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## Simulation and education

# Dominant versus non-dominant hand during simulated infant CPR using the two-finger technique: a randomised study



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### Abstract

**Aims:** The aim of this randomised study was to compare the two-finger technique (TFT) performance using dominant hand (DH) and non-dominant hand (NH) during simulated infant CPR (iCPR).

**Methods:** 24 participants performed 3-min iCPR using TFT with DH or NH followed by 3-min iCPR with their other hand. Perceived fatigue was rated using visual analogue scale. Primary outcomes - (i) difference between DH and NH for compression depth (CCD), compression rate (CCR), residual leaning (RL) and duty cycle (DC); (ii) difference between first and last 30 s of iCPR performance with DH and NH. Secondary outcomes - (i) perception of fatigue between DH and NH; (ii) relationship between perception of fatigue and iCPR performance.

**Results:** No significant difference between DH and NH for any iCPR metric. CCR (DH:  $P = 0.02$ ; NH:  $P = 0.004$ ) and DC (DH:  $P = 0.04$ ; NH:  $P < 0.001$ ) were significantly different for the last 30 s for DH and NH. Perception of fatigue for NH ( $76.8 \pm 13.4$  mm) was significantly higher ( $t = -3.7$ ,  $P < 0.001$ ) compared to DH ( $62.8 \pm 12.5$  mm). No significant correlation between iCPR metrics and perception of fatigue for DH. However, a significant correlation was found for CCR ( $r = 0.43$ ;  $P = 0.04$ ) and RL ( $r = -0.48$ ;  $P = 0.02$ ) for NH.

**Conclusion:** No difference in performance of iCPR with DH versus NH was determined. However, perception of fatigue is higher in NH and was related to CCR and RL, with no effect on quality of performance. Based on our results, individuals performing iCPR can offer similar quality of infant chest compressions regardless of the hand used or the perception of fatigue, under the conditions explored in this study.

**Keywords:** Infant cardiopulmonary resuscitation, Two-finger technique, Dominant hand, Non-dominant hand, Manikin

## Introduction

Despite advances and growing evidence that survival to hospital discharge for out-of-hospital cardiac arrest (OHCA) in the paediatric population has increased over the years, it continues to be a major public health problem, with high rates of morbidity and mortality.<sup>1,2</sup>

Most paediatric cardiac arrest events occur in infants (44–64%),<sup>1,3,4</sup> which represent the lowest survival rates (1.4–3.7%) compared to children (3.6–9.8%) or adolescents (8.9–16.3%).<sup>1,2,4,5</sup>

Key elements of infant OHCA survival are multifactorial and include high quality infant cardiopulmonary resuscitation (iCPR) with effective ventilation and chest compression techniques. The components of iCPR include chest compression rate (CCR), chest

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compression depth (CCD), residual leaning (RL) and duty cycle (DC). Two standardised techniques have been described for infant chest compressions: the two-thumb encircling technique (TTT) for more than one rescuer or the two-finger technique (TFT) for the lone rescuer. TTT has been suggested to be of superior quality when compared to TFT even for a lone rescuer because of a reduced hand fatigue and deeper chest compression depth,<sup>6–8</sup> however, the current evidence has not resulted in changes to guidelines, which still advocate the TFT for lone rescuers when performing CPR on an infant in cardiac arrest.<sup>9–11</sup> Current resuscitation guidelines do not specify which hand to use (dominant, non-dominant or either), but performance aspects related to hand dominance must be considered.

It has been suggested that the quality of chest compressions using the TFT might be influenced by factors such as finger or hand strength and fatigue,<sup>12</sup> indicating that hand dominance may impact on the quality of iCPR using this technique as the mechanisms of force generation and maintenance may differ between dominant hand (DH) and non-dominant hand (NH), thereby affecting CCR, CCD, RL and DC.

Previous studies have investigated the quality of chest compressions based on hand dominance during CPR in the adult<sup>13–18</sup> or older child populations.<sup>19</sup> Others have explored the difference between the TTT and TFT for infant chest compressions,<sup>20–25</sup> or the use of different fingers with the TFT.<sup>12</sup> However, to date, no research has specifically compared DH and NH for iCPR performance using TFT. Therefore, in an attempt to fill a gap in the knowledge and to reproduce a single rescuer performing iCPR in an OHCA episode, evaluation of hand dominance using TFT is warranted.

