

## EVIDENCE-BASED RESEARCH

### Rescuer Fatigue in Cardiopulmonary Resuscitation: A Review of the Literature

**Hendrik Gutwirth** BAppSc (Exercise and Sport Science), BAppSc (Sport Science -Tennis), MAppSc (Strength and Conditioning), Accredited Exercise Physiologist (AEP)

**Brett Williams** BAVEd, Grad Cert ICP, Grad Dip EmergHlth, MHLthSc, PhD (Candidate)

**Malcolm Boyle** ADipBus (GenAdmin), BInfoTech, MCLinEpi, PhD

Monash University Department of Community Emergency Health and Paramedic Practice,  
Melbourne, Australia

## ABSTRACT

### Introduction

Provision of adequate chest compressions remains a standard of care for optimal outcome in cardiopulmonary arrest. Given the recent changes to CPR rates and a greater emphasis on pushing faster and deeper, this has raised questions surrounding rescuer fatigue and efficacy of compressions. While a body of work has been undertaken on previous CPR rates and associated fatigue levels, there is a shortage of literature on the latest CPR rates and associated rescuer fatigue in the hospital and prehospital settings. The objective of this paper was to determine the extent of fatigue associated with CPR in both the hospital and prehospital settings.

### Design

A review of the literature using a variety of medical databases, including Cochrane Database of Systemic Reviews, Ovid MEDLINE, EMBASE, and CINAHL electronic databases. The following MeSH terms were used in the search: CPR fatigue, chest compression, compression depth, out of hospital, in-hospital, prehospital, emergency medical services.

### Results

21 articles met the inclusion criteria, with three of these papers being from the prehospital setting. Currently, there is low level evidence determining the most appropriate length of time in providing quality chest compression before rescuer fatigue occurs. Overall chest compressions were shallower at least half of the time due to fatigue, and the mean compression rate was found to be higher than recommended.

### Conclusions

The findings of this study suggest that the quality of chest compressions deteriorates soon after commencing CPR, and that high quality prehospital studies are lacking.

---

### Introduction

CPR provides minimal organ blood flow (e.g. to the brain and heart) to maintain life until other advanced procedures can be performed, such as defibrillation and advanced life support (ALS). CPR is critical if defibrillation is delayed after collapse and increases the likelihood of

survival.<sup>1</sup> CPR is the second link in the “chain of survival” that can buy time between the first link (Early Access to Emergency Care) and third link (Early Defibrillation).<sup>2</sup>

CPR is a life saving technique used by health professionals in the hospital and prehospital settings. Observational studies of health professionals performing CPR in hospital and prehospital have revealed inadequate depth of compressions<sup>3</sup>, excessive ventilations<sup>4</sup>, and excessive interruptions to external cardiac compressions.<sup>5</sup> Inadequate chest compressions may be due to rescuer fatigue which may result in insufficient blood flow, which is important given the recent changes to compression/ventilation ratios from 15:1/5:2 to 30:2.<sup>6</sup> However, there is a lack of evidence pertaining to any specific compression-ventilation ratio associated with improved outcome in patients with cardiac arrest.<sup>6</sup> The objective of this paper was to determine the extent of fatigue associated with CPR in both the hospital and prehospital settings.

## **Method**

### **Design**

This study is a review of the scientific literature covering CPR fatigue in a range of medical electronic databases.

### **Process**

The electronic databases were the Cochrane Database of Systematic Reviews, Ovid MEDLINE (1950-April 2009), EMBASE (1974-April 2009), CINAHL (1982- April 2009). The following MeSH terms and Keywords were used in the search:

*paramedic; ambulance; emergency medical services; compression depth; fatigue; exhaustion; CPR; out of hospital; in-hospital; chest compression; prehospital emergency care; rescuer fatigue.*

Articles were included if they contained information relating to CPR-related fatigue or exhaustion during resuscitation in either the prehospital or in hospital settings. There were no specific exclusion criteria. References of the included articles were also reviewed.

## **Results**

The search located 826 articles with 21 articles meeting the inclusion. The inclusion criteria included articles that used older CPR rates (15:1, 5:1) and current CPR rate (30:2). Three articles were from the prehospital setting. Overall chest compressions were shallower at least half of the time, and the mean compression rate was found to be higher than recommended (see Table 1).

