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Simulation and education

How effectively can young people perform dispatcher-instructed cardiopulmonary resuscitation without training?☆

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ABSTRACT

Aims: Survival from out-of-hospital cardiac arrest is increased by bystander cardiopulmonary resuscitation (CPR). Bystander performance can be improved when CPR instructions are delivered by a calltaker at the Emergency Communications Centre. Little is known about a young person's ability to understand these instructions and perform CPR correctly. We assessed the ability of a group of untrained young people to effectively apply these directions to an adult resuscitation manikin.

Methods: 87 youngsters aged 7–15 years with no previous training in CPR were separately equipped with a mobile phone and an adult assessment manikin. They phoned the emergency number (111) and were automatically diverted to a senior emergency medical dispatcher (EMD). The EMD delivered resuscitation instructions which complied fully with Medical Priority Dispatch System (version 12.1). Performance was monitored using a Laerdal Computerised Skill Reporting System.

Results: Average compression depth increased with age from 10.3 mm to 30 mm for 8 and 15 year olds respectively. 100 compressions per minute was achieved in youngsters aged 10 years and older but the rate fatigued over time and improved after interruption for two ventilations. Those aged 11 years and older consistently compressed the chest from 31 mm to 50 mm. Only one participant could successfully ventilate the manikin by mouth-to-mouth.

Conclusion: This study demonstrates that untrained youngsters should perform compression-only CPR. From 11 years of age, they can effectively perform dispatcher-directed CPR by compressing the chest at an appropriate rate and depth. However, their technique benefits from formal training.

1. Introduction

The survival rate for an out-of-hospital cardiac arrest (OHCA) in Australasia is approximately 12% [1,2]. This can be improved through early initiation of bystander cardiopulmonary resuscitation (CPR), an important link in the chain of survival [3–5]. However, despite extensive community CPR training, bystander CPR is not performed in many instances [2,6]. For the patient to have the greatest chance of survival without neurological deficit, CPR can be initiated when instructions are given to bystanders by the emergency medical services dispatcher (EMD) [7–9]. When dispatcher instructions are given to adult bystanders with no previous CPR training, their performance has been shown to be comparable to that of trained individuals [7].

About 80% of OHCA occur in the home [2] and the majority occur in the presence of a relative [10] with a telephone nearby. Sometimes, the only relative present is a child. The patient's chance of survival with minimal neurological deficit can therefore depend on the child's ability to pick up the phone, call the national emergency number (111), respond to questioning, disclose sufficient details for the calltaker to establish a likely diagnosis of OHCA, and then follow CPR instructions from the dispatcher until the emergency medical services arrive.

This study aimed to look at the ability of young people untrained in CPR to perform the skill when directed by a dispatcher. This followed an instance when a lone child called 111 for help after a relative collapsed at home. Many studies address the effectiveness of CPR training in young people [11–13] but none have been found that describe the performance of untrained children, or their response to dispatcher-directed CPR.

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2. Methods

2.1. Participants

Between November 2012 and October 2013, youngsters untrained in CPR were selected by means of a written questionnaire submitted through school teachers to parents in Wellington, and through open invitations on social media networks (e.g. Facebook). All young people aged 7–15 years who had received no prior CPR training (confirmed by parents and teachers) were included in the study provided they and their parents gave written consent. The main exclusion criterion was intellectual or physical disability that would affect the understanding of instructions or performance of CPR. Participants and their parents/guardians were provided with a study information sheet before written consent was obtained. The study was approved by the University of Otago Human Ethics Committee (reference number 12/234).

2.2. Procedure

The participants were introduced individually to an adult manikin who represented a collapsed relative. The youngsters were asked to activate the speaker mode on the mobile phone provided and they then called 111. The call was diverted to a senior EMD responsible for training and audit in medical dispatch. The EMD was based in the Communications Centre where the call was assessed in accordance with the Medical Priority Dispatch system (MPDS, version 12.1, Priority Dispatch Corporation, Salt Lake City, USA). The assessor remained in the room with the youngster who was provided with an answer sheet for standard MPDS questions which confirmed that the "patient" was in cardiac arrest. The EMD then delivered CPR instructions complying strictly with MPDS. The phone call from each participant was recorded in accordance with standard procedure. Resuscitation performance was monitored continuously on a Resusci Anne CPR manikin and Laerdal Skill Reporting System (version 2.1.0; Laerdal Medical AS, Norway).