The aim of this randomised study was to investigate chest compression performance of the DH and NH whilst delivering simulated iCPR using the TFT.

## Methods

### Study design and setting

This study utilised a prospective, experimental, randomised design and was conducted in a simulated setting at a university. Ethical approval was granted by the university board (reference ID: 27970) and written informed consent was obtained following a description of the study and its procedures. Data relating to age, weight, height, hand dominance, sex and self-declared physical issues, that could compromise performance, were collected via a questionnaire with the purpose of creating a demographic profile of the sample.

### Participants

A convenience sample of 24 participants was recruited from an event organised by Bournemouth University, open to students, staff and the general public. The sample size was based on a theoretical difference of 15% for compression depth between DH and NH and a standard deviation of 20%, with alpha of 0.05 and power set to 80%.

Exclusion criteria were a self-declared inability to perform iCPR for reasons such as physical limitation to complete the CPR task (e.g. unable to kneel).

### Study procedures

Potential participants were engaging in the “Restart a Heart Day”, an event to raise awareness to cardiac arrest and teach people how to

perform adult and paediatric CPR. On completion of the paediatric CPR session, interested people were invited to take part in the study. Experimental procedures were explained by the principal investigator and, after signing the consent form, volunteers were invited to perform 3-min iCPR on a modified manikin (description below) using the TFT with a compression:ventilation ratio of 30:2 (aligned with resuscitation guidelines for Basic Life Support rescuers, with no duty to respond to a paediatric cardiac arrest), using either DH or NH (trial 1). A 3-min timeframe was purposively selected in an attempt to instigate fatigue based on evidence suggesting that fatigue is induced within this timeframe,<sup>26–28</sup> particularly when TFT is used.<sup>7</sup>

After a 1-min rest, participants then completed 3-min iCPR with their other hand (trial 2). Each individual, therefore, acted as their own control. The order of the trials was randomised using a web-based computer programme.<sup>29</sup> No feedback on performance was provided. On completion of each trial, participants were asked to rate their level of perceived fatigue, using a visual analogue scale (VAS).

### Instrumented equipment

The equipment used to analyse iCPR performance included: (i) a baby manikin representing a 5 kg, three-month-old infant (Laerdal<sup>®</sup> ALS Baby, Laerdal Medical, Stavanger, Norway). This manikin was modified during a previous study to allow a maximum compression depth of 56 mm<sup>30</sup> and was instrumented with (ii) two accelerometers (one fixed on the manikin’s chest and the other on the board where the manikin was placed, acting as a differential, for the surface on which the CPR was conducted). Data were acquired by (iii) a data acquisition unit (LabView), connected to a (iv) personal computer (PC) and (v) a power supply.

Accelerometer data were generated through the LabView software platform. LabView computed acceleration and converted this into displacement, representing the displacement of the chest. Displacement data were then transferred to MATLAB 2014b (The MathWorks Inc, Natick, MA) and converted into the following metrics: average chest compression depth (maximum relative displacement between the two accelerometers), average chest compression rate (the number of compressions per minute), average residual leaning (determined through incomplete release from the chest wall measured in mm and converted to kg through the known stiffness of the manikin), and average duty cycle (the ratio of time taken for compression relative to release) via a bespoke algorithm. Validity of this acceleration data has been established previously<sup>31</sup> and details of the instrumented manikin have been published elsewhere.<sup>30</sup>

### Outcome measures

Primary outcomes were (i) the difference between DH and NH for chest compression depth, chest compression rate, residual leaning and duty cycle, and (ii) the difference between the first and last 30 s of iCPR performance with the DH and NH for chest compression depth, chest compression rate, residual leaning and duty cycle. Secondary outcomes were (i) perception of fatigue as measured via VAS between DH and NH and (ii) the relationship between perception of fatigue and performance.