## **Discussion**

There is a lack of prehospital literature describing the effect of fatigue of CPR performance, with minimal in hospital literature. It has been demonstrated by several investigators that physical fatigue in the rescuer occurs as soon as one minute after starting compressions on mannequins.<sup>8-11</sup> Furthermore, it was also reported that the rescuer is unaware that fatigue has reduced their performance of compression effectiveness.<sup>8-10</sup>

Olasveengen *et al* performed the first out-of hospital prospective study in 2008 involving a physician-manned ambulance staffed by two paramedics and an anesthesiologist in Norway. They investigated the quality of CPR before and during transport in out-of-hospital cardiac arrest. It was found that when manual CPR time without chest compressions increased so did the decline in the number of compressions per minute during transport. The authors suggested

that registered pauses in chest compressions observed in this study possibly included shallow inadequate compressions due to fatigue given the clear deterioration in CPR quality during transport.<sup>7</sup>

Although good chest compression depth is important in CPR so is chest wall recoil decompression. Aufderheide *et al* performed a 2 phase study with emergency medical services (EMS) investigating CPR quality. Phase I was observational study to evaluate the quality of chest wall recoil during CPR performed by EMS personnel on thirteen adult patients with an out-of-hospital cardiac arrest.<sup>4</sup> Phase II was a randomised trial performed on an electronic test mannequins. Thirty EMS providers (fourteen EMT-Basics, five EMT-Intermediates, and eleven EMT-Paramedics) were assessed over a 3 minute period of quality CPR using the Standard Hand Position, followed by 3 minutes of CPR using 3 alternative techniques (Two Finger Fulcrum, Five Finger Fulcrum and Hands-Off Technique).<sup>4</sup> This study is the first to report and observe incomplete chest wall recoil during CPR performed by EMS providers at the scene of out-of-hospital cardiac arrests. The authors found that rescuer fatigue was associated with incomplete wall decompression based on their visual observations in Phase I of the study. Aufderheide *et al* also reported slight fatigue with standard and alternative CPR techniques (Two Finger Fulcrum, Five Finger Fulcrum and Hands-Off Technique) in Phase II of their study further emphasising that closer examination of alternative CPR techniques from resuscitation bodies such as ILCOR should be considered.<sup>4</sup>

Physical activity obviously also plays a role in assisting the rescuer to perform adequate chest compressions over time during CPR. The study by Lucia *et al* evaluated the influence of physical fitness in the performance of CPR providers as well as their physiologic response in performing CPR on training mannequins. Two study groups were established with group 1 consisting of fourteen male professional CPR rescuers from a mobile intensive care unit and group 2 consisting of fourteen male health professionals (physicians, physical therapist, and exercise physiologist). All participants had to kneel beside the training mannequin and perform a rate of 80- 100 compressions/minute with a depth of 38 to 51 mm along with a 50% duty cycle. The authors made comparisons between group 1 (Professional rescuers experienced in CPR, but are physically inactive as well as sedentary) and group 2 (Health professionals not experienced in CPR, but physically active performing aerobic activity 3 to 5 times a week, consisting of 20-40 minutes duration).<sup>12</sup>

The authors observed that four of fourteen experienced rescuers from group 1 showed signs of physical fatigue which forced them to stop external cardiac compressions (ECC) before 18 minutes compared to group 2 the non experienced group that completed the full 30 minutes. The authors recommended that undertaking a light to moderate aerobic exercise program can have a positive impact on reducing rescuer fatigue whether experienced in CPR or not. These findings highlight an important dimension to resuscitation care. The study's findings might serve to pose further questions surrounding fitness accreditation for rescue personnel, and closer examination of medical and fitness requirements for new and ongoing personnel.

Greingor performed a prospective study using an electronic CPR mannequin to investigate the quality of cardiac massage comparing the compression-ventilation ratios of 5/1 and 15/2. One performed ventilations with a bag-valve-mask, the other performed chest compressions. Each participant provided chest compressions and ventilation for both ratios over a period of 5 minutes. Greingor assessed the quality of the compressions based on rate, correct location of hands and adequate compression depth during the 5 minutes of compressions. The authors found that the quality of CPR declined significantly after the first min with a ratio of 15/2 compared to a ratio of 5/1. The study suggested that a CPR ratio of 15/2 is more tiring than

5/1. Greingor's explanation for the decrease in quality is fatigue or the rescuer being under trained due to the increase number of chest compressions. While this study examined the previous CPR ratios, it nevertheless supports the need to examine the latest 30:2 CPR rates, not only because of its greater number of compressions, but also given the greater emphasis on pushing faster and deeper.<sup>11</sup>

