0.8) 1.0 (0.7-1.4)	 0-21.0 4.1 (2.6) 3.8 (2.5-5.3)	 0-24.0 5.4 (3.2) 5.3 (3.9-7.2)	3515 (98.0)
Not available	10				
Previous ILS experience*					

No Range Mean (SD) Median (IQR)	2704 (32.9)	 0-8.3 1.2 (0.9) 1.0 (0.8-1.5)	 0-21.0 4.5 (2.8) 4.1 (2.7-5.8)	 0-24.0 5.8 (3.4) 5.3 (3.7-7.4)	2624 (95.5)
Yes Range Mean (SD) Median (IQR)	5466 (67.1)	 0-13.2 1.1 (0.8) 1.0 (0.7-1.4)	 0-20.9 4.3 (2.6) 4.2 (2.9-5.7)	 0-24.0 5.5 (3.1) 5.4 (3.8-7.3)	5302 (97.2)
Not available	48				
Core member of resuscitation team					
No Range Mean (SD) Median (IQR)	4373 (53.8)	 0-9.4 1.2 (0.8) 1.0 (0.8-1.5)	 0-21.0 4.5 (2.7) 4.2 (2.9-5.7)	 0-23.5 5.8 (3.2) 5.4 (3.9-7.3)	4173 (95.7)
Yes Range Mean (SD) Median (IQR)	3759 (46.2)	 0-13.2 1.1 (0.8) 0.9 (0.7-1.4)	 0-21.0 4.1 (2.6) 3.8 (2.6-5.3)	 0-24.0 4.9 (3.1) 4.9 (3.5-6.8)	3668 (97.7)
Not available	86				
Total Range Mean (SD) Median (IQR)	8218	 0-13.2 1.2 (2.8) 1.0 (0.74-1.4)	 0-21.0 4.3 (2.7) 4.0 (2.7-5.5)	 0-24.0 5.6 (3.2) 5.2 (3.7-7.1)	7926 (96.6%)

**Immediate Life Support*
 # ST3+, middle grade equivalent
$ Consultant or associate specialist

170

171 ***Assessment outcomes***

172 Assessment outcome data are displayed in Table 2. 99.1% of participants completed the post e-learning MCQ, with a
173 mean score of 83.7 (SD 7.3). The mean post-course MCQ score was 87.7 (SD 7.9). Resuscitation officers had the
174 highest mean score in the post-course MCQ (90.5, SD 5.5), with operating department practitioners (ODP) the lowest
175 (79.2, SD 17.0). Those participants who had previous ALS experience or were a core member of the resuscitation
176 team performed better in the post-course MCQ (P<0.001, P<0.001 respectively), as did the more senior doctors and
177 nurses. Participants with previous ILS experience performed worse in the post-course MCQ (P<0.001).

Table 2: Univariate predictors of assessment outcomes

Independent variables	Mean post e-learning MCQ score	Mean post-course MCQ score	P-value	CAS-Test pass (%)	Odds ratio (95% CI)	P-value	Overall course pass (%)	Odds ratio (95% CI)	P-value
Healthcare profession									
Doctor (comparision)	84.7	88.7	<0.001[£]	5352 (86.0)			6095 (97.8)		
Nurse	79.7	80.0		1005 (81.3)	0.71 (0.60-0.83)	<0.001	1122 (90.9)	0.22 (0.17-0.29)	<0.001
Medical student	83.4	86.5		425	0.64	<0.001	525 (98.3)	1.31	0.435

				(79.6)	(0.51-0.79)			(0.66-2.59)	
Operating Department Practitioner	73.0	79.2		51 (70.8)	0.40 (0.24-0.66)	<0.001	67 (93.1)	0.30 (0.12-0.76)	0.011
Ambulance staff/ Paramedic	81.4	85.4		37 (92.5)	2.00 (0.62-6.62)	0.247	39 (97.5)	0.88 (0.12-6.43)	0.897
Resuscitation Officer	86.6	90.5		13 (86.7)	1.06 (0.24-4.69)	0.941	15 (100.0)	$3.6x10^6$	<0.001
Other	79.9	83.6		46 (66.7)	0.33 (0.20-0.54)	<0.001	62 (84.9)	0.12 (0.06-0.24)	<0.001
Stage of training									
Medical Student	83.3	86.4	<0.001[£]	426 (79.5)	0.72 (0.56-0.92)	0.010	526 (98.0)	0.70 (0.34-1.44)	0.332
Foundation Year 1 Doctor	83.0	86.6		1394 (84.7)	1.03 (0.85-1.24)	0.754	1624 (98.4)	0.92 (0.52-1.60)	0.754
Foundation Year 2 Doctor (comparision)	83.2	87.7		1401 (84.3)			1639 (98.6)		
Junior Grade Doctor (ST1/ST2)	85.2	89.1		667 (85.6)	1.11 (0.87-1.40)	0.406	768 (96.8)	0.45 (0.26-0.79)	0.006
Middle Grade Doctor[#]	87.0	91.1		1322 (90.4)	1.75 (1.40-2.17)	<0.001	1434 (97.9)	0.70 (0.41-1.20)	0.197
Senior Grade Doctor[$]	87.9	92.0		425 (87.3)	1.28 (0.95-1.72)	0.107	469 (96.1)	0.40 (0.22-0.76)	0.005
Junior Nurse (Band 4-6)	78.8	82.8		777 (78.3)	0.67 (0.55-0.82)	<0.001	886 (88.4)	0.12 (0.08-0.19)	<0.001
Senior Nurse (Band 7-9)	81.4	86.6		346 (87.8)	1.34 (0.97-1.87)	0.080	378 (95.5)	0.31 (0.17-0.57)	<0.001
Other	82.6	86.6		163 (74.1)	0.53 (0.38-0.74)	<0.001	202 (90.2)	0.14 (0.08-0.26)	<0.001
Previous life support course experience									
Previous ALS experience	85.5	89.7	<0.001[#]	3204 (89.3)	1.97 (1.73-2.24)	<0.001	3515 (98.0)	2.27 (1.73-2.98)	<0.001
No previous ALS experience	82.3	86.1		3727 (81.0)			4411 (95.6)		
Previous ILS experience	83.2	87.4	<0.001[#]	4666 (85.6)	1.24 (1.09-1.40)	0.001	5302 (97.2)	1.64 (1.29-2.09)	<0.001
No previous ILS experience	84.5	88.3		2265 (82.7)			2624 (95.5)		
Core member of	84.4	88.8	<0.001[#]	3305	1.67	<0.001	3668	1.91	<0.001

resuscitation team					(88.0)	(1.48-1.90)		(97.7)	(1.48-2.47)	
Not a core member of resuscitation team	83.0	86.6			3540 (81.4)			4173 (95.7)		
Age (years)			-0.33 ([-0.52]-[-0.11])*	0.003		0.98 (0.97-0.98)	<0.001		0.93 (0.93-0.94)	<0.001
Time spent on e-Learning (hours)			-0.24 ([-0.30]-[-0.19])*	<0.001		0.93 (0.91-0.94)	<0.001		0.90 (0.87-0.93)	<0.001

[#] *Independent samples t-test*
[£] *One way ANOVA*
**Linear regression to predict post course MCQ score (B value with 95% confidence intervals)*
[#] *ST3+, registrar equivalent*
[$] *Consultant or associate specialist*

The first attempt pass rate for CAS-Test was 84.6%. Univariate analysis found that paramedic and resuscitation officer pass rates were similar to physicians whilst nurses, medical students and those in the 'other' category had lower pass rates. Those participants with previous ALS experience were 1.97 times more likely to pass the CAS-Test assessment on the first attempt (OR 1.97 (95% CI 1.73-2.24), P<0.001) compared to those with no previous ALS experience. Those who were core members of the resuscitation team were 1.67 times more likely to pass the CAS-Test scenario, compared with those who were not core members (95% CI 1.48-1.90), P<0.001). Middle grade doctors were 1.75 times more likely to pass the CAS-Test compared to Foundation Year 2 doctors. (95% CI 1.40-2.17, P<0.001).

The overall course pass rate was 96.6%. Resuscitation officers demonstrated the highest pass rate at 100%. Junior nurses had the lowest pass rate of 88.4%. When compared to doctors in the univariate analysis; nurses (OR 0.22, 95% CI 0.17-0.29, P<0.001), ODPs (OR 0.30, 95% CI 0.12-0.76, P=0.011) and participants from the 'other' category (OR 0.12, 95% CI 0.06-0.24, P<0.001) had significantly lower overall pass rates. Participants were more likely to pass if they had previously undertaken ALS training (OR 2.27, 95% CI 1.73-2.98, P<0.001), ILS training (OR 1.64, 95% CI 1.29-2.09, P<0.001) or were a core member of the resuscitation team (OR 1.91, 95% CI 1.48-2.47, P<0.001).

The significant independent variables from the univariate analyses were assessed for co-linearity. Grade of training was removed due to co-linearity with healthcare background. The remaining independent variables were entered into multivariate analyses. Figures 1-3 present the findings from the multivariate analyses, with full data in supplementary material. Previous ILS and ALS experience and being a core member of a resuscitation team were

199 independent predictors of CAS-Test performance, post course MCQ score and overall success rates. Increasing age
200 was associated with worse post course MCQ score, CAS-Test outcome and overall result.
201
202 ***Time spent accessing e-learning***
203 Median time spent on the e-learning was 5.2 hours (IQR 3.7-7.1). Resuscitation officers spent the longest time
204 (median 7.5 hours, IQR 5.7-9.2). Doctors spent the least amount of time (median 4.9 hours, IQR 3.4-6.7). In general,
205 those doctors with more clinical experience spent less time accessing the e-learning material. This is demonstrated
206 below in table 3 where middle grade doctors spend the least time on every module. In the univariate analysis,
207 increased hours spent accessing e-learning was a statistically significant predictor of failing the post-course MCQ (B=-
208 0.24, 95% CI [-0.30]-[-0.19], P<0.001), the CAS-Test assessment (OR 0.93, 95% CI 0.91-0.94, P<0.001) and the overall
209 course (OR 0.90, 95% CI 0.87-0.93, P<0.001). When all other co-variates were controlled for in the multivariate
210 regression, time spent accessing e-learning remained a significant predictor of CAS-Test failure (OR 0.96, 95% CI
211 0.95-0.98, P<0.001) but was not a significant predictor of overall course failure (OR 0.98, 95% CI 0.95-1.02, P=0.367).