2.3. Pre-assessment

Participants completed a data questionnaire capturing their demographics and their height and weight were measured. Lean body weight (LBW) was estimated from linear regression models [14] (Appendix 1).

2.4. Assessment

Once the EMD had established that the "patient" was in cardiac arrest, standard MPDS instructions required that 100 compressions per minute were performed for 6 min, followed by 2 breaths, then 100 more compressions. The assessor, a fully trained CPR instructor, was not allowed to assist or comment during this period. As well as providing intermittent timing to help rescuers achieve an appropriate compression rate, the EMD encouraged the participants over the phone, particularly when they began to fatigue. This represents normal practice and does not conflict with MPDS protocol. The EMD was responsible for recording the phone calls and documenting notes relevant to communication and interaction over the phone.

A number of rescuers of different ages and stature were videoed to capture details of their chest compression technique. No individual could be identified from these videos.

2.5. Post-assessment

Participants were asked to complete a questionnaire asking about the clarity and their understanding of instructions given by the EMD; the terminology used in the instructions, and the perception of their compression rate, depth and ventilations. Before leaving, they were provided with a formal teaching session in CPR, emphasising the identification of cardiac arrest and correct CPR technique.

2.6. Analysis

Resuscitation performance was monitored throughout each scenario. The following data were recorded using the Laerdal PC Skill Reporting System: average compression rate, average compression depth, number and position of incorrect hand placements, total number of incomplete chest releases (not released to a depth of less than 10 mm) and average ventilation volume. The compression period lasted 6 min before ventilations and 1 min after. Compressions less than 10 mm were undetected by the equipment, were recorded as 0 mm, and were classified as ineffectual for the purpose of this study if they endured 1 min or longer. A child who could only perform ineffectual CPR was considered incapable of effective chest compression, and CPR by that individual was discontinued at that point.

For each 1 min interval, the number of compressions in the following ranges was calculated: 11–30 mm, 31–50 mm and greater than 50 mm. In addition, the longest period of interrupted CPR was recorded, as well as the number of interruptions across the entire period.

All data was recorded on Excel software (Microsoft, Redmond, USA) for statistical analysis. Means, standard deviations, and confidence intervals for descriptive statistics were calculated in Excel; linear regression analyses (comparing age against compression depth/rate, and comparing lean body weight against compression depth/rate) were also conducted in Excel.

3. Results

3.1. Participant demographics

A total of 87 participants were assessed, with a similar number of males and females (Table 1). Weight, height and LBW were calculated. It was noted that the average weight of the 8 year olds was less than expected.

3.2. Compression depth

The relationship between average compression depth across the entire 7-min compression period, and the participant's age and LBW are portrayed in Fig. 1(A–C). As participant age and LBW increase, so does average compression depth (averages per age group with standard deviations are included in Table 1). Seven children were stopped prematurely due to ineffectual compressions. Their ages were 7 in two cases, 8 in four cases and 9 in one. They had LBW's below the average for 7-year-olds in four cases (20.3, 18.5, 22.7, and 20.4 kg).

Only youngsters of 11 years and older were capable of compressing the chest consistently more than 30 mm across the 7 min, whereas 14 and 15 year olds could compress the chest to a depth of 50 mm or more, as depicted in Fig. 2. At all ages, there was a general decline in compression depth during the first 6 min and this is attributed to fatigue observed in the study group. However, an upsurge in CPR strength was then observed after the two attempted ventilations. The 7 year olds on average performed more strongly than expected. However, one 7 year old weighed 50 kg and had a LBW of 33.4 kg which contributed to this result.

Table 1
Participant demographics.

