EMJ Online First, published on July 31, 2012 as 10.1136/emermed-2012-201610

Rescuer fatigue under the 2010 ERC guidelines, and its effect on cardiopulmonary resuscitation (CPR) performance

Catherine H McDonald,[1] James Heggie,[1] Christopher M Jones,[1] Christopher J Thorne,[1] Jonathan Hulme[2]

▸ An additional figure is published online only. To view this file please visit the journal online (http://dx.doi.org/10.1136/emermed-2012-201610).

[1]School of Clinical & Experimental Medicine, The Medical School, University of Birmingham, Birmingham, UK
[2]Sandwell and West Birmingham Hospitals NHS Trust, Birmingham City Hospital, Birmingham, UK

Correspondence to
Dr Jonathan Hulme, Sandwell and West Birmingham Hospitals NHS Trust, Birmingham City Hospital, Birmingham, UK; jonhulme@doctors.org.uk

Accepted 3 July 2012

ABSTRACT

Background Updated life-support guidelines were published by the European Resuscitation Council (ERC) in 2010, increasing the required depth and rate of chest compression delivery. This study sought to determine the impact of these guidelines on rescuer fatigue and cardiopulmonary resuscitation (CPR) performance.

Methods 62 Health science students performed 5 min of conventional CPR in accordance with the 2010 ERC guidelines. A SkillReporter manikin was used to objectively assess temporal change in determinants of CPR quality. Participants subjectively reported their end-fatigue levels, using a visual analogue scale, and the point at which they believed fatigue was affecting CPR delivery.

Results 49 (79%) participants reported that fatigue affected their CPR performance, at an average of 167 s. End fatigue averaged 49.5/100 (range 0–95). The proportion of chest compressions delivered correctly decreased from 52% in min 1 to 39% in min 5, approaching significance ($p=0.071$). A significant decline in chest compressions reaching the recommended depth occurred between the first (53%) and fifth (38%) min ($p=0.012$). Almost half this decline (6%) was between the first and second minutes of CPR. Neither chest compression rate, nor rescue breath volume, were affected by rescuer fatigue.

Conclusion Fatigue affects chest compression delivery within the second minute of CPR under the 2010 ERC guidelines, and is poorly judged by rescuers. Rescuers should, therefore, be encouraged to interchange after 2 min of CPR delivery. Team leaders should be advised to not rely on rescuers to self-report fatigue, and should, instead, monitor for its effects.

INTRODUCTION

The incidence of sudden cardiac arrest (SCA) across Europe is significant, with the emergency services alone treating an estimated 38 SCAs per 100 000 person-years.[1 2] In addition, survival following SCA is low, impacting negatively on overall health outcomes.[3] However, cardiopulmonary resuscitation (CPR) following SCA is known to reduce mortality in all settings and leads to as great as a threefold increase in post-SCA discharge from hospital, potentially negating its significant healthcare burden.[4 5]

Nevertheless, outcome following SCAs in which life-support measures are initiated is reliant on the effectiveness of CPR provision.[6] This is dependent on a number of variables, the majority of which are themselves influenced by rescuer fatigue.[7]

Updated life-support guidelines issued by the European Resuscitation Council (ERC) in 2010 both increased the required depth of chest compressions (from 4–5 cm to >5 cm) and narrowed the accepted range for the rate of their delivery (100–120 compressions per minute (cpm), from 80 to 120 cpm).[8] This may increase physical exertion for rescuers and, as such, both their levels of felt fatigue and the effects of enacted fatigue may present earlier, or be of greater magnitude. Yet, the 2010 ERC recommendations maintain previous guidance that, if possible, rescuers should interchange every 2 min in order to limit the impact of fatigue.[8]

This study sought to determine the effects of the 2010 ERC life-support guideline changes on rescuers' fatigue, and to delineate a temporal relationship between fatigue (both felt and enacted) and CPR quality.

METHODS

Sixty-two health science students were recruited from the University of Birmingham, UK, over two consecutive academic years during 2010–2012, after successfully completing an ERC-accredited basic life-support (BLS) course. This sample size was based on previous research by Hightower *et al*, which identified an 18.6% decrease per minute in the percentage of correct chest compressions when rescuers carried out 5 min of CPR.[9] In order to detect a similar change, at an α error of 5% and a power of 80%, we estimated that a minimal sample size of at least 38 participants was required.