### Statistical analysis

Descriptive statistics were used to explore the demographic data. Normality was determined via Skewness, Kurtosis and Shapiro-Wilk

**Table 1 – Mean (SD), Median [IQR] and P values for iCPR metrics – DH and NH.**

	DH	NH	P value
CCR (cpm)	118.9 (14.3)	117.3 (16.7)	0.57
CCD (mm)	42.6 (4.5)	43.5 (4.4)	0.19
RL (kg)	2.9 (1.2)	2.6 [0.7] <sup>a</sup>	0.42
DC (%)	39.3 (9.2)	39.3 (9.5)	0.99

CCR; chest compression rate, CCD; chest compression depth, RL; Residual Leaning, DC; Duty Cycle, cpm; compressions per minute, DH; dominant hand, NH; non-dominant hand.

<sup>a</sup> Wilcoxon test for non-parametric.

tests. Mean and standard deviation (SD) were used to report the data with a normal distribution; *median and interquartile range [IQR]*, when the assumption of normality was not met.

A two-sided paired *t*-test was used for normally distributed data and Wilcoxon signed-rank test for non-parametric data for each metric (CCD, CCR, RL, DC and perception of fatigue) and for the change in chest compression performance over time (first 30 s and last 30 s). Correlation between iCPR metrics and perceived fatigue was analysed using Pearson Correlation and the non-parametric alternative Spearman's Rho test was used as appropriate.

Statistical calculations were performed using SPSS software (SPSS 25, IBM Corp., Armonk, NY, USA) and Microsoft Office Excel 2016 (Microsoft Corporation). All P values were two-tailed, and significance was established at  $P < 0.05$ .

## Results

### Participant demographics

A total of 24 people participated in this study, 14 females (58%) and 10 males (42%). Data from one participant was incomplete due to equipment malfunction at the point of collection and was not included in the final analysis. The mean (SD) age was 31.6 (11.6) years, weight 80.2 (16) kg and height 171.2 (9.8) cm. Four participants were left-hand dominant.

### Difference between DH and NH for iCPR performance

Each iCPR metric for both DH and NH was normally distributed apart from RL with the NH. This metric failed the test for normality ( $P = 0.008$ ), due to a series of outliers and, after being manually screened to determine whether the numbers were likely to be true

results, the Wilcoxon signed-rank test was performed for this particular variable.

The mean (SD), *median [IQR]* and *P* values for DH and NH are shown in Table 1, which explores the difference between DH and NH for each metric. CCR, CCD, RL and DC were not significantly different when performed with the DH compared to the NH.

### Difference between the first and last 30 s of chest compressions during iCPR performance

Each chest compression metric for both DH and NH were normally distributed for the first and last 30 s of iCPR performance apart from RL performed with the NH. This metric failed the test for normality for both the first and the last 30 s ( $P = 0.02$ ).

The mean (SD), *median [IQR]* and *P* values for the first and last 30 s of iCPR performance are displayed in Table 2, which explores the difference between DH and NH for each metric in the first and last 30 s of iCPR performance. CCR and DC were significantly different for the last 30 s compared to the first 30 s for both DH and NH. CCD and RL were not significantly different for DH and NH.

### Perception of fatigue between DH and NH

The results for perception of fatigue between DH and NH are demonstrated in Fig. 1. This metric was normally distributed for both DH and NH. The mean difference in the scores for perception of fatigue between the DH ( $62.8 \pm 12.5$  mm) was significantly lower ( $t = -3.7$ ,  $P < 0.001$ ) than the NH ( $76.8 \pm 13.4$  mm).

### Relationship between perception of fatigue and iCPR performance with DH and NH

There was no correlation between DH and perception of fatigue for any of the metrics. However, there was a significant correlation between perception of fatigue and CCR ( $r = 0.43$ ,  $P = 0.04$ ) and RL ( $r = -0.48$ ,  $P = 0.02$ ) for the NH (Table 3). The coefficient of determination demonstrated that for the NH, 19% of CCR and 23% of RL can be explained by perception of fatigue.