Age (years)	7	8	9	10	11	12	13	14	15	Total
Number (male/female)	9 3/6	10 4/6	10 1/9	9 8/1	10 4/6	8 7/1	10 4/6	11 9/2	10 5/5	87 45/42
Average weight in kg (SD)	31.1 (8.7)	29 (6.2)	34.3 (4.2)	36.9 (6.3)	43.9 (8.7)	44.3 (6.2)	56.4 (6.1)	54.3 (11.9)	66.4 (13.2)	
Average height in cm (SD)	126 (5.9)	131 (7.1)	138 (4.9)	145 (7.0)	149 (7.0)	154 (6.1)	168 (8.3)	169 (10.6)	175 (8.1)	
Average lean body weight in kg (SD)	23.3 (4.7)	23.1 (3.4)	26.5 (2.06)	30.3 (4.4)	33.9 (4.9)	36.2 (4.2)	45.5 (4.2)	44.7 (8.6)	51.9 (6.4)	
Average compression depth in mm (SD)	12.6 (9.3)	10.3 (3.8)	13.8 (4.9)	15.7 (5.0)	21 (7.0)	22 (7.9)	24.5 (4.5)	25.2 (11.5)	30 (10.5)	
Average compression rate per minute (SD)	65.4 (38.0)	74.3 (33.5)	77.5 (31.0)	95.2 (26.5)	108.1 (13.0)	97.6 (4.5)	105.3 (6.3)	106.9 (15.4)	103.8 (18.7)	

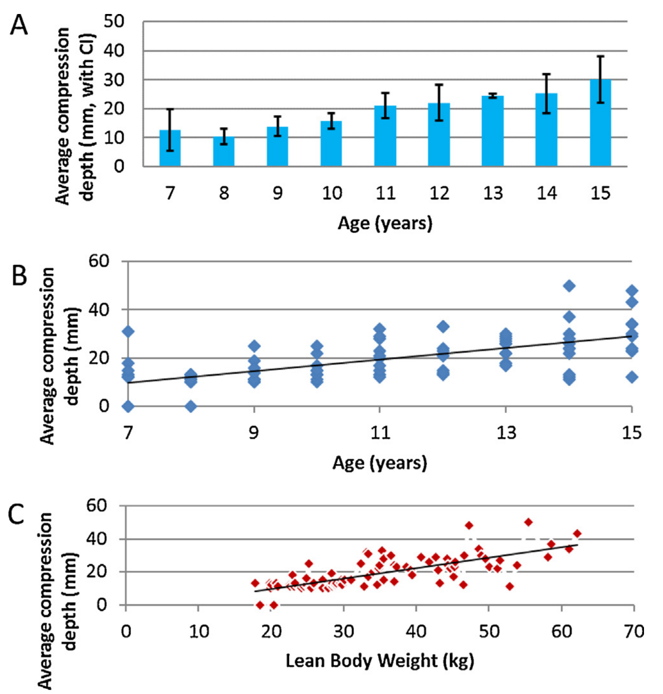

Fig. 1. Average compression depth over the 7 min of compressions as a function of age (A – bar chart with 95% confidence intervals and B – individual data with line of best fit equation: $y = 2.3772x - 6.7382$, $R = 0.64$, $P < 0.001$). Average compression depth is also plotted against LBW (C – line of best fit equation: $y = 0.6364x - 3.0369$, $R = 0.733$, $P < 0.001$). Compressions < 10 mm were recorded as 0 mm.