Participants were informed that the purpose of the study was to measure CPR quality. In order to minimise the confounding effects of skill decay, recruits completed the study immediately after their assessment. Exclusion criteria included students who had either failed to pass their BLS assessment at the first attempt, completed a resuscitation course within the previous 6 months, or who had an injury that prevented them from adequately performing CPR. No financial incentive was offered, and consent was sought from each of the participants. Ethical approval was not required for this study.

The innovative, peer-led course from which study participants were recruited has been extensively described previously, and is of high repute.[10 11] This programme, which utilises senior healthcare students trained as ERC BLS/AED instructors, follows a standardised 8 h syllabus. Given their lack of clinical experience, all candidates are taught and assessed as lay-rescuers in accordance with the latest ERC adult life-support guidelines. Participants for this study received training using the 2010 ERC adult life-support guidelines.[8] Instruction is delivered in small groups using the ERC-accredited 4-stage approach, and participants' efforts are corrected as required.[12] The ability of these prospective lay-rescuers to correctly perform BLS on a Resusci Anne Basic manikin (Laerdal Medical Limited, Norway) is observed at the end of their course under examination conditions by an assessor, at a 1:1 ratio.[11]

Comprehensive demographic data was collated for all study participants, and comprised of age (years), gender (male/female), ethnicity (self-reported), height (cm), weight (kg) and calculated body mass index (BMI; kg/m^2).

Each participant completed 5 min of conventional CPR on a SkillReporter manikin (Laerdal Medical Ltd, Norway) in accordance with the 2010 ERC guidelines.[8] Timing was initiated at the start of the first compression. Participants were asked to report verbally to the investigator at the time at which they believed fatigue was affecting the quality of their CPR delivery. Upon completion of 5 min of CPR, participants scored their final level of felt fatigue, using a visual analogue scale (VAS) from 0 to 100; 0 scored as 'no fatigue at all' and 100 as 'maximum possible fatigue'.

The quality of CPR delivered was recorded using a SkillReporter manikin with Laerdal PC Skillmeter VAM and Laerdal PC SkillReporter software. An in-house system was used to extract data concerning chest compression rate and depth, and rescue breath volume, over defined time periods.

Descriptive statistics were calculated for each minute of CPR, and overall temporal changes compared using the ANOVA statistical test. Statistical comparisons between the mean results for two individual minutes were calculated using the independent t test. P values of less than 0.05 were considered significant.

RESULTS

Sociodemographics

As indicated within table 1, sixty-two persons participated in this study; 41(66%) of whom were female. The mean age of the study participants was 19.6 years (SD=3.5). Forty-eight (77%) of the participants were Caucasian, 10 (16%) were Asian and four (7%) were of mixed race. The average height of participants was 171.5 cm (SD 9.0), weight 63.8 kg (SD 9.5) and calculated BMI 21.6 (SD 2.4).

Table 1 Summary of participants' baseline demographic data

	Variable			
	Age (years)	**Height (cm)**	**Weight (kg)**	**BMI (kg/m^2)**
Mean	19.6	171.5	63.8	21.6
SD	3.5	9.0	9.8	2.4

	Ethnicity		
	Caucasian	**Asian**	**Mixed**
Number	48	10	4
%	77.4	16.1	6.5

	Gender	
	Male	**Female**
Number	21	41
%	33.9	66.1

Subjective 'felt' fatigue

Of the 62 participants, 49 (79%) reported that fatigue affected the quality of CPR delivery, while 13 (21%) did not. For those reporting fatigue, the mean time at which they considered it to hinder the quality of their CPR delivery was 167 s. Felt fatigue following 5 min of CPR delivery averaged 49.5/100 (range 0–95) as reported using the VAS.

A greater proportion of females reported feeling fatigued (80.5%), compared with their male counterparts (76.2%). Females were also quicker to declare that fatigue was affecting the quality of their CPR delivery (mean reported fatigue at 151 s, compared with 203 s for males). Males also reported lower levels of end fatigue than females after 5 min of CPR, respectively, scoring average VAS scores of 40.8/100 (range 5–70) and 53.7/100 (range 0–95).