Physical fatigue occurs as soon as one minute, with rescuers often unaware that fatigue has reduced their compression effectiveness. Riera *et al* investigated the physiological effects on rescuers performing 2 minutes of uninterrupted chest compressions. The authors measured the effects of fatigue using a visual analogical scale (VAS).<sup>13</sup> All participants (nurses and doctors) performed good chest compressions for 2 minutes recording a maximum mean heart rate ( $61 \pm 8\%$ ) and a mean value of  $3 \pm 2$  from the VAS.<sup>13</sup> This indicated that participants were able to physically tolerate 2 minutes of chest compression without fatigue. Contrasting studies by Ashton *et al*,<sup>8</sup> Hightower *et al*,<sup>9</sup> Ochoa *et al*<sup>10</sup> and Greingor<sup>11</sup> which showed some discrepancy with chest compressions deteriorating after the first minute and participants complaining of fatigue after 3-4 minutes.

Performing CPR on different sizes of mannequins can have different results relating to rescuer fatigue. Srikantan *et al* performed a clinical investigation on the effect of one-rescuer compression/ventilation ratios of 3:1, 5:1, 10:2, and 15:2 on CPR in infant, paediatric and adult mannequins. The study consisted of thirty five health care providers whom performed 5 minutes of one-rescuer CPR in random order on infant, paediatric and adult mannequins utilising the different compression-ventilation ratios. The number of effective compressions and ventilations delivered per minute by the participants were recorded by a trained instructor in basic life support. A subjective assessment of fatigue was performed by self-reporting and exertion (change in rescuer pulse rate compared to baseline). The authors found infant CPR caused less exertion and subjective fatigue compared to paediatric or adult CPR techniques.<sup>14</sup>

In a cross-over study design by Jantti *et al* forty four Intensive Care Unit (ICU) nurses participated in 44 simulated cardiac arrest scenarios of 10 minutes using a 30:2 chest compression-to-ventilation ratio, rotating every 2 minutes. Nurses were randomly assigned in pairs in two groups to perform CPR on their knees using a training mannequin on the floor or the bed without a backboard. The authors found 44% of chest compressions on the floor and 58% of chest compressions on the bed were within correct depth, however, the mean compression depth decreased over time on both surfaces indicating rescuer fatigue. These findings are particularly relevant given the unpredictable nature of prehospital care, and that CPR is often performed on a variety of surfaces in different settings.<sup>15</sup>

Ashton *et al* undertook a study to evaluate the effects of rescuer fatigue on performance of continuous external chest compressions.<sup>8</sup> Forty healthcare providers (twenty nurses and seventeen doctors) competent in basic life support (BLS) took part in the study. The participants performed two consecutive 3-minute periods of continuous compressions separated by a 30- second timed interval on a training mannequin using a 15/2 compression/ventilation ratio. The results indicated that performance of chest compressions over 3 minutes declined progressively as follows: first min: 82 min; second 68 min; third 52 min; fourth, 70 min; fifth 44min; sixth 27min. Seven subjects were unable to complete a second 3 minute interval due to exhaustion. This was observed in two other studies of rescuer fatigue using previous resuscitation guidelines. Hightower *et al* in a small study of eleven subjects found, adequate chest compressions deteriorated significantly from 93% to 39% after 3 minutes and only 18% were satisfactory after 5 minutes.<sup>9</sup> Similarly, a decrease in performance was observed in another study by Ochoa *et al* after only 1 minute, however, time

to report fatigue was about 3 minutes.<sup>10</sup> The authors also found that profession, gender, weight and height did not influence the quality of compressions or the capacity to notice when fatigue affects the rescuer.<sup>10</sup> The authors also concluded that “leaders of CPR teams should ask for a change of rescuer after 1 min of chest compressions”.<sup>10</sup>

### **Conclusion**

There is clearly a lack of high quality evidence identifying when fatigue may occur, and which factors may exacerbate fatigue during resuscitation in prehospital care providers. Further research is also warranted to examine the clinical practice implications of CPR related fatigue among Australian prehospital providers.