Table 3: Duration spent on individual ALS modules stratified by grade, profession and specialty background (minutes)

	ALS in perspective	ALS algorithm	Causes and Prevention of Cardiac Arrest	Acute Coronary Syndromes	Post Resuscitation Care	Monitoring, Rhythm Recognition and 12-lead ECG	Tachycardia, Cardioversion and Drugs	Bradycardia, Pacing and Drugs	Special Circumstances	Decisions Relating to Resuscitation	Arterial Blood Gas Analysis
Grade/healthcare profession											
Foundation year doctor	9.2	44.0	17.0	27.1	22.5	34.3	32.3	15.7	25.1	8.0	14.5
Junior grade doctor (ST1/ST2)	9.8	45.3	17.7	26.6	22.7	32.5	30.4	14.6	24.6	8.9	15.3
Middle grade doctor	9.5	43.8	17.0	26.4	21.8	30.7	27.8	13.6	22.8	8.0	12.4
Senior grade doctor	10.1	48.0	17.8	25.8	21.4	33.5	31.6	14.2	26.1	9.0	15.4
Junior nurse	11.0	51.0	21.4	31.1	24.9	53.5	39.6	19.9	32.7	10.3	25.1
Senior nurse	10.6	50.1	19.7	29.9	24.8	46.9	38.2	17.6	31.0	9.7	22.4
Paramedic	10.5	42.9	19.4	29.7	25.2	42.4	36.4	17.6	28.9	10.2	19.8
Operating department practitioner	10.6	49.5	22.6	29.5	24.8	57.8	43.8	20.3	33.0	12.1	28.6
Resuscitation officer	13.3	41.7	20.0	40.0	25.9	83.8	42.2	25.6	41.4	11.4	29.9
Medical student	9.3	45.0	17.8	28.1	24.1	38.5	35.8	16.5	28.7	9.3	15.6
Specialty background											
Anaesthetics	9.7	45.5	17.9	27.5	23.0	36.2	32.9	16.0	26.1	8.6	16.0
Cardiology	10.0	44.6	17.9	25.7	21.7	33.1	33.9	15.4	31.8	9.0	19.1
Surgery	9.3	45.0	17.9	28.0	23.0	35.9	33.7	15.5	25.5	8.1	15.5
Medicine	9.3	44.2	17.2	26.5	22.4	33.0	30.9	14.8	25.3	8.1	14.3

Emergency	10.0	45.2	18.2	27.6	23.4	38.3	32.6	16.4	25.6	9.1	18.3
Critical Care	11.1	52.1	20.8	30.7	23.8	46.1	38.2	18.9	32.0	9.8	18.5

Table 3 demonstrates the homogeneity between time spent on individual e-learning modules when stratified by specialty. Those from a critical care background spent slightly more time on modules compared to others, but this is likely due to the high proportion of nurses participating in the e-ALS course from this specialty (357/487, 73.3%).

DISCUSSION

This study has shown that previous experience in life support courses and being a core member of the resuscitation team predicts a favourable outcome on an e-ALS course. It also identifies the extent to which different candidate groups access the e-learning material and highlights particular modules that may be more challenging. Time spent accessing e-learning material was not related to course outcome; this was thought to be because participants who utilise these skills on a daily basis are already familiar with the material and thus require less time to re-familiarise themselves.

There are increasing pressures to minimise time spent on courses for both participants and faculty and to improve outcomes. It has been postulated that pre-course preparation could lead to either better outcomes or a reduced amount of face-to-face time needed on the course. This could in theory lead to equivalent or better participant outcomes with less resources (time off work for faculty/participants, venue hire etc.). There is very little evidence relating specifically to pre-learning for advanced life support courses, so this study goes some way towards filling that void.

Perkins et al.[11] looked at one example of pre-course preparation. This open label, multicentre RCT was a study of 572 participants on Resuscitation Council (UK) ALS courses. The control group received the course manual four weeks before the course. The intervention group received the course manual and also a CD with an interactive e-learning simulation programme. Although there were no significant differences in the primary outcome (performance during a standard cardiac arrest simulation), user evaluations were favourable. The results however cannot necessarily be generalised to all other types of pre-course learning or pre-course learning for other populations/course groups.

A multi-centre RCT demonstrated equivalence in outcome when comparing e-ALS and c-ALS learning methods and was significantly less costly to deliver.[8] The findings of this were corroborated by a large observational study of

238 27,170 participants which demonstrated almost identical assessment outcomes for participants enrolled on either a
239 c-ALS or e-ALS course.[9] These studies were a comparison of a standard life support course against specific pre-course
240 e-learning associated with a shorter duration hybrid life support course.

241 The topic of pre-course learning was addressed during the 2015 ILCOR international consensus on science process. It
242 was felt that a specific recommendation for or against pre-course preparation in ALS courses was too speculative
243 due to the lack of evidence in the literature.[15] These findings were balanced with a statement highlighting the
244 considerable ambiguity in the definition of "pre-course learning" and the difficulty in comparing single interventions
245 like a pre-course CD[11] with an intervention followed by a hybrid version of the face-to-face element.[8,9]

246 With regard to the findings from this study, we found some unexpected and interesting results. The most surprising
247 result was that time spent accessing prerequisite e-learning material was actually associated with worse assessment
248 and overall course outcome in the univariate regression. On further analysis however, this is explained by the fact
249 that those with greater clinical experience spent less time accessing the e-learning but paradoxically performed
250 better in the course assessments. This demonstrates the educational notion that when learning can be based on
251 previous experience; it will normally lead to improved outcomes. This is demonstrated in the multivariate regression
252 where time spent on e-learning was no longer a significant predictor of overall course outcome. Increased age was
253 associated with significantly poorer assessment outcomes. Whilst there is a paucity of evidence for the literature
254 regarding the effect of age on ALS outcomes, this pattern has been found in BLS studies and has been attributed to
255 skill decline over time[16,17] and psychological factors where younger participants are more motivated to learn.[18] It has
256 been found that those working in a high risk area for area for cardiac arrest were more motivated to learn life
257 support skills.[19]
258
259 Participants with greater experience in managing critically unwell patients (paramedics, middle grade doctors,
260 previous ALS/ILS experience, core member of the resuscitation team) performed substantially better in the CAS-Test
261 and overall result. This should not come as a surprise, but is a useful insight for course organisers when identifying
262 participants at the start of a course who do not fall into these groups and may benefit from additional support.
263
264 The e-learning package allows participants to dictate their own level of access dependent upon their prior
265 knowledge, experience and specialty background. They can access material at an appropriate time for them and

266 dedicate a greater amount of time to their weaker knowledge areas. The need for this degree of flexibility is
267 demonstrated by the vastly different durations spent accessing the online content. This is exemplified in table 3
268 which highlights that certain candidate groups (junior nurses and operating department practitioners) spent twice as
269 long on the 'Monitoring, rhythm recognition and 12-lead ECG' module compared to middle grade doctors, perhaps
270 because they do not routinely utilise such skills on a daily basis. The flexibility that the e-ALS course creates is just
271 one reason amongst many why participant satisfaction is greater on e-learning courses than compared to traditional
272 didactic courses.[20,21]
273
274 ***Limitations and Further Research***
275 The main limitation of this exploratory study is its observational nature. This means that the authors are only able to
276 suggest causality when determining whether independent variables influence assessment outcome. A specifically
277 designed RCT would be needed to establish a cause-effect relationship on assessment outcome.
278
279 Time is not necessarily an accurate marker of whether participants have truly engaged with the material and as this
280 study has shown, it is significantly confounded by clinical experience (ie if participants are already well versed in ECG
281 interpretation they will spend less time on this module). Furthermore, different individuals possess a spectrum of
282 learning abilities with some participants learning faster than others. A proportion of participants may have chosen to
283 preferentially utilise the course manual as opposed to the e-learning package and others may leave the e-learning
284 running whilst not at the computer, providing a falsely elevated time spent accessing the material. There remains a
285 need for more specific markers for determining whether participants have truly engaged with the e-learning
286 material.
287
288 A final limitation is that it does not determine whether accessing e-learning actually affects patient outcome from
289 cardiac arrest. Whilst this should be the overriding aim behind all resuscitation-related research, such studies are
290 very difficult to achieve. The authors believe however, that by critically appraising course outcome data and
291 continuously improving the delivery methods of resuscitation courses this will ultimately improve the care of the
292 critically unwell patient.
293
294 ***Conclusion***

295 Clinical experience through core membership of cardiac arrest teams and previous ILS or ALS training were
296 independent predictors of performance on the e-ALS course whilst time spent accessing e-learning materials did not
297 affect course outcomes. The large variation in time spent accessing e-learning reflects the diverse nature of
298 participants on our e-ALS courses and the spectra of learning needs that they possess. This supports the blended
299 approach to e-ALS which allows participants to tailor their e-learning experience to their specific needs.
300

301 **CONFLICTS OF INTEREST**

302 CJT is a Trainee Representative for the ALS Subcommittee for the Resuscitation Council (UK). ASL is Honorary
303 Secretary of the Resuscitation Council (UK) and a member of the European Resuscitation Council ALS Course
304 Committee. IB is an Educator for the Resuscitation Council (UK). SH is Director of Course Development and Training
305 for the Resuscitation Council (UK). SB-A is Project and Development Manager for the Resuscitation Council (UK). GDP
306 is Chair of the ALS Subcommittee for the Resuscitation Council (UK) and member of the European Resuscitation
307 Council ALS Course Committee.
308

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316 Resuscitation Council (UK) to oversee the hundreds of ALS courses that take place each year.
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LEGENDS TO FIGURES

Table 1: Participant demographics on the e-ALS course and time spent on e-learning

Table 2: Univariate predictors of assessment outcomes

Table 3: Duration spent on individual ALS modules stratified by grade, profession and specialty background

Figure 1: Multivariate analysis demonstrating factors that influence CAS-Test outcome

Figure 2: Multivariate analysis demonstrating factors that influence post-course MCQ score

Figure 3: Multivariate analysis demonstrating factors that influence overall course outcome

Supplementary material 1: Multivariate predictors of assessment outcomes

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Supplementary material 1: Multivariate predictors of assessment outcomes

Independent variables	Mean post e-learning MCQ score	Mean post-course MCQ score	Mean difference (95% CI)	P-value	CAS-Test result		Odds ratio of CAS-Test Pass (95% CI)	P-value	Overall course result		Odds ratio of course Pass (95% CI)	P-value
					Pass (%)	Fail (%)			Pass (%)	Fail (%)		
Healthcare profession												
Doctor (comparison)	84.7	88.7			5352 (86.0)	871 (14.0)			6095 (97.8)	137 (2.2)		
Nurse	79.7	80.0	-4.35 ([-4.85]-[-3.85])	<0.001	1005 (81.3)	231 (18.7)	0.92 (0.76-1.10)	0.356	1122 (90.9)	113 (9.1)	0.27 (0.20-0.37)	<0.001
Medical student	83.4	86.5	-0.43 ([-1.31]-0.45)	0.334	425 (79.6)	109 (20.4)	0.87 (0.63-1.20)	0.390	525 (98.3)	9 (1.7)	2.16 (0.96-4.48)	0.063
Operating Department Practitioner	73.0	79.2	-9.41 ([-11.13]-[-7.69])	<0.001	51 (70.8)	21 (29.2)	0.44 (0.25-0.78)	0.005	67 (93.1)	5 (6.9)	0.36 (0.13-1.01)	0.052
Ambulance staff/ Paramedic	81.4	85.4	-2.42 ([-4.71-[0.12])	0.039	37 (92.5)	3 (7.5)	3.75 (1.10-12.85)	0.035	39 (97.5)	1 (2.5)	2.34 (0.27-20.54)	0.444
Resuscitation Officer	86.6	90.5	0.98 ([-3.18]-5.14)	0.644	13 (86.7)	2 (13.3)	0.79 (0.17-3.73)	0.769	15 (100.0)	0 (0)	78518 (0-infinity)	0.986
Other	79.9	83.6	-4.27 ([-6.00]-[-2.53])	<0.001	46 (66.7)	23 (32.4)	0.47 (0.27-0.81)	0.007	59 (84.3)	11 (15.7)	0.19 (0.09 - 0.42)	<0.001
Previous life support experience												
Previous ALS experience	85.5	89.7	3.83 (3.44 – 4.21)	<0.001	3204 (89.3)	383 (10.7)	2.61 (2.22-3.07)	<0.001	3515 (98.0)	72 (2.0)	5.13 (3.66-7.19)	<0.001
No previous ALS experience	82.3	86.1			3727 (81.0)	877 (19.0)			4411 (95.6)	205 (4.4)		
Previous ILS experience	83.2	87.4	-0.27 ([-0.66]-0.12)	0.172	4666 (85.6)	787 (14.4)	1.19 (1.02-1.39)	0.024	5302 (97.2)	153 (2.8)	2.18 (1.61-2.95)	<0.001
No previous ILS experience	84.5	88.3			2265 (82.7)	473 (17.3)			2624 (95.5)	124 (4.5)		
Core member of resuscitation team	84.4	88.8	1.28 (0.94-1.62)	<0.001	3305 (88.0)	451 (12.0)	1.39 (1.21-1.59)	<0.001	3668 (97.7)	87 (2.3)	1.47 (1.10-1.98)	0.009
Not a core member of resuscitation	83.0	86.6			3540 (81.4)	809 (18.6)			4173 (95.7)	189 (4.3)		

team												
Age (years)			-0.06 ([-0.09]-[-0.04])	<0.001			0.96 (0.95-0.97)	<0.001			0.93 (0.92-0.94)	<0.001
Time spent on e-Learning (hours)			-0.05 ([-0.11]-0.00)	0.047			0.96 (0.95-0.98)	<0.001			0.98 (0.95-1.02)	0.367

[#] *ST3+, middle grade equivalent*

[$] *Consultant or associate specialist*

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e-learning in Advanced Life Support – What factors influence assessment outcome?