Objective- 'enacted' fatigue

Figure 1 and table 2 depict the temporal decline in the mean proportion of chest compressions correctly delivered. This fell from 52% in the first minute to 39% in the fifth minute, giving an overall decrease of 13%. This failed to reach statistical significance (p=0.071). Almost half of this overall decline (6%) was witnessed between the first and second minutes. Smaller decreases were seen between the second and third (3%), third and fourth (2%), and fourth and fifth minutes (2%). The mean proportion of compressions delivered correctly was marginally higher over the first minute (52.4%, SD=42.2) than it was for the first 30 s of CPR delivered (49.5%, SD=43.8).

Figure 2 demonstrates that the mean percentage of chest compressions reaching an adequate depth (>5 cm) also decreased over the 5 min period from 53% in the first minute to 38% in the fifth minute. Chest compression depth over the first minute was marginally superior to that of the first 30 s (50%), indicating no decline in depth during the first minute of CPR. Again, the majority of the decline occurred between the first and second minutes (7%), with more modest decreases between the second and third (4%), third and fourth (2%), and fourth and fifth minutes (2%). This demonstrated a strong positive correlation with the percentage of chest compressions correctly delivered (R=0.822, p<0.001). This association is portrayed graphically in supplementary figure 1. The decrease in the delivery of chest compressions to an adequate depth seen between each minute only approached significance (F=2.05, p=0.087). There was, however, a significant decrease between the first and fifth minutes of CPR (t=2.55, p=0.012).

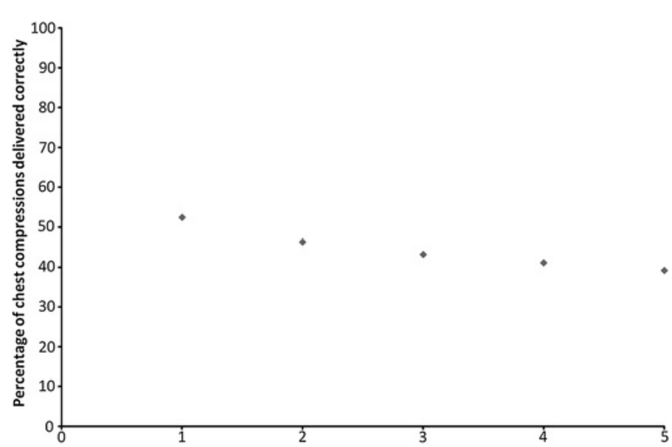

Figure 1 The effect of time on the proportion of chest compressions delivered correctly.

 McDonald CH, Heggie J, Jones CM, *et al*. *Emerg Med J* (2012). doi:10.1136/emermed-2012-201610

Table 2 Summary of participants' fatigue and CPR performance over time

Summary of rescuers' fatigue

Attribute	Male	Female	All
Did not report fatigue (%)	5 (23.8)	8 (19.5)	13 (21.0)
Average time until fatigue reported (s)	203	151	167
Average end-fatigue level (0—100)	40.8	53.7	49.5
Maximum reported end-fatigue level (0—100)	70	95	95
Minimum reported end-fatigue level (0—100)	5	0	0

Summary of rescuers' CPR performance

Time period	Total number of compressions	Correct compressions		Compressions achieving recommended depth			Rate (cpm)		Ventilated volume (ml)	
		%	SD	Mean	SD	%	Mean	SD	Mean	SD
0—30 S	38	49.5	49.5	19	16.8	50	117	11.7	690	332
Minute 1	76	52.4	42.2	40	32.5	53	113	17.6	534	224
Minute 2	74	46.3	44.0	34	32.1	46	116	13.7	517	235
Minute 3	73	43.2	44.3	31	31.7	42	118	17.4	555	238
Minute 4	72	41.1	43.5	29	30.6	40	118	23.2	541	244
Minute 5	73	39.2	42.5	28	30.7	38	117	19.1	519	243

Participants' mean chest compression rate remained relatively consistent throughout the 5 min CPR period. This is illustrated in figure 3. The first CPR cycle mean chest compression rate was 117 cpm (SD 11.7), which fell by 4 cpm to 113 cpm (SD 17.6) over the first minute as a whole. Compression rate subsequently fluctuated between 116 cpm (SD 13.7) in the second minute, 118 cpm in the third and fourth minutes (respective SD of 17.4 and 23.2), and 117 cpm (SD 19.1) over the fifth minute. Despite this, a greater number of chest compressions was delivered over the first minute of CPR delivery than over any subsequent time period; a mean of 76 (SD 8.4) compressions were delivered within the first minute of CPR, compared with 74 (SD 6.7) during the second, 73 (SD 8.3) during the third and fifth, and 72 (SD 9.7) during the fourth.