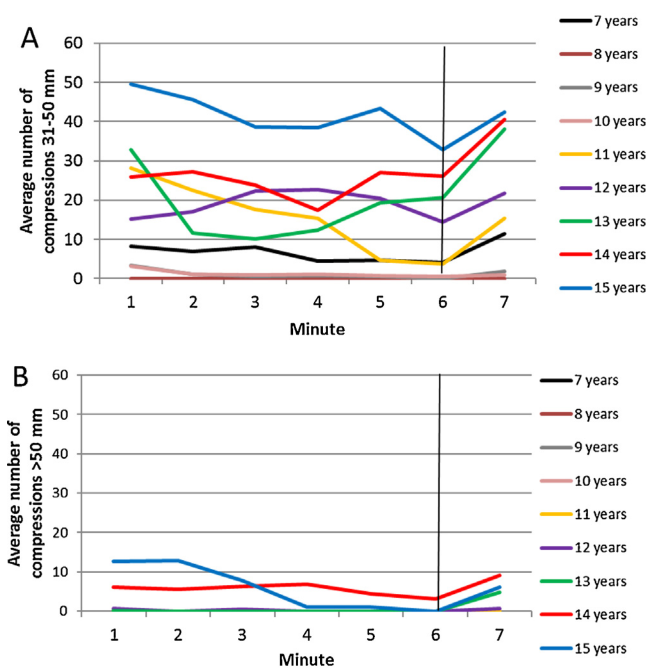

Fig. 2. Average number of compressions per minute within (A) 31–50 mm and (B) > 50 mm ranges for each age group. Note the upsurge in performance after the two attempted ventilations at 6 min.

3.3. Compression rate

The average compression rate across the entire 7-min period was approximately 100 compressions per minute for participants aged 12 years or older and with a LBW over 40 kg, as illustrated in Fig. 3 (averages per age group with standard deviations are included in Table 1).

3.4. Interruptions and chest recoil

The average number of interruptions in chest compressions counted across the 7 min period was 5.18. Fig. 4 illustrates the results for each age group. The longest interruption averaged 3.02 s. The average number of interruptions within the first and sixth min were 2.56 and 0.45 respectively. On average, compression was released incompletely only once per participant across the 7-min period.

3.5. Hand positions

The number of incorrect hand positions over the 7-min period, as a percentage of total compressions, was greater amongst the 15 year olds as well as youngsters with the highest LBW (see supplementary Fig. 5). Of these incorrect hand positions, the percentage of total compressions that tended to be too high, too far right, too low and too far left were 13.2%, 2.4%, 4.0% and 0.02% respectively.

3.6. Ventilations

Only one participant was able to ventilate the manikin and this was inadequate, averaging 250 ml.

3.7. Assessor's observations

The average time taken from call answer to first compression was 2 min 42 s. When assessing for breathing, 43% (37/87) of youngsters looked at the chest and 76% (61/80) did not perform head tilt for ventilation, as instructed. In three cases, the head was flexed rather tilted back. Compressions were accurately counted aloud by

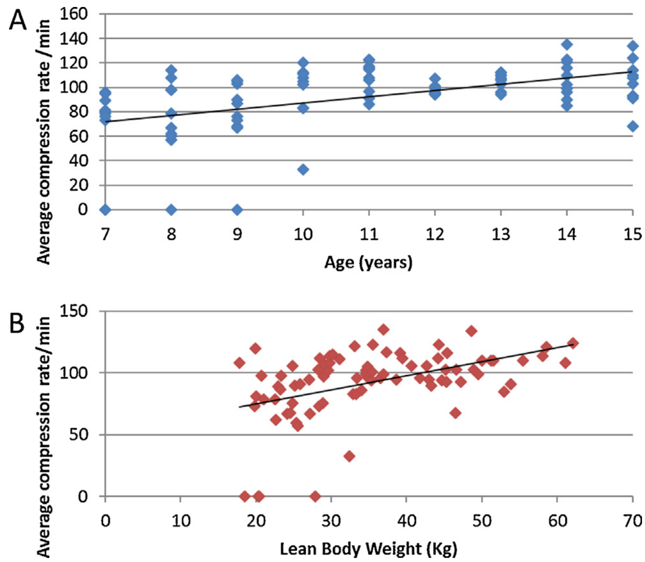

Fig. 3. Average compression rate across the 7-min compression period per individual, separated by (A) age (line of best fit equation: $y = 5.1169x + 36.384$, $R = 0.493$, $P < 0.001$) and (B) lean body weight (line of best fit equation: $y = 1.1451x + 52.088$, $R = 0.466$, $P < 0.001$). Compressions <10 mm were not sensed and were therefore not included in the compression rate.