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ABSTRACT

Aim

To establish variables which are associated with favourable Advanced Life Support (ALS) course assessment outcomes, maximising learning effect.

Method

Between 1 January 2013 and 30 June 2014, 8,218 ~~candidates~~ individuals participated in a Resuscitation Council (UK) e-learning Advanced Life Support (e-ALS) course. ~~Candidates~~ Participants ~~were asked to~~ completed 5-8 hours of online e-learning prior to attending a~~the~~ one day ~~modified~~ face-to-face course. ~~The extent to which they accessed this material was ascertained online~~ e-learning access data were collected through the Learning Management System (LMS). All ~~candidates~~ participants were assessed by ~~a pre and post-course MCQ~~a multiple choice questionnaire (MCQ) before and after the face to face aspect alongside ~~and~~ a practical cardiac arrest simulation (CAS-Test). ~~Candidate~~ Participant demographics and assessment outcomes were analysed.

Results

The mean ~~pre-course~~post e-learning MCQ score was 83.7 (SD 7.3) and the mean post-course MCQ score was 87.7 (SD 7.9). The first attempt CAS-Test pass rate was 84.6% and overall pass rate 96.6%. ~~Candidates~~Participants ~~who had~~ with previous ALS course experience, ILS course experience, or who were a core member of the resuscitation team performed better in the post-course MCQ, CAS-Test and overall assessment. Median time spent on the e-learning was 5.2 hours (IQR 3.7-7.1). There was a large range in the degree of access to e-learning content. Increased time spent accessing e-learning had no effect on the overall result (OR 0.98~~9~~, P=0.367~~435~~) on simulated learning outcome.

Conclusion

Clinical experience through core membership of cardiac arrest teams and previous ILS or ALS training were independent predictors of performance on the ALS course whilst time spent accessing e-learning materials did not affect course outcomes. This supports the blended approach to e-ALS which allows participants to tailor their e-learning experience to their specific needs.

~~Regular clinical experience in managing critically unwell patients is the most discriminating factor for a more significant predictor of ALS assessment outcome as opposed tothan time spent on pre-course e-learning. Candidates have a spectrum of learning needs and it is imperative that they have the opportunity to shape their e-learning around prior knowledge and experience.~~

INTRODUCTION

The Formula for Survival[1] ~~proposes~~ identifies three ~~critical~~ factors that influence survival from cardiac arrest: high-quality research, efficient education of patient caregivers and ~~a slick~~an effective chain of survival from the early recognition of cardiac arrest through to post resuscitation care.[2] Advanced Life Support (ALS) courses, which address both the second and third aspects of this formula, are used internationally to train healthcare personnel how to manage patients in cardiac arrest. Previous studies have linked ~~candidate~~ participation on ALS courses to improved ~~patient~~ outcomes from cardiac arrest.[3–5] Courses use multimodal delivery methods to equip ~~candidates~~ participants with background scientific knowledge, targeted clinical skills and non-technical skill development. This blended learning approach is from course manuals, online e-learning material, didactic lectures, hands-on skill stations and formative assessment. In the United Kingdom (UK) and many other countries, successful completion of an ALS course (or similar) is ~~essential~~ required for healthcare professionals who manage acutely unwell patients on a regular basis.

The Resuscitation Council (UK) has a 25 year history in delivering ALS courses.,[6] ~~and year on year sees increasing demand for such courses.~~ A total of 20,268 ~~candidates~~ individuals participated in an ALS course between January 2015 and December 2015.[6,7] In 2011, a strategic decision was taken to meet increasing demand, and to increase the

flexibility of learning for ~~candidates~~participants. The Resuscitation Council (UK) launched a novel e-learning ALS course (e-ALS), as an alternative to the conventional two day face-to-face (c-ALS) course, valuing this key educational approach of blended learning. This constitutes 5-8 hours of online e-learning that is undertaken pre-course, followed by attendance for a condensed, focussed one day face-to-face element. A multi-centre randomised control trial in 2012[8] and a large observational study of 27,170 ~~candidates~~participants in 2015[9] demonstrated almost identical assessment outcomes for ~~candidates~~participants enrolled upon either c-ALS or e-ALS. The findings of these two studies consolidated the emerging role of the Resuscitation Council (UK) e-ALS course. Whilst outcome data were comparable in the observational study,[9] it did not assess the extent to which those ~~candidates~~participants enrolled on the e-ALS course actually accessed the e-learning material, or its effect on assessment outcomes.

Previous studies investigating the utility of e-learning~~,~~ all display a common limitation, whereby participants often do not fully access the e-learning material.~~have all found a common trend for candidates failing to access a significant quantity of the required material.~~[10,11] Jensen et al. investigated e-learning as a means for retaining ALS competency but found that only 57.5% of candidates accessed all of the stipulated modules.[10] Similarly Perkins et al. found that only 64% of candidates accessed pre-course e-learning via a CD prior to attending an ALS course.[11] ~~This has several adverse outcomes; firstly it increases the likelihood of a type II error,~~This limitation was acknowledged by the authors, who postulated that any true difference between the control and intervention groups ~~whereby any difference between the groups is not identified~~ may not have been detected because the intervention had~~s~~ not been implemented effectively. Secondly, it provides challenges for ALS course organisers to establish exactly what extent of e-learning has been undertaken by the ~~candidates~~participants prior to attending a face-to-face course. Whilst in theory this allows personalisation of the learning experience, it also potentially reduces the standardisation of content delivered to those on an ALS course. Consequently, it is currently unknown whether making e-learning non-compulsory adversely affects candidate outcome.

This study was designed to access the aforementioned observational study data set,[9] analysing the extent to which ~~candidates~~participants access pre-requisite e-learning material, establishing the effect on candidate outcome in their subsequent ALS assessments. In doing this, study authors intend to highlight independent predictors of successful ALS course outcome.

METHODS

Setting and Participants

ALS ~~candidates~~participants voluntarily enrolled on a one-day e-ALS course at one of 94 national training centres. Each candidate ~~was required to register~~registered on the Resuscitation Council (UK) Learning Management System (LMS) prior to attending the course. ~~Candidates~~Participants were from a wide range of healthcare professions and stages of training.

The e-ALS Course

The e-ALS course consists of 5-8 hours of e-learning content covering essential ALS topics. Each candidate is given access to the LMS 8 weeks prior to their course and is asked to complete the 12 electronic learning modules. Additionally, ~~Candidates~~participants receive ~~the~~a physical copy of the ALS course manual ~~a minimum of~~at least four weeks before the course date. ~~Progress on the e-learning content~~e-learning progress is monitored by the course centres ~~and this information is available to the faculty at the start of the course~~. ~~Candidates~~Participants are free to choose to personalise their learning experience – undertaking as little or as much of the e-learning preparation as they feel necessary although there are three compulsory modules: ALS in perspective; advanced life support algorithm; non-technical skills (progress data are~~is~~ not routinely collected on the LMS for this module as it was only introduced in 2013).

~~In addition to the three compulsory modules listed above, the~~There are nine non-compulsory modules ~~are~~: causes and prevention of cardiac arrest; acute coronary syndromes; monitoring, rhythm recognition and 12 lead ECG; bradycardia, pacing and drugs; tachycardia, cardioversion and drugs; special circumstances; post resuscitation care; arterial blood gas analysis; and decisions relating to resuscitation.

On completion of the e-learning ~~package~~, ~~candidates~~participants undertake a compulsory ~~pre-course~~ multiple choice questionnaire (MCQ), although their results in this ~~are formative and~~ do not affect the ~~candidates~~participants' post-course outcome. After completing the one-day face to face aspect, each candidate ~~is subject to~~undertakes a ~~compulsory~~ post-course MCQ and a practical cardiac arrest management simulation test (CAS-Test). In order to achieve ALS competency ~~candidates~~participants need to pass both ~~the post-course MCQ and the CAS-Test.~~of these aspects. ~~Candidates~~Participants are permitted two attempts at the MCQ and three attempts at the CAS-Test. The pre

and post-course MCQs comprise 30 different stem questions, with each having four true/false answers, creating a total of 120 questions to answer. The pass mark is 75%. The CAS-Test simulations are criterion based and are well validated.[12,13] They assess ~~candidates~~participants' abilities in patient assessment, formulating a treatment plan and leadership of the cardiac arrest team. Overall scores and pass/fail data are recorded.

Statistical analysis

Demographic data were~~is~~ collected ~~for each participant at the time of registration~~ on the LMS. Anonymised data we~~a~~re transferred to Microsoft Excel *(Microsoft Corporation, Redmond, USA)* and ~~subject to statistical analysis using~~analysed using SPSS 23 *(IBM, Armonk, USA)* and R statistical program Version 3.3.1.[14] Categorical baseline characteristics were summarised using counts and percentages while continuous baseline characteristics ~~spent on e-learning~~ were summarised using median and interquartile range (IQR).

A multivariable logistic regression model was fitted to assess which variables predict whether a trainee passes the CAS-Test on the first attempt. Trainees attending the same course session tend to have similar outcomes[8] and so the multivariable logistic regression model included a random effects term for course session. A similar model was fitted to assess which variables predict whether a trainee passes the overall test. Odds ratios (OR), 95% confidence intervals and p-values from the multivariable random effects logistic regression models were reported. To assess which variables predict the MCQ score of a trainee in the first attempt, MCQ scores were analysed by fitting a linear mixed model with a random effects term for course session. Mean difference in MCQ scores, 95% confidence intervals and p-values from the linear missed model were reported. An analysis of standard residuals was carried out and outliers removed. ~~Descriptive statistics were calculated. Independent t-tests, one-way ANOVAs and linear regression models were utilised to determine differences between continuous variables, and logistic regression was used for the dichotomous variables. Significant predictors of assessment outcome were entered into a multivariate logistic regression model and reported as odds ratios (OR) and 95% confidence intervals. All independent variables were assessed for co-linearity before running the models.~~Co-linearity was assessed by independently entering each independent variable into a logistic regression with the remaining variables entered as dependent variables. Collinearity diagnostics were calculated and the variance inflation factor (VIF) in all instances was <1. In all models, ~~M~~missing data were excluded from the complete case analysis by a listwise deletion. Statistical significance was set at P-values of <0.05.

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RESULTS

~~450 e-ALS courses took place between 1st January 2013 and 30th June 2014 at 94 different ALS centres across the UK.~~

Demographics

8,218 participants were enrolled on one of 450 e-ALS courses during the study period.~~8,218 candidates undertook an e-ALS course during the study period.~~ Mean age was 32.0 years (SD 8.2). 15 ~~candidates~~participants started but failed to complete the course. 1.8% of the total ~~candidates~~participants had a degree of missing data and ~~this was~~these were excluded from the analysis. Any missing data occurred due to incomplete data entry by ~~candidates~~participants or local course facilitators on the LMS. Stratified participant demographics are displayed below in table 1 in addition to time spent accessing the e-learning and corresponding pass rates.