## Discussion

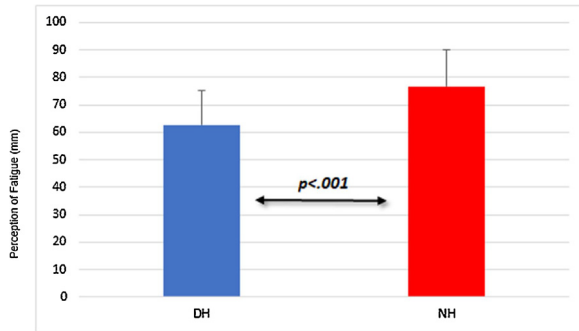
The results of this randomised study suggest that there is no significant difference between DH and NH in terms of the overall chest compression performance for the four measured variables for iCPR. Although differences have been demonstrated in older children and adults, our result is consistent with some of the existing data on hand

**Table 2 – Mean (SD), Median [IQR] and P values for first and last 30 s – DH and NH.**

	DH first 30 s	DH last 30 s	P value	NH first 30 s	NH last 30 s	P value
CCR (cpm)	112.1 (11.5)	107.1 (9.8)	0.02	110.8 (11.5)	106 (13.5)	0.004
CCD (mm)	43.1 (4.4)	42.6 (4.7)	0.25	44.3 (4.7)	43.8 (5.2)	0.59
RL (kg)	2.9 (1.1)	3 (1.3)	0.75	2.4 [1] <sup>a</sup>	2.7 [1] <sup>a</sup>	0.18
DC (%)	38.3 (9.7)	41.7 (10.6)	0.04	38.7 (9.6)	44.4 (9.4)	<0.001

CCR; chest compression rate, CCD; chest compression depth, RL; Residual Leaning, DC; Duty Cycle, cpm; compressions per minute, DH; dominant hand, NH; non-dominant hand.

<sup>a</sup> Wilcoxon test for non-parametric.



**Fig. 1 – Perception of fatigue between dominant and non-dominant hand.**

**Data representing the mean results and standard deviation for perception of fatigue after 3-min simulated infant CPR performance with the dominant hand and after 3-min simulated infant CPR performance with the non-dominant hand.**

dominance. Oh et al. (2014)<sup>32</sup> investigated if hand dominance correlates to the quality of one-handed chest compressions during paediatric CPR and concluded that the average values for the metrics measured (CCR and CCD) were not significantly different using the DH or NH. Similarly, Kim et al. (2015)<sup>19</sup> compared one-hand technique in paediatric CPR for CCR, CCD and peak compression pressure and found no significant differences. In the adult population, Nikandish et al. (2008)<sup>17</sup> investigated the quality of adult chest compressions in relation to the hand in contact with the sternum delivered by first year healthcare students and concluded that it was not significantly different. However, the results from our experiment and the studies cited above contrast with the findings from Kim et al. (2016),<sup>12</sup> who compared infant chest compressions using index-middle vs. middle-ring fingers for the right vs. the left hand and concluded that the most effective performance for the TFT was obtained using the index-middle fingers of the right hand. Despite hand dominance not being specified in their study, it demonstrated a significant difference between performance with the right and left hand. The explanation for this difference may lie in the metrics measured by Kim et al.<sup>12</sup> Their results are based on the comparison between right vs. left hand for mean compression depth and the percentage of “deep enough” compressions. It has been raised recently by Almeida et al.<sup>33</sup> that converting numbers related to CPR performance into percentage or quality indices produces greater variance in measured performance. This could have impacted the results of the afore-mentioned study, which used percentage as a metric of performance. Another

occurrence that deserves a remark is the intermanual transfer of learned skill. This phenomenon of skill transfer suggests that a motor task learned with one hand generates practice effects for the opposite, untrained hand.<sup>34</sup> This theory may have influenced the results of our study by potentially narrowing down the observed difference in performance between hands, particularly because of the short interval (1-min) between the DH and NH trials. However, such a short duration is likely to mirror that of the lone rescuer where the time delay between switching hands is minimal. It is not clear as to the effect of intermanual transfer with longer durations of pauses between hands during iCPR.