There were no significant changes in the volume of participants' ventilations during CPR delivery, although initial efforts during the first 30 s of CPR (690 ml, SD 332) were greater than for the first minute as a whole (534 ml, SD 224). Mean ventilated volume decreased over the second minute to 517 ml (SD 235), before again increasing to 555 ml (SD 238), 541 ml (SD 244) and 519 ml (SD 243) in the third, fourth and fifth minutes, respectively.

Given that chest compression depth was the only determinant of CPR quality to decline temporally, this parameter was compared with participants' subjective assessment of their end-level fatigue. Figure 4 indicates that there is no identifiable correlation between the overall decline in participants' chest compression depth and their assessment of their own fatigue. There is, however, a weak negative correlation between minute 5 depth and end-point fatigue (R=−0.225), although this did not reach significance (p=0.081). The linear regression model only accounts for 5.1% of the variability in the dependent variable (compression depth at 5 min).

DISCUSSION

There has been little previous assessment of the effect of the 2010 ERC guideline changes on participants' levels of fatigue and, correspondingly, CPR performance. Consequently, rescuers performing CPR have been advised to interchange once every 2 min, in line with previous guidelines, with minimal supporting evidence for this recommendation.[8]

This study demonstrates that the overall quality of rescuers' CPR performance decreases over time, falling most rapidly

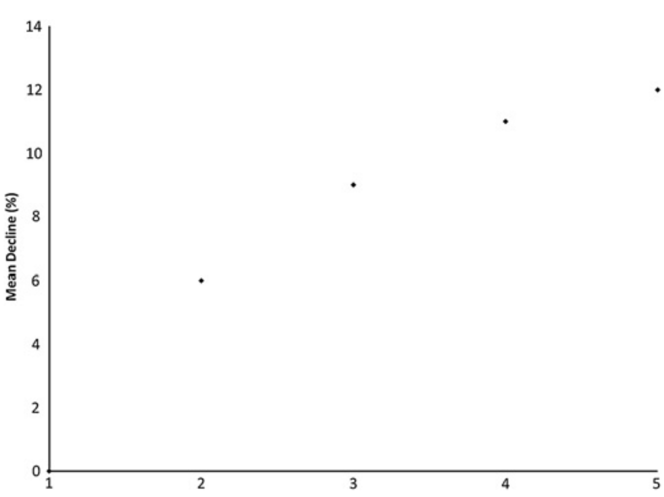

Figure 2 The average relative decline in the proportion of chest compressions delivered to an adequate depth (>5 cm) when compared with the first minute of delivery.

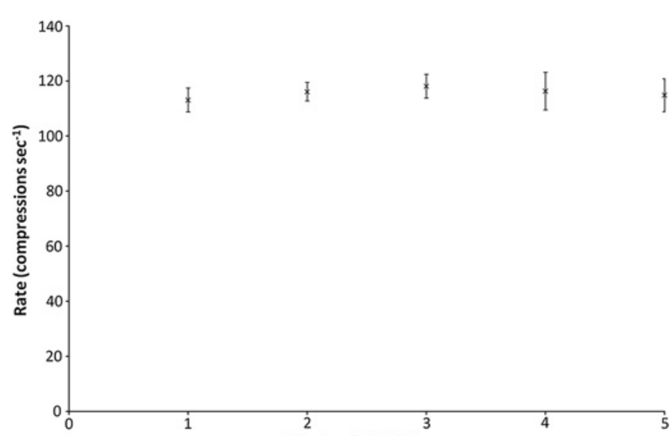

Figure 3 The effect of time on the average rate of chest compression delivery.