Table 1: Participant demographics on the e-ALS course and time spent on e-learning

Characteristics/outcomes	n, (%)	Hours spent on compulsory modules	Hours spent on non-compulsory modules	Total hours spent on e-Learning	Overall pass rate (%)
Healthcare background					
Doctor Range Mean (SD) Median (IQR)	6236 (75.9)	0-13.2 1.1 (0.8) 0.9 (0.7-1.4)	0-21.0 4.1 (2.5) 3.8 (2.6-5.3)	0-24.0 5.3 (3.0) 4.9 (3.4-6.7)	6095 (97.8)
Nurse Range Mean (SD) Median (IQR)	1244 (15.1)	0-8.9 1.3 (0.9) 1.1 (0.8-1.6)	0-17.2 5.4 (3.4) 4.8 (3.4-6.6)	0-24.0 6.9 (3.9) 6.2 (4.5-8.5)	1122 (90.9)
Medical student Range Mean (SD) Median (IQR)	534 (6.5)	0-4.7 1.1 (0.7) 0.9 (0.7-1.3)	0-16.0 4.4 (2.2) 4.1 (2.9-5.6)	0-17.6 5.6 (2.6) 5.3 (4.0-6.9)	525 (98.3)

Operating Department Practitioner	73 (0.9)				67 (93.1)
Range		0-6.9	0-11.5	0.2-21.4	
Mean (SD)		1.3 (1.1)	5.3 (2.7)	7.0 (3.7)	
Median (IQR)		1.0 (0.8-1.4)	5.2 (3.5-7.2)	6.4 (4.8-8.8)	
Ambulance staff/ Paramedic	40 (0.5)				39 (97.5)
Range		0-6.4	0-18.7	0-22.7	
Mean (SD)		1.3 (1.2)	4.7 (3.1)	6.5 (4.0)	
Median (IQR)		1.1 (0.7-1.9)	4.8 (3.3-5.7)	6.4 (4.4-8.0)	
Resuscitation Officer	15 (0.2)				15 (100.0)
Range		0.6-3.0	4.3-9.5	5.1-10.4	
Mean (SD)		1.3 (0.7)	6.1 (1.5)	7.5 (1.7)	
Median (IQR)		1.0 (0.8-2.1)	6.1 (4.8-7.1)	7.5 (5.7-9.2)	
Other	74 (0.9)				62 (84.9)
Range		0-5.5	0-18.0	0-20.6	
Mean (SD)		1.4 (0.9)	6.0 (3.4)	7.8 (4.1)	
Median (IQR)		1.2 (0.9-1.5)	4.8 (3.7-7.5)	6.7 (5.0-9.7)	
Not available	2				
		Stage of training			
Medical Student	537 (6.5)				526 (98.0)
Range		0-4.7	0-16.0	0-17.6	
Mean (SD)		1.1 (0.7)	4.4 (2.2)	5.6 (2.6)	
Median (IQR)		0.9 (0.7-1.3)	4.1 (2.9-5.6)	5.3 (4.0-6.9)	
Foundation Year 1 Doctor	1650 (20.1)				1624 (98.4)
Range		0-7.0	0-21.0	0-21.7	
Mean (SD)		1.1 (0.7)	4.0 (2.2)	5.2 (2.6)	
Median (IQR)		0.9 (0.7-1.3)	3.8 (2.7-5.2)	4.9 (3.6-6.5)	
Foundation Year 2 Doctor	1663 (20.2)				1639 (98.6)
Range		0-10.0	0-18.4	0-20.8	
Mean (SD)		1.1 (0.8)	4.1 (2.3)	5.3 (2.8)	
Median (IQR)		0.9 (0.7-1.3)	3.9 (2.7-5.2)	5.0 (3.6-6.6)	
Junior Grade Doctor (ST1/ST2)	794 (9.7)				768 (96.8)
Range		0-9.4	0-20.6	0-24.0	
Mean (SD)		1.2 (0.8)	4.3 (2.7)	5.5 (3.3)	
Median (IQR)		1.0 (0.7-1.5)	3.7 (2.6-5.4)	4.9 (3.5-7.0)	
Middle Grade Doctor[#]	1465 (17.8)				1434 (97.9)
Range		0-13.2	0-20.8	0-23.5	
Mean (SD)		1.1 (0.8)	3.9 (2.5)	5.1 (2.9)	
Median (IQR)		0.9 (0.7-1.4)	3.5 (2.3-5.0)	4.7 (3.2-6.5)	
Senior Grade Doctor[$]	488 (5.9)				469 (96.1)
Range		0-5.1	0-17.7	0-21.2	
Mean (SD)		1.2 (0.9)	4.1 (2.7)	5.4 (3.4)	
Median (IQR)		1.0 (0.8-1.5)	3.7 (2.5-5.3)	4.9 (3.3-7.1)	
Junior Nurse (Band 4-6)	1002 (12.2)				886 (88.4)
Range		0-8.9	0-17.2	0-23.1	
Mean (SD)		1.3 (0.9)	5.0 (3.2)	7.1 (3.9)	
Median (IQR)		1.1 (0.8-1.6)	4.9 (3.5-6.7)	6.4 (4.7-8.7)	
Senior Nurse (Band 7-9)	395 (4.8)				378 (95.5)
Range		0-6.8	0-15.4	0-24.0	
Mean (SD)		1.3 (0.9)	5.0 (3.2)	6.6 (3.8)	
Median (IQR)		1.1 (0.8-1.6)	4.5 (3.1-6.5)	5.9 (4.2-8.1)	

Other Range Mean (SD) Median (IQR)	223 (2.7)	 0-8.3 1.6 (1.2) 1.2 (0.9-1.9)	 0-18.7 5.9 (3.3) 5.3 (3.5-7.7)	 0-22.7 7.6 (4.2) 6.9 (4.9-9.5)	202 (90.2)
Not available	1				
Previous ALS experience					
No Range Mean (SD) Median (IQR)	4615 (56.2)	 0-10.0 1.2 (0.8) 1.0 (0.7-1.4)	 0-21.0 4.5 (2.7) 4.1 (3.9-7.2)	 0-24.0 5.8 (3.2) 5.3 (3.8-7.2)	4411 (95.6)
Yes Range Mean (SD) Median (IQR)	3593 (43.8)	 0-13.2 1.2 (0.8) 1.0 (0.7-1.4)	 0-21.0 4.1 (2.6) 3.8 (2.5-5.3)	 0-24.0 5.4 (3.2) 5.3 (3.9-7.2)	3515 (98.0)
Not available	10				
Previous ILS experience*					
No Range Mean (SD) Median (IQR)	2704 (32.9)	 0-8.3 1.2 (0.9) 1.0 (0.8-1.5)	 0-21.0 4.5 (2.8) 4.1 (2.7-5.8)	 0-24.0 5.8 (3.4) 5.3 (3.7-7.4)	2624 (95.5)
Yes Range Mean (SD) Median (IQR)	5466 (67.1)	 0-13.2 1.1 (0.8) 1.0 (0.7-1.4)	 0-20.9 4.3 (2.6) 4.2 (2.9-5.7)	 0-24.0 5.5 (3.1) 5.4 (3.8-7.3)	5302 (97.2)
Not available	48				
Core member of resuscitation team					
No Range Mean (SD) Median (IQR)	4373 (53.8)	 0-9.4 1.2 (0.8) 1.0 (0.8-1.5)	 0-21.0 4.5 (2.7) 4.2 (2.9-5.7)	 0-23.5 5.8 (3.2) 5.4 (3.9-7.3)	4173 (95.7)
Yes Range Mean (SD) Median (IQR)	3759 (46.2)	 0-13.2 1.1 (0.8) 0.9 (0.7-1.4)	 0-21.0 4.1 (2.6) 3.8 (2.6-5.3)	 0-24.0 4.9 (3.1) 4.9 (3.5-6.8)	3668 (97.7)
Not available	86				
Total Range Mean (SD) Median (IQR)	8218	 0-13.2 1.2 (2.8) 1.0 (0.74-1.4)	 0-21.0 4.3 (2.7) 4.0 (2.7-5.5)	 0-24.0 5.6 (3.2) 5.2 (3.7-7.1)	7926 (96.6%)

**Immediate Life Support*
 # ST3+, middle grade equivalent
$ Consultant or associate specialist

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~~Table 1: Participant demographics on the e-ALS course and time spent on e-learning~~						
~~Healthcare background~~	~~Total (%)~~	~~Median hours spent on compulsory modules (IQR)~~	~~Median hours spent on non-compulsory modules (IQR)~~	~~Median total hours spent on e-Learning (IQR)~~	~~Median completed modules (max 11)~~	~~Overall pass rate (%)~~
~~Doctor~~	~~6236 (75.9)~~	~~0.9 (0.7-1.4)~~	~~3.8 (2.6-5.3)~~	~~4.9 (3.4-6.7)~~	~~11~~	~~6095 (97.8)~~

Nurse	1244 (15.1)	1.1 (0.8-1.6)	4.8 (3.4-6.6)	6.2 (4.5-8.5)	11	1122 (90.9)
Medical student	534 (6.5)	0.9 (0.7-1.3)	4.1 (2.9-5.6)	5.3 (4.0-6.9)	11	525 (98.3)
Operating Department Practitioner	73 (0.9)	1.0 (0.8-1.4)	5.2 (3.5-7.2)	6.4 (4.8-8.8)	11	67 (93.1)
Ambulance staff/ Paramedic	40 (0.5)	1.1 (0.7-1.9)	4.8 (3.3-5.7)	6.4 (4.4-8.0)	11	39 (97.5)
Resuscitation Officer	15 (0.2)	1.0 (0.8-2.1)	6.1 (4.8-7.1)	7.5 (5.7-9.2)	11	15 (100.0)
Other	74 (0.9)	1.2 (0.9-1.5)	4.8 (3.7-7.5)	6.7 (5.0-9.7)	11	62 (84.9)
Not available	2					
Stage of training						
Medical Student	537 (6.5)	0.9 (0.7-1.3)	4.1 (2.9-5.6)	5.3 (4.0-6.9)	11	526 (98.0)
Foundation Year 1 Doctor	1650 (20.1)	0.9 (0.7-1.3)	3.8 (2.7-5.2)	4.9 (3.6-6.5)	11	1624 (98.4)
Foundation Year 2 Doctor	1663 (20.2)	0.9 (0.7-1.3)	3.9 (2.7-5.2)	5.0 (3.6-6.6)	11	1639 (98.6)
Junior Grade Doctor (ST1/ST2)	794 (9.7)	1.0 (0.7-1.5)	3.7 (2.6-5.4)	4.9 (3.5-7.0)	11	768 (96.8)
Middle Grade Doctor[#]	1465 (17.8)	0.9 (0.7-1.4)	3.5 (2.3-5.0)	4.7 (3.2-6.5)	11	1434 (97.9)
Senior Grade Doctor[$]	488 (5.9)	1.0 (0.8-1.5)	3.7 (2.5-5.3)	4.9 (3.3-7.1)	11	469 (96.1)
Junior Nurse (Band 4-6)	1002 (12.2)	1.1 (0.8-1.6)	4.9 (3.5-6.7)	6.4 (4.7-8.7)	11	886 (88.4)
Senior Nurse (Band 7-9)	395 (4.8)	1.1 (0.8-1.6)	4.5 (3.1-6.5)	5.9 (4.2-8.1)	11	378 (95.5)
Other	223 (2.7)	1.2 (0.9-1.9)	5.3 (3.5-7.7)	6.9 (4.9-9.5)	11	202 (90.2)
Not available	1					
Previous ALS experience						
Never	4615 (56.2)	1.0 (0.7-1.4)	4.1 (2.9-5.7)	5.3 (3.8-7.2)	11	4402 (95.4)
0-6 months	209 (2.5)	1.0 (0.7-1.4)	4.2 (2.4-6.0)	5.4 (3.5-7.5)	11	205 (98.1)
7-12 months	220 (2.7)	0.9 (0.7-1.4)	4.0 (2.5-5.4)	5.1 (3.6-6.9)	11	216 (98.2)
18-24 months	119 (1.4)	1.0 (0.7-1.5)	4.3 (3.2-5.7)	5.5 (4.2-7.1)	11	116 (97.5)
2-4 years	1157 (14.1)	0.9 (0.7-1.4)	3.5 (2.4-5.1)	4.6 (3.2-6.6)	11	1140 (98.5)
> 4 years	1888 (23.0)	1.0 (07-1.4)	3.9 (2.5-5.4)	5.0 (3.4-6.9)	11	1838 (97.7)
Not available	10					
Previous ILS experience*						
Never	2704 (32.9)	1.0 (0.8-1.5)	4.1 (2.7-5.8)	5.3 (3.7-7.4)	11	2577 (95.3)
0-6 months	1010	1.0	4.2	5.4	11	970