## References

1. Part 4: Adult Basic Life Support. *Circulation*. 2005 December 13, 2005;112(24\_suppl):IV-19-34.
2. Handley AJ, Koster R, Monsieurs K, Perkins GD, Davies S, Bossaert L. European Resuscitation Council Guidelines for Resuscitation 2005: Section 2. Adult basic life support and use of automated external defibrillators. *Resuscitation*. 2005;67(Supplement 1):S7-S23.
3. Wik L, Kramer-Johansen J, Myklebust H, Sorebo H, Svensson L, Fellows B, et al. Quality of Cardiopulmonary Resuscitation During Out-of-Hospital Cardiac Arrest. *JAMA*. 2005 January 19, 2005;293(3):299-304.
4. Aufderheide TP, Pirralo RG, Yannopoulos D, Klein JP, von Briesen C, Sparks CW, et al. Incomplete chest wall decompression: a clinical evaluation of CPR performance by EMS personnel and assessment of alternative manual chest compression-decompression techniques. *Resuscitation*. 2005 Mar;64(3):353-62.
5. Abella BS, Alvarado JP, Myklebust H, Edelson DP, Barry A, O'Hearn N, et al. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. *JAMA*. 2005 Jan 19;293(3):305-10.
6. Part 2: Adult basic life support. *Resuscitation*. 2005;67(2-3):187-201.
7. Olasveengen TM, Wik L, Steen PA. Quality of cardiopulmonary resuscitation before and during transport in out-of-hospital cardiac arrest. *Resuscitation*. 2008;76(2):185-90.
8. Ashton A, McCluskey A, Gwinnutt CL, Keenan AM. Effect of rescuer fatigue on performance of continuous external chest compressions over 3 min. *Resuscitation*. 2002 Nov;55(2):151-5.
9. Hightower D, Thomas SH, Stone CK, Dunn K, March JA. Decay in quality of closed-chest compressions over time. *Ann Emerg Med*. 1995 Sep;26(3):300-3.
10. Ochoa FJ, Ramalle-Gomara E, Lisa V, Saralegui I. The effect of rescuer fatigue on the quality of chest compressions. *Resuscitation*. 1998 Jun;37(3):149-52.
11. Greingor JL. Quality of cardiac massage with ratio compression-ventilation 5/1 and 15/2. *Resuscitation*. 2002 Dec;55(3):263-7.
12. Lucia A, de las Heras JF, Perez M, Elvira JC, Carvajal A, Alvarez AJ, et al. The importance of physical fitness in the performance of adequate cardiopulmonary resuscitation. *Chest*. 1999 Jan;115(1):158-64.
13. Riera SQ, Gonzalez BS, Alvarez JT, Fernandez Mdel M, Saura JM, Riera SQ, et al. The physiological effect on rescuers of doing 2min of uninterrupted chest compressions. *Resuscitation*. 2007 Jul;74(1):108-12.
14. Srikantan SK, Berg RA, Cox T, Tice L, Nadkarni VM, Srikantan SK, et al. Effect of one-rescuer compression/ventilation ratios on cardiopulmonary resuscitation in infant, paediatric, and adult manikins. *Paediatric Critical Care Medicine*. 2005 May;6(3):293-7.
15. Jantti H, Silfvast T, Turpeinen A, Kiviniemi V, Uusaro A. Influence of chest compression rate guidance on the quality of cardiopulmonary resuscitation performed on manikins. *Resuscitation*. 2009 Apr;80(4):453-7.

**Table 1:** Located prehospital literature

<b>Authors, Date and Country</b>	<b>Participated Subjects</b>	<b>Method</b>	<b>Findings</b>	<b>Location</b>
Wik, L., et al., 2005 Norway(3)	176 adult patients with out-of-hospital cardiac arrest	Case Series	Chest compressions were not delivered half the time and most compressions were too shallow	Out-of-Hospital
Aufderheide, T.P., et al., 2005 United States(4)	13 adult patients with out-of-hospital cardiac arrest	Phase I: Observational Study Phase II: Randomised Trial	Inadequate chest compression depth was poor more than half the time and chest wall recoil was incomplete during CPR	Out-of-Hospital
Olasveengen, T., et al., 2008 Norway(7)	787 adult patients with out-of-hospital cardiac arrest	Clinical/Observational study	Manual CPR time without chest compressions increased so did the decline in the number of compressions per minute during transport	Out-of-Hospital
Riera SQ., et al., 2007 Spain	23 healthy volunteers, nurses, doctors of intensive care unit. All trained in CPR	Observational Study	The practice of uninterrupted chest compression was well tolerated during 2 min of CPR by health professionals	In-Hospital
Greingor JL., 2002 France	21 participants of the Emergency and Resuscitation Mobile Unit. All trained in CPR	Prospective Study	The quality of CPR declined significantly after the first min with a ratio of 15/2 compared to a ratio of 5/1. CPR ratio of 15/2 is more tiring than 5/1	In-Hospital
Jantti H., et al., 2009 Finland	44 intensive care unit nurses (experienced)	Randomised Control Study	44% of chest compressions on the floor and 58% of chest compressions on the bed were within correct depth. The mean compression depth decreased over time on both surfaces	In-Hospital
Lucia., et al., 1999 Spain	14 male, professional CPR rescuers from a mobile ICU and 14 male health professionals with no previous CPR experience.	Randomised Control Study	Undertaking a light to moderate aerobic exercise program can have a positive impact on reducing rescuer fatigue whether experienced in CPR or not	In-Hospital
Srikantan et al., 2005	35 healthcare providers	Observational Study	Infant CPR caused less exertion and subjective fatigue compared to paediatric or adult CPR techniques	In-Hospital
Ashton A., et al., 2002 UK	40 subjects competent in basic life support	Randomised Control Study	Number of satisfactory compressions decreased from 86 compressions in the first min to 27 compressions by the sixth minute. This progressive decrease in CPR may not be recognised by the rescuer	In-Hospital
Hightower D., et al., 1995	11 experienced nursing assistants	Randomised Control Study	Correct chest compressions decreased dramatically:	In-Hospital