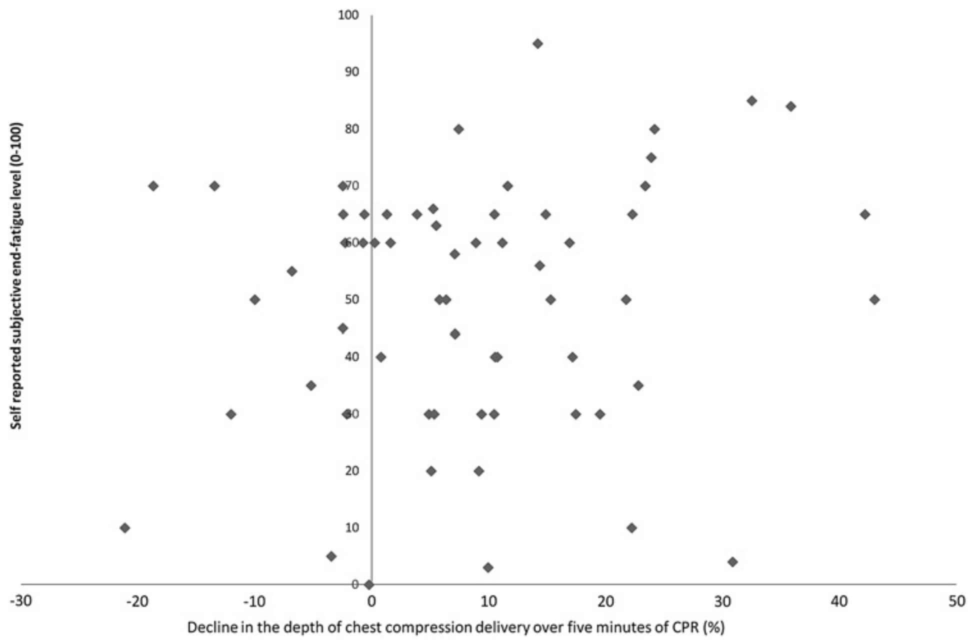

Figure 4 A representation of the correlation between participants' felt fatigue and the decline in the depth of their chest compression delivery over 5 min.

within the first two minutes of CPR delivery. Given that the overall quality of chest compression delivery during the first minute of CPR appeared to be very similar to that of the first CPR cycle, but was much greater than that of the second minute of CPR delivery (with decreases in both the average proportion of correct compressions and the average proportion of compressions to the correct depth narrowing thereafter), it can be inferred that decay is evident from a time point within the second minute of participants' performance.

This correlates well with the results of a number of previous studies, indicating that fatigue manifests under the 2010 guidelines at a similar time point to that of previous ERC guidelines.[7 9 13 14] It is, however, in contrast with a recent study conducted on a smaller cohort by Lyngeraa *et al*, which suggested that the quality of CPR was maintained throughout 2 min of CPR delivery by rescuers using the 2010 ERC guidelines.[15] The participants in this study were attending a resuscitation field-specific conference and, therefore, may have been better trained than the lay rescuers discussed within this article, perhaps explaining their better CPR performance.

There is a strong correlation between the proportion of rescuers achieving a sufficient chest compression depth, and the proportion of successfully delivered chest compressions (supplementary figure 1; table 2). It thus appears evident that changes in chest compression effectiveness closely mirror those in chest compression depth. It can, therefore, be inferred that fatigue hinders a rescuer's ability to deliver effective chest compressions by limiting his/her ability to reach the greater depth required by the 2010 ERC guidelines. This, in itself, is perhaps not surprising—the greater physical demand placed on rescuers attempting to reach a greater depth is likely to have reduced their ability to comply with this part of the recommendations—but the background to the decline offers a useful insight to the overall potential effectiveness of the 2010 guidelines.

While previous studies highlight that rescuers following pre-2010 guidelines suffered from as great as a 55% increase in compressions of insufficient depth between minutes 1 and 2, the increases in aberrant compressions described within this study are far more modest (we identified a comparatively minor 7% increase).[7 9 13 14] This must be seen in the context of the overall quality of rescuers' CPR delivery within our study. The average proportion of compressions delivered correctly peaked at 52%, which was significantly lower than the 70% limit for effective circulatory support suggested by the Royal College of General Practitioners,[16] and much below figures achieved by most other comparative studies.[7 13 14] This is with the exception of two studies by Vaillancourt *et al* and Heidenreich *et al*, in which elderly participants achieved a maximum of only 33 and 37 adequate cpm, respectively.[17 18] Had our study participants been assessed according to the 2005 ERC guidelines, as in previous studies, the corresponding percentage of correct chest compressions delivered would have been substantially greater. This raises important questions about the achievability of the 2010 guidelines and their subsequent clinical impact.