	(12.4)	(0.7-1.4)	(2.9-5.7)	(3.8-7.3)		(96.0)
7-12 months	1766 (21.5)	0.9 (0.7-1.4)	3.9 (2.7-5.3)	5.1 (3.7-6.7)	11	1714 (97.1)
18-24 months	1126 (13.7)	0.9 (0.7-1.4)	4.0 (2.9-5.4)	5.2 (3.8-6.8)	11	1126 (97.7)
2-4 years	505 (6.1)	1.0 (0.8-1.5)	4.3 (2.9-6.0)	5.4 (3.8-7.5)	11	475 (94.1)
> 4 years	1059 (12.9)	0.9 (0.7-1.3)	3.5 (2.4-5.0)	4.7 (3.3-6.4)	11	1043 (98.5)
Not available	48					
Total	**8218**	1.0 (0.74-1.4)	4.0 (2.7-5.5)	5.2 (3.7-7.1)	11	7926 (96.6%)

**Immediate Life Support*
#ST3+, middle grade equivalent
$-Consultant or associate specialist

Assessment outcomes

Full assessment outcome data are displayed in Supplementary MaterialTable 21. 99.1% of candidatesparticipants completed the pre-coursepost e-learning MCQ. The mean pre-course MCQ, with a mean score was of 83.7 (SD 7.3). and tThe mean post-course MCQ score was 87.7 (SD 7.9). Resuscitation officers had the highest mean score in the post-course MCQ (90.5, SD 5.5), with operating department practitioners (ODP) the lowest (79.2, SD 17.0). Those candidatesparticipants who had previous ALS course experience or were a core member of the resuscitation team on a day-to-day basis performed better in the post-course MCQ (P<0.001, P<0.001 respectively), as did the more senior doctors and nurses. CandidatesParticipants who had previous ILS course experience actually performed minimally worse in the post-course MCQ (P<0.001).

Table 2: Univariate predictors of assessment outcomes

Independent variables	Mean post e-learning MCQ score	Mean post-course MCQ score	P-value	CAS-Test pass (%)	Odds ratio (95% CI)	P-value	Overall course pass (%)	Odds ratio (95% CI)	P-value
Healthcare profession									
Doctor (comparision)	84.7	88.7	<0.001£	5352 (86.0)			6095 (97.8)		
Nurse	79.7	80.0		1005 (81.3)	0.71 (0.60-0.83)	<0.001	1122 (90.9)	0.22 (0.17-0.29)	<0.001
Medical student	83.4	86.5		425 (79.6)	0.64 (0.51-0.79)	<0.001	525 (98.3)	1.31 (0.66-2.59)	0.435
Operating Department Practitioner	73.0	79.2		51 (70.8)	0.40 (0.24-0.66)	<0.001	67 (93.1)	0.30 (0.12-	0.011

								0.76)	
Ambulance staff/ Paramedic	81.4	85.4		37 (92.5)	2.00 (0.62-6.62)	0.247	39 (97.5)	0.88 (0.12-6.43)	0.897
Resuscitation Officer	86.6	90.5		13 (86.7)	1.06 (0.24-4.69)	0.941	15 (100.0)	$3.6x10^{6}$	<0.001
Other	79.9	83.6		46 (66.7)	0.33 (0.20-0.54)	<0.001	62 (84.9)	0.12 (0.06-0.24)	<0.001
Stage of training									
Medical Student	83.3	86.4	<0.001[£]	426 (79.5)	0.72 (0.56-0.92)	0.010	526 (98.0)	0.70 (0.34-1.44)	0.332
Foundation Year 1 Doctor	83.0	86.6		1394 (84.7)	1.03 (0.85-1.24)	0.754	1624 (98.4)	0.92 (0.52-1.60)	0.754
Foundation Year 2 Doctor (comparision)	83.2	87.7		1401 (84.3)			1639 (98.6)		
Junior Grade Doctor (ST1/ST2)	85.2	89.1		667 (85.6)	1.11 (0.87-1.40)	0.406	768 (96.8)	0.45 (0.26-0.79)	0.006
Middle Grade Doctor[#]	87.0	91.1		1322 (90.4)	1.75 (1.40-2.17)	<0.001	1434 (97.9)	0.70 (0.41-1.20)	0.197
Senior Grade Doctor[$]	87.9	92.0		425 (87.3)	1.28 (0.95-1.72)	0.107	469 (96.1)	0.40 (0.22-0.76)	0.005
Junior Nurse (Band 4-6)	78.8	82.8		777 (78.3)	0.67 (0.55-0.82)	<0.001	886 (88.4)	0.12 (0.08-0.19)	<0.001
Senior Nurse (Band 7-9)	81.4	86.6		346 (87.8)	1.34 (0.97-1.87)	0.080	378 (95.5)	0.31 (0.17-0.57)	<0.001
Other	82.6	86.6		163 (74.1)	0.53 (0.38-0.74)	<0.001	202 (90.2)	0.14 (0.08-0.26)	<0.001
Previous life support course experience									
Previous ALS experience	85.5	89.7	<0.001[#]	3204 (89.3)	1.97 (1.73-2.24)	<0.001	3515 (98.0)	2.27 (1.73-2.98)	<0.001
No previous ALS experience	82.3	86.1		3727 (81.0)			4411 (95.6)		
Previous ILS experience	83.2	87.4	<0.001[#]	4666 (85.6)	1.24 (1.09-1.40)	0.001	5302 (97.2)	1.64 (1.29-2.09)	<0.001
No previous ILS experience	84.5	88.3		2265 (82.7)			2624 (95.5)		
Core member of resuscitation team	84.4	88.8	<0.001[#]	3305 (88.0)	1.67 (1.48-1.90)	<0.001	3668 (97.7)	1.91 (1.48-2.47)	<0.001
Not a core member of resuscitation	83.0	86.6		3540 (81.4)			4173 (95.7)		

team										
Age (years)			-0.33 ([-0.52]-[-0.11])*	0.003		0.98 (0.97-0.98)	<0.001		0.93 (0.93-0.94)	<0.001
Time spent on e-Learning (hours)			-0.24 ([-0.30]-[-0.19])*	<0.001		0.93 (0.91-0.94)	<0.001		0.90 (0.87-0.93)	<0.001

[#]Independent samples t-test
[£] One way ANOVA
**Linear regression to predict post course MCQ score (B value with 95% confidence intervals)*
[#] ST3+, registrar equivalent
[$] Consultant or associate specialist

The overall first attempt pass rate for CAS-Test was 84.6%. Univariate analysis found that paramedic and resuscitation officer pass rates were similar to physicians whilst nurses, medical students and those in the 'other' category had lower pass rates. Those ~~candidates~~participants with previous ALS experience were ~~twice~~ 1.97 times more~~as~~ likely to pass the CAS-Test assessment on the first attempt (OR 1.97 (95% CI 1.73-2.24), P<0.001) compared to those with no previous ALS experience. Those who were ~~a~~ core members of the resuscitation team were ~~also significantly~~1.67 times more likely to pass the CAS-Test scenario, compared with those who were not core members ~~(OR 1.67~~ (95% CI 1.48-1.90), P<0.001)., ~~as were m~~Middle grade doctors were 1.75 times more likely to pass the CAS-Test compared to Foundation Year 2 doctors. ~~(OR 1.75,~~ (95% CI 1.40-2.17, P<0.001).

~~In terms of overall e-ALS course results the~~The overall course pass rate was 96.6%. Resuscitation officers demonstrated the highest pass rate at 100%. Junior nurses had the lowest pass rate of 88.4%. When compared to doctors in the univariate analysis; nurses (OR 0.22, 95% CI 0.17-0.29, P<0.001), ODPs (OR 0.30, 95% CI 0.12-0.76, P=0.011) and ~~candidates~~participants from the 'other' category (OR 0.12, 95% CI 0.06-0.24, P<0.001) had significantly lower overall pass rates. ~~Candidates~~Participants were more likely to pass if they had previously undertaken ALS training (OR 2.27, 95% CI 1.73-2.98, P<0.001), ILS training (OR 1.64, 95% CI 1.29-2.09, P<0.001) or were a core member of the resuscitation team (OR 1.91, 95% CI 1.48-2.47, P<0.001).

The significant independent variables from the univariate analyses were assessed for co-linearity. Grade of training was removed due to co-linearity with healthcare background. The remaining independent variables were entered

into multivariate analyses. ~~Figure 1 and figure 2~~Figures 1-3 present~~s~~ the findings from the multivariate analyses, with full data in supplementary material. ~~The full outcome data from the analyses can be accessed in Supplementary Material 2.~~ Previous ILS and ALS experience and being a core member of a resuscitation team were independent predictors of CAS-Test performance, post course MCQ score and overall success rates. Increasing age was associated with worse post course MCQ score, CAS-Test outcome and overall result.