United States	who regularly provide CPR in ED		92.9% during 1st Min 67.2% in 2nd Min 39.2% in 3rd Min 31.3% in 4th Min 18.0% in 5th Min	
Ochoa FJ., et al., 1998 Spain	38 people: 20 females, 15 staff physicians, 15 nurses and 8 residents	Randomised Control	Percentage of correct compressions: 79.7% in the 1st Min 24.9% in the 2nd Min 18% in the 3rd Min 17.7 in the 4th Min 18.5% in the 5th Min	In-Hospital
Heidenreich JW., et al., 2006 United States	53 medical students (first and second year). Out of 53 students, 46 had no experience in CPR	Prospective, Randomised Crossover Study	In the first 2 minutes, participants delivered significantly more adequate compressions per minute with CCC-CPR then STD-CPR. The difference diminished after 3 min	In-Hospital
Haque UI., et al., 2008 United States	80 Subjects. Certified in CPR.	Randomised Crossover Observational Study	Increased HR with 30:2 C:V ratio was noted during larger mannequin CPR without subjective difference of reported fatigue. Most rescuers in AD and TF group did not achieve recommended compression depth regardless of C:V ratio	In-Hospital
Deschilder K., 2007 Belgium	138 subjects: 56 lay participants (no CPR experience) and 82 professional participants (CPR experience)	Prospective, Randomised Crossover Design	30:2 ratio rated to be much more tiring compared to 15:2	In-Hospital
Chi CH., et al., 2008 Taiwan	18 healthcare providers: 9 emergency medical technician fire fighters and 9 nurses experienced in CPR	Randomised Control Study	Significant differences were observed in the head, shoulder, lower trunk, hip and knee angles between the three methods	In-Hospital
Elding C., et al., 1998 UK	40 nurses experienced in CPR.	Randomised crossover design	CPR-Plus adjunct compared with no adjunct or standard CPR resulted in a reduction in excessive application of pressure and incorrect hand position	In-Hospital
Perkins GD., et al., 2006 UK	40 medical students (2nd year)	Randomised Controlled Cross-Over Trial	No difference in compression depth, duty cycle and fatigue between standard CPR and CPR performed on a backboard	In-Hospital
Yannopoulos D., et al., 2006 United States	20 female pigs and 20 BLS certified rescuers	Prospective Randomised Animal and Mannequin Study	Data strongly supports that ratio of 30:2 in both human and animal is superior to 15:2 during manual CPR	In-Hospital
Bjorshol CA., et al., Norway	50 Paramedics	Randomised Control Study	Mean number of chest compression depth did not change significantly between 15:2, 30:2 and 50:2. Compression depth declined	In-Hospital



			in the first 2 min period for 30:2 and 50:2 as did compression rate for all three ratios	
Van Berkomp PFJ., et al., 2008 Netherlands	An air pressure driven piston device was used.	Observational Study	No additional force is needed to achieve a given depth of compression with or without the CPRezy device	In- Hospital
Boyle AJ., et al., 2002 Australia	32 Subjects with CPR experience	Randomised Control Study	CPR-Ezy can improve timing and effectiveness of ECC, and reduce the effects of resuscitator fatigue in community trained subjects	In- Hospital

**This Article was peer reviewed for the Journal of Emergency Primary Health Care Vol.7, Issue 4, 2009**