With this said, the modest decline in the proportion of compressions delivered correctly within our study ensured that the proportion of compressions delivered correctly had only fallen to 39% by the fifth minute. By comparison, previous studies demonstrated far worse end-CPR performance (rescuers in Ochoa's study achieved only 13% for correct compression delivery over the fifth minute of CPR, for instance).[7]

In common with studies that utilise pre-2010 guidelines, we noted no deterioration in the participants' rate of chest compressions, or mean ventilated volume, over the 5 min course of CPR. It is encouraging that as fatigue manifests over 5 min of CPR, participants remain able to adequately open an airway, and deliver a satisfactory-sized ventilatory effort. The fact that these CPR components are unaffected by rescuer fatigue, perhaps reflect the nature of the changes made by the 2010 ERC guidelines—while the range for rate of chest compression delivery was simply narrowed to the upper range of previous recommendations; the target depth was increased beyond previous guidelines. In prior studies, rescuers have always been able to reach a target rate with a top end of 120 cpm—in a manner that is unaffected by fatigue—but struggled to maintain even a depth of 4–5 cm. Now that this target is deeper, initial performance of chest compressions is even worse, but, perhaps because candidates know they must compress very deeply throughout (ie, that they approach CPR delivery with a more depth-focussed psyche), the overall deterioration in fatigue is more moderate.

We have demonstrated that failure to achieve an adequate depth of chest compressions is intrinsically linked to overall chest compression performance. A confounding factor is—as shown by this study—the inability of participants to measure the impact of their own fatigue. When overall decline in chest compression depth was compared with end-point fatigue, the resultant lack of correlation was striking. What rescuers considered to be their level of fatigue bore no resemblance to measurements of the effect of their fatigue on CPR performance. In fact, rescuers reported that fatigue affected their performance after an average of 167 s (ie, after approximately 2.5 min), with males reporting later than females. Yet, we know that chest compression depth deteriorated within the second minute of CPR delivery, highlighting that rescuers continued to deliver chest compressions for at least 1 min before realising that they had been overcome by fatigue.

This, to our knowledge, is the first study to conclusively correlate rescuers' inability to identify the impact of their own fatigue with their CPR performance. It should be noted, however, that Ochoa *et al* reported that rescuers noticed that fatigue was affecting their performance at an average time of 186 s, when using earlier life-support guidelines.[7] The greater physical demands imposed by the 2010 ERC guidelines do then appear to have hastened the point at which rescuers recognise fatigue.

Limitations

The participants used for this study represent a motivated, physically fit cohort who had recently completed their BLS training. Although it can be inferred from this that our results are not representative of the general population, the converse approach is to highlight that if our physically and mentally gifted cohort were affected by fatigue and unable to deliver effective chest compressions, the actual effects of fatigue may be far greater.

Additionally, we have not analysed data on a 'second-by-second' basis, and are, therefore, unable to provide a specific time point at which chest compression depth began to deteriorate. This is, however, a conscious effort on the part of the authors to reflect the variability of CPR performance across different cohorts, in that it is more useful to define a broad period of time (ie, the second minute) in which CPR performance worsens, rather than a very specific time point. Thus, by recommending that rescuers interchange after one minute, we are confident that the effects of fatigue on all rescuers will be limited.

Indeed, this study may also find association with a number of strengths. We have more than doubled the number of participants required to fulfil the required sample size, far exceeding the numbers of participants included in previous studies on the subject. Additionally, we have offered the very first comprehensive analysis of the effects of fatigue on rescuers performing CPR under the 2010 ERC guidelines.

CONCLUSIONS

This is the first study to fully analyse the effect of fatigue on rescuers performing CPR using the 2010 ERC guidelines. We have shown that CPR performance declines most rapidly during the second minute of CPR delivery, due, most pertinently, to rescuers' decreased ability to deliver chest compressions to a sufficient depth.

In order to minimise interruptions while maintaining adequate performance, we propose that rescuers utilising the 2010 ERC life-support guidelines should interchange after 2 min of CPR delivery, in line with current guidance. In addition, given the inability to recognise fatigue until an average of 90 s after it has affected CPR performance, we recommend that resuscitation team leaders are advised to remind rescuers of the need to interchange.

Acknowledgements The authors are grateful to all students who kindly volunteered to take part in this study.