~~**Figure 1: Multivariate analysis demonstrating factors that influence CAS-Test outcome**~~

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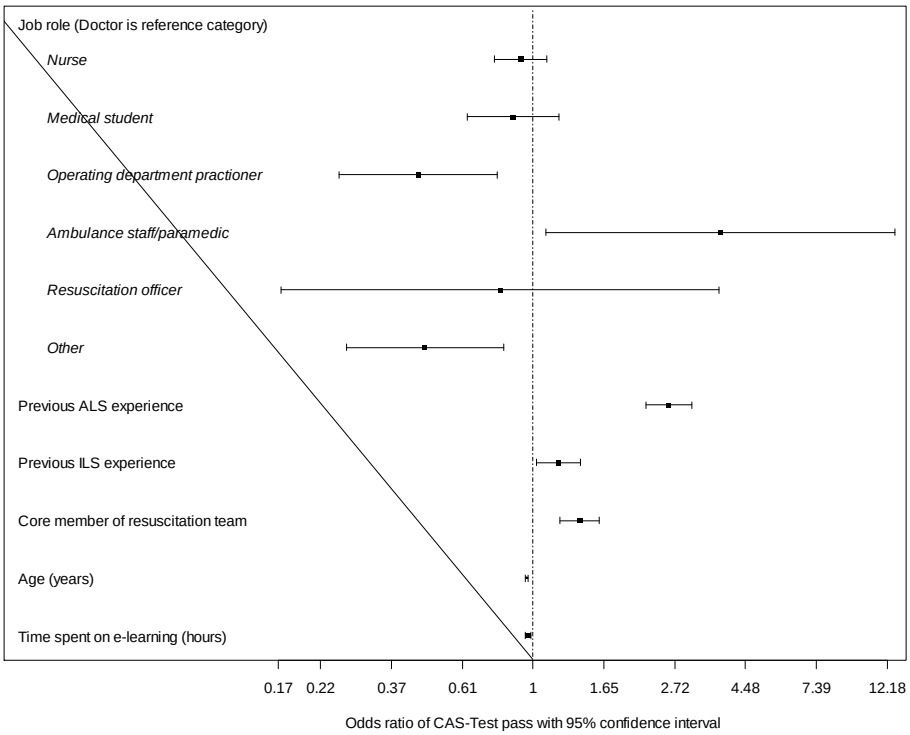


Figure 2: Multivariate analysis demonstrating factors that influence post-course MCQ score

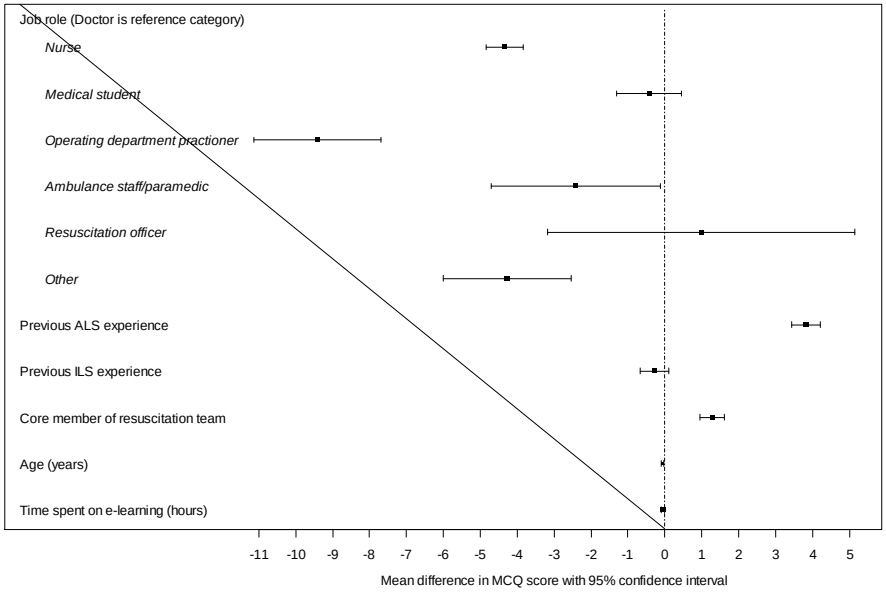
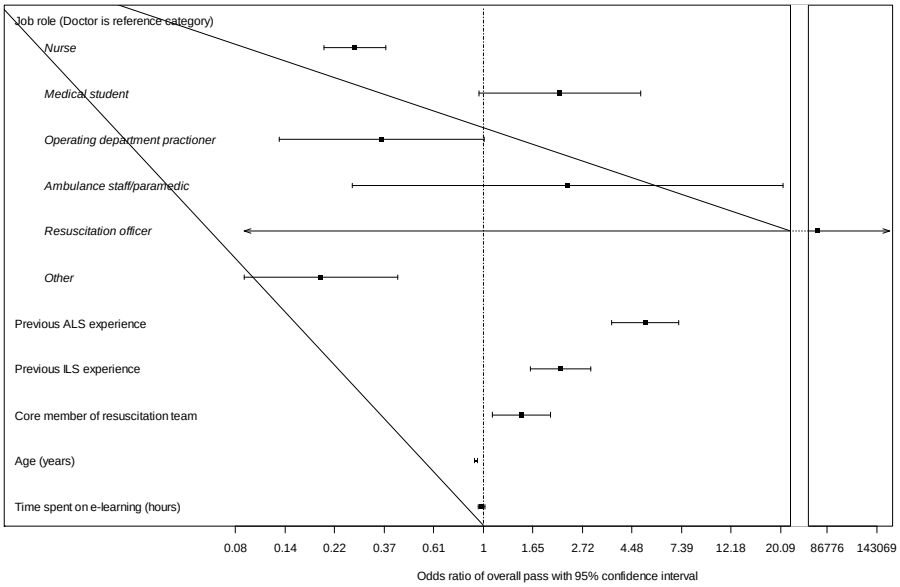


Figure 3: Multivariate analysis demonstrating factors that influence overall course outcome



Time spent accessing e-learning

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Median time spent on the e-learning was 5.2 hours (IQR 3.7-7.1)~~ and the median number of modules completed was 11 (only 11/12 modules had access data recorded).~~. Resuscitation officers spent the longest time on the e-learning package (median 7.5 hours, IQR 5.7-9.2). Doctors spent the least amount of time accessing the content (median 4.9 hours, IQR 3.4-6.7). In general, those doctors with more clinical experience spent less time accessing the e-learning material. This is demonstrated below in ~~figure~~ table 3 where middle grade doctors spend the least time on every module. In the univariate analysis, increased hours spent accessing e-learning was a statistically significant predictor of failing the post-course MCQ (B=-0.24, 95% CI [-0.30]-[-0.19], P<0.001), the CAS-Test assessment (OR 0.93, 95% CI 0.91-0.94, P<0.001) and the overall course (OR 0.90, 95% CI 0.87-0.93, P<0.001). When all other co-variates were controlled for in the multivariate regression, time spent accessing e-learning remained a significant predictor of CAS-Test failure (OR 0.96, 95% CI 0.95-0.98, P<0.001) but was not a significant predictor of overall course failure (OR 0.98~~9~~, 95% CI 0.95~~6~~-1.02, P=0.367~~435~~).

Table 3: Duration spent on individual ALS modules stratified by grade, profession and specialty background

	ALS in perspective	ALS algorithm	Causes and Prevention of Cardiac Arrest	Acute Coronary Syndromes	Post Resuscitation Care	Monitoring, Rhythm Recognition and 12-lead	Tachycardia, Cardioversion and Drugs	Bradycardia, Pacing and Drugs	Special Circumstances	Decisions Relating to Resuscitation	Arterial Blood Gas Analysis
Grade/healthcare profession											
Foundation year doctor	9.2	44.0	17.0	27.1	22.5	34.3	32.3	15.7	25.1	8.0	14.5
Junior grade doctor (ST1/ST2)	9.8	45.3	17.7	26.6	22.7	32.5	30.4	14.6	24.6	8.9	15.3
Middle grade doctor	9.5	43.8	17.0	26.4	21.8	30.7	27.8	13.6	22.8	8.0	12.4
Senior grade doctor	10.1	48.0	17.8	25.8	21.4	33.5	31.6	14.2	26.1	9.0	15.4
Junior nurse	11.0	51.0	21.4	31.1	24.9	53.5	39.6	19.9	32.7	10.3	25.1
Senior nurse	10.6	50.1	19.7	29.9	24.8	46.9	38.2	17.6	31.0	9.7	22.4
Paramedic	10.5	42.9	19.4	29.7	25.2	42.4	36.4	17.6	28.9	10.2	19.8
Operating department practitioner	10.6	49.5	22.6	29.5	24.8	57.8	43.8	20.3	33.0	12.1	28.6
Resuscitation officer	13.3	41.7	20.0	40.0	25.9	83.8	42.2	25.6	41.4	11.4	29.9
Medical student	9.3	45.0	17.8	28.1	24.1	38.5	35.8	16.5	28.7	9.3	15.6
Specialty background											
Anaesthetics	9.7	45.5	17.9	27.5	23.0	36.2	32.9	16.0	26.1	8.6	16.0
Cardiology	10.0	44.6	17.9	25.7	21.7	33.1	33.9	15.4	31.8	9.0	19.1
Surgery	9.3	45.0	17.9	28.0	23.0	35.9	33.7	15.5	25.5	8.1	15.5
Medicine	9.3	44.2	17.2	26.5	22.4	33.0	30.9	14.8	25.3	8.1	14.3
Emergency	10.0	45.2	18.2	27.6	23.4	38.3	32.6	16.4	25.6	9.1	18.3
Critical Care	11.1	52.1	20.8	30.7	23.8	46.1	38.2	18.9	32.0	9.8	18.5

~~Figure~~ Table 3~~4~~ demonstrates the homogeneity between time~~s~~ spent on individual e-learning modules when stratified by special~~i~~ty. Those from a critical care background spent slightly more time on modules compared to others, but this is likely due to the high proportion of nurses participating in the e-ALS course from this specialty (357/487, 73.3%).

DISCUSSION

This study has shown that previous experience in life support courses and being a core member of the resuscitation team predicts a favourable outcome on an e-ALS course. It also identifies the extent to which different candidate groups access the e-learning material and highlights particular modules that may be more challenging. Time spent accessing e-learning material was not related to course outcome;~~, largely~~this was thought to be because ~~candidates~~participants who utilise these skills on a daily basis are already familiar with the material and thus require less time to re-familiarise themselves.

There are increasing pressures to minimise time spent on courses for both participants and faculty and to improve outcomes. It has been postulated that pre-course preparation could lead to either better outcomes or a reduced amount of face-to-face time needed on the course. This could in theory lead to equivalent or better participant outcomes with less resources (time off work for faculty/participants, venue hire etc.). There is very little evidence relating specifically to pre-learning for advanced life support courses, so this study goes some way towards filling that void.

Perkins et al.[11] looked at one example of pre-course preparation. This open label, multicentre randomised controlled trial was a study of 572 participants on Resuscitation Council (UK) ALS courses. The control group received the course manual four weeks before the course. The intervention group received the course manual and also a CD with an interactive e-learning simulation programme. Although there were no significant differences in the primary outcome (performance during a standard cardiac arrest simulation), user evaluations were favourable. The results however cannot necessarily be generalised to all other types of pre-course learning or pre-course learning for other populations/course groups.

A multi-centre randomised controlled trial demonstrated equivalence in outcome when comparing e-ALS and c-ALS learning methods and was significantly ~~cheaper~~ less costly to deliver.[8] The findings of this were corroborated by a

large observational study of 27,170 ~~candidates~~participants which demonstrated almost identical assessment outcomes for ~~candidates~~participants enrolled on either a c-ALS or e-ALS course.[9] These studies were a comparison of a standard life support course against specific pre-course e-learning associated with a shorter duration hybrid life support course.

The topic of pre-course learning was addressed during the 2015 ILCOR international consensus on science process. It was felt that a specific recommendation for or against pre-course preparation in ALS courses was too speculative due to the lack of evidence in the literature.[15] These findings were balanced with a statement highlighting the considerable ambiguity in the definition of "Pre-course learning" and the difficulty in comparing single interventions like a pre-course CD[11] with an intervention followed by a hybrid version of the face-to-face element.[8,9]

With regard to the findings from this study, we found some unexpected and interesting results. The most surprising result was that time spent accessing prerequisite e-learning material was actually associated with worse assessment and overall course outcome in the univariate regression. On further analysis however, this is explained by the fact that those with greater clinical experience spent less time accessing the e-learning but paradoxically performed better in the course assessments. This ~~intuitively underpins~~demonstrates the educational ~~position of~~notion that when learning can be based on previous experience; it will normally lead to improved outcomes. This is demonstrated in the multivariate regression where time spent on e-learning was no longer a significant predictor of overall course outcome. ~~Whilst the influence of both time and age on~~Increased age was associated with significantly poorer assessment outcomes. Whilst there is a paucity of evidence for the literature regarding the effect of age on ALS outcomes, this pattern has been found in BLS studies and has been attributed to skill decline over time[16,17] and psychological factors where younger participants are more motivated to learn.[18] It has been found that those working in a high risk area for area for cardiac arrest were more motivated to learn life support skills.[19] ~~assessment outcomes were statistically significant, this is largely due to the large sample size and is unlikely to be of any clinical significance.~~

~~Candidates~~Participants ~~presenting~~ with greater ~~clinical~~ experience in managing critically unwell patients (paramedics, middle grade doctors, ~~those with~~ previous ALS/ILS experience, ~~and those who are a~~ core member of the resuscitation team) performed substantially better in the CAS-Test and overall result. This should not come as a

surprise, but is a useful insight for course organisers when identifying ~~candidates~~participants at the start of a course who do not fall into these groups and may benefit from additional support.