Another finding demonstrated by our present study was a significant difference in performance during the final 30 s of iCPR, compared with the first 30 s for CCR and DC. This suggests that there was inconsistent performance during the 3 min of CPR, which is comparable with the results from Nikandish et al. (2008)<sup>17</sup> and Jiang et al. (2015),<sup>7</sup> whose studies show a significant reduction in the percentage of correct compressions during ongoing resuscitation. One reason to explain this difference may lie in fatigue, as previous research has shown that CPR performance is affected by greater variability over time.<sup>7,21,27,28,35,36</sup> However, the correlation between perception of fatigue and performance in our study was modest at best for CCR and non-existent for DC. Therefore, the mechanism behind this difference in performance between the first and last 30 s of iCPR performance remains unclear. Despite the finding being significant, the mean values of those metrics remain within current iCPR guidelines, raising the question as to the clinical significance of this finding.

Whilst the iCPR performance in the present study was not different for the DH vs. the NH, the perception of fatigue, represented by VAS, was significantly higher for the NH when compared to the DH after 3 min of iCPR. This indicates that, although participants can perform similarly, regardless of hand used, the effort to maintain quality is greater for the NH. This finding may be explained by the relationship between iCPR and finger strength. It has been determined that performance of TFT may be influenced by the amount of finger strength, finger slave (unintentional force produced by fingers that are not used or required during performance—i.e. thumb, ring and little finger) and hand grip power.<sup>12</sup> Some studies have identified that the hand grip power and finger strength are greater in the right hand even if finger slaving is not significantly different,<sup>37–40</sup> indicating that hand dominance may impact on the perceived fatigue of iCPR using the TFT as the mechanisms of force generation and maintenance may differ between DH and NH.

## Limitations

Our study has some limitations. First, the participants were lay people, selected from a convenience sample, with little or no previous CPR

**Table 3 – Correlation Coefficients and P values for iCPR metrics and perception of fatigue.**

iCPR variables X perception of fatigue	DH Correlation	P value	NH Correlation	P value	R squared
CCR (cpm)	−0.16	0.47	0.43	0.04	0.185
CCD (mm)	0.05	0.82	0.36	0.09	
RL (kg)	−0.01	0.98	−0.48 <sup>a</sup>	0.02	0.229
DC (%)	−0.04	0.87	0.29	0.18	

iCPR; infant cardiopulmonary resuscitation, CCR; chest compression rate, CCD; chest compression depth, RL; Residual Loading, DC; Duty Cycle, cpm; compressions per minute, DH; dominant hand, NH; non-dominant hand.

<sup>a</sup> Spearman's rho test for non-parametric.

training, which does not necessarily represent a sample of general population, limiting the generalisability of the findings. Second, this was a manikin-based study conducted in a simulated environment, so direct transferability to real resuscitation may be limited. Third, our study examined a 3-min interval of infant chest compression, therefore the results cannot be applied to the situation where a single rescuer performs iCPR for a longer period where increased levels of fatigue could be expected. Fourth, the large number of bivariate comparisons were conducted, potentially raising the chance of type 1 error, as no correction for multiple comparisons were made. However, the reporting of actual P-values enables the reader to make their own interpretation. Moreover, the majority of findings were non-significant. Finally, important parameters such as ventilation, hands-off time and hand preference were not part of the outcome measures, which could have impacted the results. Further studies are required to investigate the aspects of these parameters in relation to fatigue and performance.

## Conclusions

In this randomised, simulated trial, no significant difference was found in the quality of chest compressions during iCPR performance for DH and NH using the TFT. Despite a small association between perception of fatigue and performance, no effect on quality was determined and participants were able to maintain similar quality iCPR, regardless of reporting higher levels of perception of fatigue in the NH. Nevertheless, future studies should investigate the effect of prolonged iCPR to further the understanding of these factors on performance. Based on the findings of the present study, individuals performing iCPR can be confident in their ability to offer similar quality of infant resuscitation regardless of the hand used or the perception of fatigue, under the conditions explored in this study.

## Credit author statement

DA, CC, UR, MJ, and JW have made substantial contributions to the conception, design of the study and final approval of the version to be submitted and have agreed to the Journal's submission policies.

DA and JW have considerably contributed to the acquisition, analysis and interpretation of data.

DA, CC, UR, MJ and JW have drafted the article and revised it critically for important intellectual content.

## Declaration of interest

None.

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