Contributors CHM, CMJ, CJT and JHu jointly conceived and designed the study. CHM, JHe, CMJ and CJT collected data, which was collated and analysed by CHM, JHe and CMJ. All authors contributed to data interpretation. CHM, JHe and CMJ drafted the manuscript. All authors read and critically appraised the manuscript, and all made significant contributions to revisions. All authors have read and approved the final manuscript.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. **Cummins RO,** Eisenberg MS, Hallstrom AP, *et al*. Survival of out-of-hospital cardiac arrest with early initiation of cardiopulmonary resuscitation. *Am J Emerg Med* 1985;**3**:114—19.
2. **Priori SG,** Alliot E, Blomstrom-Lundqvist C, *et al*. Task force on sudden cardiac death of the European Society of Cardiology. *Eur Heart J* 2001;**22**:1374—450.
3. **Leal J,** Luengo-Fernandez R, Gray A, *et al*. Economic burden of cardiovascular diseases in the enlarged European Union. *Eur Heart J* 2006;**27**:1610—19.
4. **Sasson C,** Roger DM, Dahl J, *et al*. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. *Circ Cardiovasc Qual Outcomes* 2010;**3**:63—81.
5. **Herlitz J,** Ekstrom L, Wennerblom B. Effect of bystander initiated cardiopulmonary resuscitation on ventricular fibrillation and survival after witnessed cardiac arrest outside hospital. *Br Heart J* 1994;**72**:408—12.
6. **Gallagher EJ,** Lombard G, Gennis P. Effectiveness of bystander cardiopulmonary resuscitation and survival following out of hospital cardiac arrest. *JAMA* 1995;**274**:1922—5.
7. **Ochoa FJ,** Ramalle-Gómara E, Lisa V, *et al*. The effect of rescuer fatigue on the quality of chest compressions. *Resuscitation* 1998;**37**:149—52.
8. **Koster RW,** Baubin MA, Bossaert LL, *et al*. European Resuscitation Council Guidelines for Resuscitation 2010. Section 2: adult basic life support and the use of automated external defibrillators. *Resuscitation* 2010;**81**:1277—92.
9. **Hightower D,** Thomas SH, Stone CK, *et al*. Decay in quality of closed-chest compressions over time. *Ann Emerg Med* 1995;**27**:300—3.
10. **Perkins GD,** Hulme J, Bion JF. Peer-led resuscitation training for healthcare students: a randomised controlled study. *Intens Care Med* 2002;**28**:698—700.
11. **Bucknall V,** Sobic EM, Wood HL, *et al*. Peer assessment of resuscitation skills. *Resuscitation* 2007;**77**:211—15.
12. **Peyton J.** *The Learning Cycle*. Rickmansworth, UK: Manticore Europe Limited, 1998.
13. **Lyngeraa TS,** Hjortrup PB, Wulff NB, *et al*. Effect of feedback on delaying deterioration in quality of compressions during 2 minutes of continuous chest compressions: a randomised manikin study investigating performance with and without feedback. *SJTREM* 2012;**20**:16.
14. **Sugermana NT,** Herzberga D, Learya M, *et al*. Rescuer fatigue during actual in-hospital cardiopulmonary resuscitation with audiovisual feedback: a prospective multicenter study. *Resuscitation* 2009;**80**:981—4.
15. **Ashton A,** McCluskey A, Gwinnutt CL, *et al*. Effect of rescuer fatigue on performance of continuous external chest compressions over 3 minutes. *Resuscitation* 2002;**55**:151—5.
16. **Colquhoun M,** Simons RS. Training manikins. In: Colquhoun M, Handley AJ, Evans TR, eds. *ABC of Resuscitation*. London: BMJ Publishing Group, 1995:63—8.
17. **Vaillancourt C,** Midzic I, Taljaard M, *et al*. Performer fatigue and CPR quality comparing 30:2 to 15:2 compression to ventilation ratios in older bystanders; A randomized crossover trial. *Resuscitation* 2011;**82**:51—6.
18. **Heidenreich JW,** Bonner A, Sanders AB. Rescuer fatigue in the elderly: standard vs hands-only CPR. *J Emerg Med* 2012;**42**:88—92.

Rescuer fatigue under the 2010 ERC guidelines, and its effect on cardiopulmonary resuscitation (CPR) performance

Catherine H McDonald, James Heggie, Christopher M Jones, et al.

Emerg Med J published online July 31, 2012
doi: 10.1136/emermed-2012-201610

Notes