The e-learning package allows ~~candidates~~participants to dictate their own level of access dependent upon their prior knowledge, experience and specialty background. They ~~are able to~~can access material ~~at a time that is~~at an appropriate time for~~to~~ them and ~~spend~~ dedicate a greater amount of time ~~on~~ to their weaker knowledge areas. ~~In essence, this is no different to providing candidates with a course manual where they may not read some chapters as the topics are familiar to them.~~ The need for this degree of flexibility is demonstrated by the vastly different durations spent accessing the online content. This ~~need~~ is exemplified in table 3~~figure 3~~ which highlights that certain candidate groups (~~in this instance~~ junior nurses and operating department practitioners) spent twice as long on the 'Monitoring, rhythm recognition and 12-lead ECG' module compared to middle grade doctors, perhaps because they do not routinely utilise such skills on a daily basis. The flexibility that the e-ALS course creates is just one reason amongst many why participant satisfaction is greater on e-learning courses than compared to traditional didactic courses.[20,21]

Limitations and Further Research

The main limitation of this exploratory study is its observational nature. This means that the authors are only able to suggest causality when determining whether independent variables influence assessment outcome. ~~Whilst a~~A specifically designed randomised controlled trial would ~~perhaps~~ be needed to~~definitively~~ establish a cause-effect relationship on assessment outcome~~, such a trial would not be pragmatic given that half of the candidates would have to sacrifice preparatory e-learning to facilitate such a trial.~~.

Time is not necessarily an accurate marker of whether ~~candidates~~participants have truly engaged with the material and as this study has shown, it is significantly confounded by clinical experience (ie if ~~candidates~~participants are already well versed in ECG interpretation they will spend less time on this module). Furthermore, different individuals possess a spectrum of learning abilities with some ~~candidates~~participants learning faster than others. A proportion of ~~candidates~~participants may have chosen to preferentially utilise the course manual as opposed to the e-learning package and others may leave the e-learning running whilst not at the computer, providing a falsely elevated time spent accessing the material. ~~The authors have circumvented this to some extent by presenting the~~

~~descriptive statistics using non-parametric methods to reduce the influence of outliers on the results. Nevertheless, t~~There remains a need for more specific markers for determining whether ~~candidates~~participants have truly engaged with the e-learning material.

A final limitation ~~to this study~~ is that it does not determine whether accessing e-learning actually affects patient outcome from cardiac arrest. Whilst this should be the overriding aim behind all resuscitation-related research, such studies are very difficult to achieve. The authors believe however, that by critically appraising course outcome data and continuously improving the delivery methods of resuscitation courses this will ultimately improve the care of the critically unwell patient.

Conclusion

~~Our study has demonstrated that clinical experience through core membership of cardiac arrest teams and previous ILS or ALS training were independent predictors of performance on the ALS course. The large variation in time spent accessing e-learning reflects the diverse nature of candidatesparticipants who participate on our e-ALS courses and the spectra of learning needs that they possess. It reinforces for course organisers that these modules should be optional rather than compulsory and identifies certain aspects of our course that candidatesparticipants designate more attention to and may need more support with.~~

Clinical experience through core membership of cardiac arrest teams and previous ILS or ALS training were independent predictors of performance on the e-ALS course whilst time spent accessing e-learning materials did not affect course outcomes. The large variation in time spent accessing e-learning reflects the diverse nature of participants on our e-ALS courses and the spectra of learning needs that they possess. This supports the blended approach to e-ALS which allows participants to tailor their e-learning experience to their specific needs.

CONFLICTS OF INTEREST

CJT is a Trainee Representative for the ALS Subcommittee for the Resuscitation Council (UK). ASL is Honorary Secretary of the Resuscitation Council (UK) and a member of the European Resuscitation Council ALS Course Committee. IB is an Educator for the Resuscitation Council (UK). SH is Director of Course Development and Training for the Resuscitation Council (UK). SB-A is Project and Development Manager for the Resuscitation Council (UK). GDP

is Chair of the ALS Subcommittee for the Resuscitation Council (UK) and member of the European Resuscitation Council ALS Course Committee.

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LEGENDS TO FIGURES

Table 1: Participant demographics on the e-ALS course and time spent on e-learning

~~Figure 1: Multivariate regression of independent variables that predict CAS-Test outcome~~

~~Figure 2: Multivariate regression of independent variables that predict overall course outcome~~

Figure 1~~3~~: Time spent on e-learning modules stratified by grade and profession

Figure 2~~4~~: Time spent on e-learning modules stratified by specialty

~~Supplementary material 1~~Table 2: Univariate predictors of assessment outcomes

~~Supplementary material 2~~Table 3: Multivariate predictors of assessment outcomes

~~Supplementary material 1: Univariate predictors of assessment outcomes~~

~~Independent variables~~	~~Mean pre-course MCQ score~~	~~Mean post-course MCQ score~~	~~P-value~~	~~CAS Test pass (%)~~	~~Odds ratio (95% CI)~~	~~P-value~~	~~Overall course pass (%)~~	~~Odds ratio (95% CI)~~	~~P-value~~
~~Healthcare profession~~									
~~Doctor~~	~~84.7~~	~~88.7~~	~~<0.001[6]~~	~~5352 (86.0)~~			~~6095 (97.8)~~		
~~Nurse~~	~~79.7~~	~~80.0~~		~~1005 (81.3)~~	~~0.71 (0.60-0.83)~~	~~<0.001~~	~~1122 (90.9)~~	~~0.22 (0.17-0.29)~~	~~<0.001~~
~~Medical student~~	~~83.4~~	~~86.5~~		~~425 (79.6)~~	~~0.64 (0.51-0.79)~~	~~<0.001~~	~~525 (98.3)~~	~~1.31 (0.66-2.59)~~	~~0.435~~
~~Operating Department Practitioner~~	~~73.0~~	~~79.2~~		~~51 (70.8)~~	~~0.40 (0.24-0.66)~~	~~<0.001~~	~~67 (93.1)~~	~~0.30 (0.12-0.76)~~	~~0.011~~
~~Ambulance staff/ Paramedic~~	~~81.4~~	~~85.4~~		~~37 (92.5)~~	~~2.00 (0.62-6.62)~~	~~0.247~~	~~39 (97.5)~~	~~0.88 (0.12-6.43)~~	~~0.897~~
~~Resuscitation Officer~~	~~86.6~~	~~90.5~~		~~13 (86.7)~~	~~1.06 (0.24-4.69)~~	~~0.941~~	~~15 (100.0)~~	~~3.6×10^{6}~~	~~<0.001~~
~~Other~~	~~79.9~~	~~83.6~~		~~46 (66.7)~~	~~0.33 (0.20-0.54)~~	~~<0.001~~	~~62 (84.9)~~	~~0.12 (0.06-0.24)~~	~~<0.001~~
~~Stage of training~~									

Medical Student	83.3	86.4	<0.001[£]	426 (79.5)	0.72 (0.56-0.92)	0.010	526 (98.0)	0.70 (0.34-1.44)	0.332
Foundation Year 1 Doctor	83.0	86.6		1394 (84.7)	1.03 (0.85-1.24)	0.754	1624 (98.4)	0.92 (0.52-1.60)	0.754
Foundation Year 2 Doctor	83.2	87.7		1401 (84.3)			1639 (98.6)		
Junior Grade Doctor (ST1/ST2)	85.2	89.1		667 (85.6)	1.11 (0.87-1.40)	0.406	768 (96.8)	0.45 (0.26-0.79)	0.006
Middle Grade Doctor[#]	87.0	91.1		1322 (90.4)	1.75 (1.40-2.17)	<0.001	1434 (97.9)	0.70 (0.41-1.20)	0.197
Senior Grade Doctor[$]	87.9	92.0		425 (87.3)	1.28 (0.95-1.72)	0.107	469 (96.1)	0.40 (0.22-0.76)	0.005
Junior Nurse (Band 4-6)	78.8	82.8		777 (78.3)	0.67 (0.55-0.82)	<0.001	886 (88.4)	0.12 (0.08-0.19)	<0.001
Senior Nurse (Band 7-9)	81.4	86.6		346 (87.8)	1.34 (0.97-1.87)	0.080	378 (95.5)	0.31 (0.17-0.57)	<0.001
Other	82.6	86.6		163 (74.1)	0.53 (0.38-0.74)	<0.001	202 (90.2)	0.14 (0.08-0.26)	<0.001
Previous life support course experience									
Previous ALS experience	85.5	89.7	<0.001[#]	3204 (89.3)	1.97 (1.73-2.24)	<0.001	3515 (98.0)	2.27 (1.73-2.98)	<0.001
No previous ALS experience	82.3	86.1		3727 (81.0)			4411 (95.6)		
Previous ILS experience	83.2	87.4	<0.001[#]	4666 (85.6)	1.24 (1.09-1.40)	0.001	5302 (97.2)	1.64 (1.29-2.09)	<0.001
No previous ILS experience	84.5	88.3		2265 (82.7)			2624 (95.5)		
Core member of resuscitation team	84.4	88.8	<0.001[#]	3305 (88.0)	1.67 (1.48-1.90)	<0.001	3668 (97.7)	1.91 (1.48-2.47)	<0.001
Not a core member of resuscitation team	83.0	86.6		3540 (81.4)			4173 (95.7)		
Age (years)			-0.33 ([-0.52]-[-0.11])*	0.003		0.98 (0.97-0.98)	<0.001		0.93 (0.93-0.94)	<0.001
Time spent on e-Learning (hours)			-0.24 ([-0.30]-[-0.19])*	<0.001		0.93 (0.91-0.94)	<0.001		0.90 (0.87-0.93)	<0.001

[#]Independent samples t-test
[£] One way ANOVA
**Linear regression to predict post course MCQ score (B value, with 95% confidence intervals)*
[#]ST3+, registrar equivalent
[$] Consultant or associate specialist

Supplementary material 1: Multivariate predictors of assessment outcomes

Independent variables	Mean post e-learning MCQ score	Mean post-course MCQ score	Mean difference (95% CI)	P-value	CAS-Test result		Odds ratio of CAS-Test Pass (95% CI)	P-value	Overall course result		Odds ratio of course Pass (95% CI)	P-value
					Pass (%)	Fail (%)			Pass (%)	Fail (%)		
Healthcare profession												
Doctor (comparison)	84.7	88.7			5352 (86.0)	871 (14.0)			6095 (97.8)	137 (2.2)		
Nurse	79.7	80.0	-4.35 ([-4.85]-[-3.85])	<0.001	1005 (81.3)	231 (18.7)	0.92 (0.76-1.10)	0.356	1122 (90.9)	113 (9.1)	0.27 (0.20-0.37)	<0.001
Medical student	83.4	86.5	-0.43 ([-1.31]-0.45)	0.334	425 (79.6)	109 (20.4)	0.87 (0.63-1.20)	0.390	525 (98.3)	9 (1.7)	2.16 (0.96-4.48)	0.063
Operating Department Practitioner	73.0	79.2	-9.41 ([-11.13]-[-7.69])	<0.001	51 (70.8)	21 (29.2)	0.44 (0.25-0.78)	0.005	67 (93.1)	5 (6.9)	0.36 (0.13-1.01)	0.052
Ambulance staff/ Paramedic	81.4	85.4	-2.42 ([-4.71-[0.12])	0.039	37 (92.5)	3 (7.5)	3.75 (1.10-12.85)	0.035	39 (97.5)	1 (2.5)	2.34 (0.27-20.54)	0.444
Resuscitation Officer	86.6	90.5	0.98 ([-3.18]-5.14)	0.644	13 (86.7)	2 (13.3)	0.79 (0.17-3.73)	0.769	15 (100.0)	0 (0)	78518 (0-infinity)	0.986
Other	79.9	83.6	-4.27 ([-6.00]-[-2.53])	<0.001	46 (66.7)	23 (32.4)	0.47 (0.27-0.81)	0.007	59 (84.3)	11 (15.7)	0.19 (0.09 - 0.42)	<0.001
Previous life support experience												
Previous ALS experience	85.5	89.7	3.83 (3.44 – 4.21)	<0.001	3204 (89.3)	383 (10.7)	2.61 (2.22-3.07)	<0.001	3515 (98.0)	72 (2.0)	5.13 (3.66-7.19)	<0.001
No previous ALS experience	82.3	86.1			3727 (81.0)	877 (19.0)			4411 (95.6)	205 (4.4)		
Previous ILS experience	83.2	87.4	-0.27 ([-0.66]-0.12)	0.172	4666 (85.6)	787 (14.4)	1.19 (1.02-1.39)	0.024	5302 (97.2)	153 (2.8)	2.18 (1.61-2.95)	<0.001
No previous ILS experience	84.5	88.3			2265 (82.7)	473 (17.3)			2624 (95.5)	124 (4.5)		
Core member of resuscitation team	84.4	88.8	1.28 (0.94-1.62)	<0.001	3305 (88.0)	451 (12.0)	1.39 (1.21-1.59)	<0.001	3668 (97.7)	87 (2.3)	1.47 (1.10-1.98)	0.009
Not a core member of resuscitation team	83.0	86.6			3540 (81.4)	809 (18.6)			4173 (95.7)	189 (4.3)		
Age (years)			-0.06 ([-	<0.001			0.96	<0.001			0.93	<0.001

		0.09]-[-0.04])			(0.95-0.97)			(0.92-0.94)	
Time spent on e-Learning (hours)		-0.05 ([-0.11]-0.00)	0.047		0.96 (0.95-0.98)	<0.001		0.98 (0.95-1.02)	0.367

[#] *ST3+, middle grade equivalent*
[$] *Consultant or associate specialist*

Figure 1

Figure 1: Multivariate analysis demonstrating factors that influence CAS-Test outcome

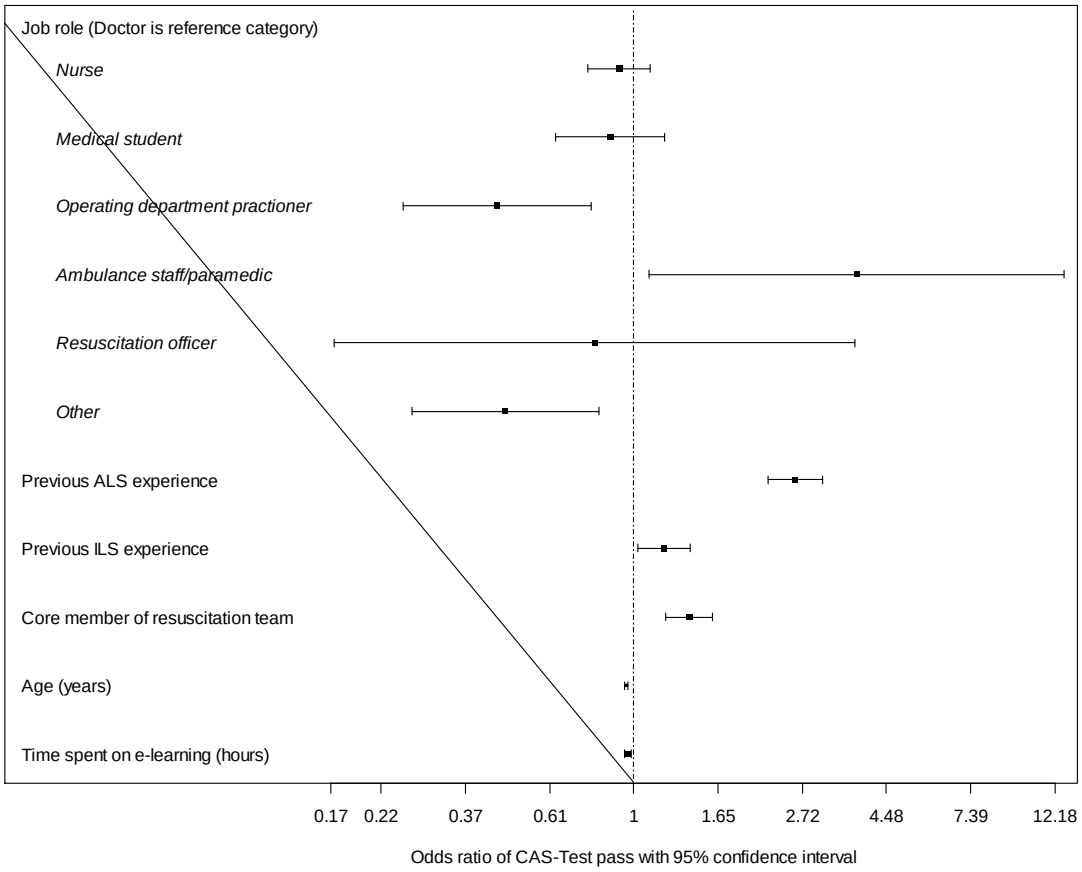


Figure 2

Figure 1: Multivariate analysis demonstrating factors that influence post-course MCQ score

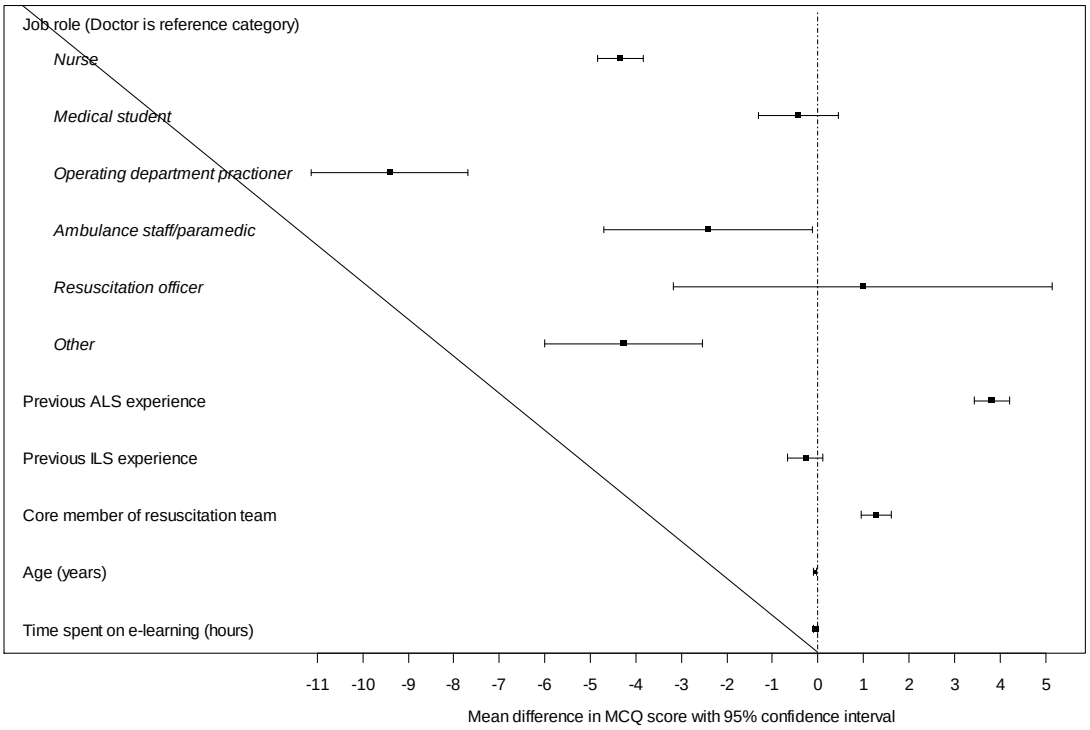
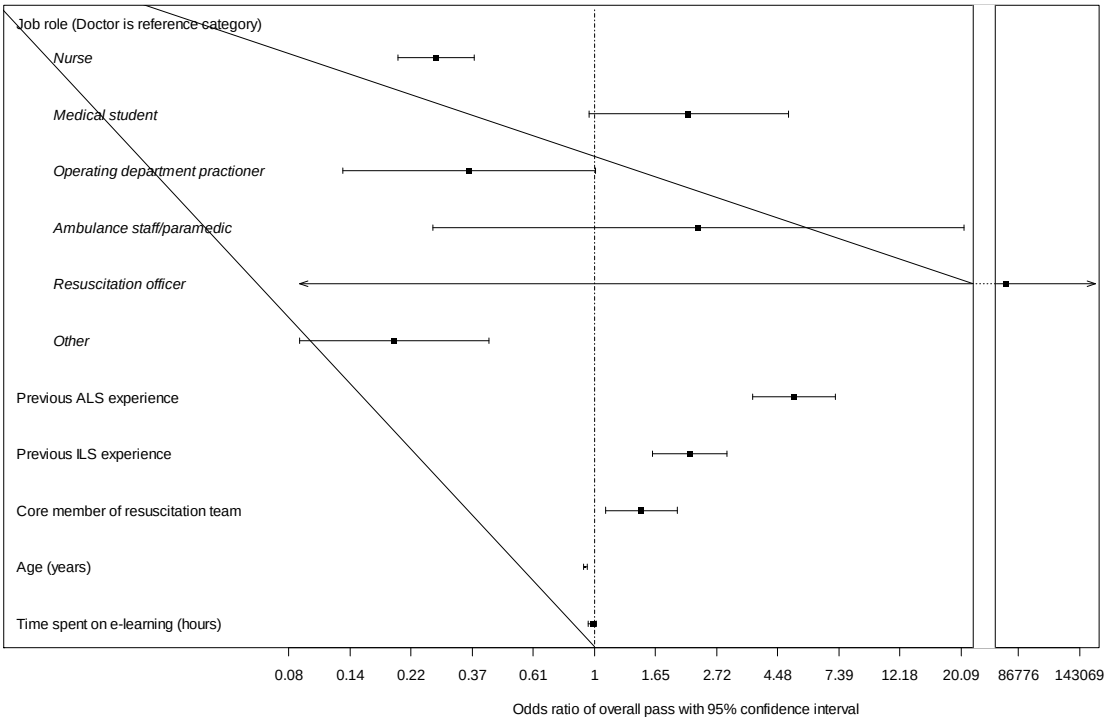


Figure 3

Figure 1: Multivariate analysis demonstrating factors that influence overall course outcome



*Conflict of Interest Statement

CONFLICTS OF INTEREST

CJT is a Trainee Representative for the ALS Subcommittee for the Resuscitation Council (UK). ASL is Honorary Secretary of the Resuscitation Council (UK) and a member of the European Resuscitation Council ALS Course Committee. IB is an Educator for the Resuscitation Council (UK). SH is Director of Course Development and Training for the Resuscitation Council (UK). SB-A is Project and Development Manager for the Resuscitation Council (UK). GDP is Chair of the ALS Subcommittee for the Resuscitation Council (UK) and member of the European Resuscitation Council ALS Course Committee.

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