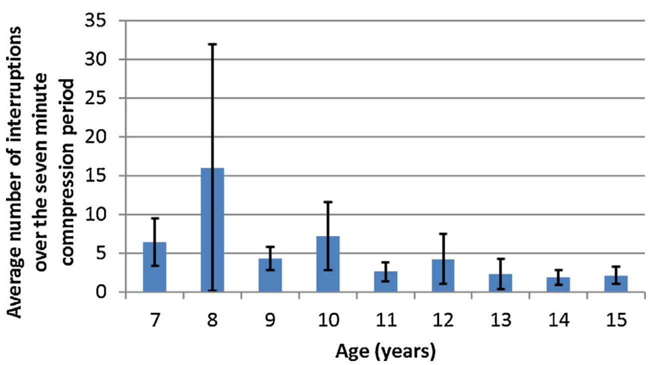

Fig. 4. Average number of interruptions over the 7-min compression period as a function of age (with 95% confidence intervals).

80% (70/87) of youngsters when asked to do so by the EMD. However, 47% (41/87) stopped compressions briefly at least once whilst the EMD was speaking.

3.8. Post-performance questionnaire

71% of the youngsters found the instructions delivered by the EMD to be clear or very clear. None classified the instructions as 'very difficult' to understand (supplementary Fig. 6).

24% of participants (21/87) did not know where the breastbone was located and 5% (4/87) did not know what the heel of their hand was.

36% (31/87) believed that they had ventilated the manikin and the majority believed they had compressed the chest to the desired depth and at the correct rate.

4. Discussion

From 11 years of age, untrained youngsters were consistently able to follow the EMD's instructions and compress the adult manikin's chest in the range 31–50 mm (Fig. 2). Only 14 and 15 year olds exhibited enough strength to compress the chest further than the recommended 50 mm [15]. Average compression depth across the entire 7-min period as a function of LBW mirrored the age results (Fig. 1), suggesting that the rescuer's muscle mass is related to compression depth performance, as demonstrated in another study [12].

From 12 years of age, untrained youngsters could effectively sustain the speed of compression encouraged by the EMD and perform CPR at the recommended rate of 100 compressions per minute [15] on an adult manikin (Fig. 3). As all participants were exposed to the timing provided by the EMD, the lower rate of compression within the younger age groups (and those with LBW's of 30–45 kg) is partially explained by the higher incidence of interruptions (Fig. 4) and by weak compressions that did not reach the monitoring threshold. When the call taker was speaking, 47% of youngsters paused compressions briefly on at least one occasion. Hence more interruptions occurred in the first compared to the 6-min of compressions.

In addition to compression depth and rate, effective chest compressions are dependent on proper chest recoil [15]. It was therefore pleasing to observe an average of 1 incomplete release per youngster across the 7-min period. However, this may be explained by low-depth chest compressions in the younger participants.

There was evidence of fatigue at all ages throughout the first 6 min of compressions (Fig. 2). However, resurgences in depth of compression occurred during this period and our observation was that this was associated with words of encouragement from the EMD. An improvement in compression depth also followed the two ventilation attempts at 6 min and it is hypothesised that this resulted from the brief rest from CPR which occurred at that point.

The higher prevalence of incorrect hand positions in older participants (supplementary Fig. 5) is attributed to activation of the manikin sensors by deeper compressions and larger hands in this age group. The commonest misplacement consisted of placing the hands too high during CPR.

Only one youngster (a 13 year old female) was able to ventilate the manikin, producing an average inflation volume of only 250 ml. Poor airway opening appeared to be one contributing factor, an observation consistent with adult studies [10]. In general, the majority of youngsters waited for the entire ventilation instructions to be delivered before attempting breaths and this resulted in the omission of vital steps including head tilt. Younger participants appeared to have difficulty performing whilst listening but it was assumed that this is probably a normal part of education in this age group. Only 43% of participants faced the chest when assessing breaths although precise instructions to do this are not scripted into MPDS version 12.1. In combination, these findings support our recommendation that untrained youngsters should perform compression-only CPR. It is understood that the next version of MPDS will allow for that option.

The average call pick up to CPR time was 2 min and 42 s. During this period when the phone number, patient's address, patient's health status and compression instructions were being addressed, no compressions were delivered. In a real situation, it is likely that this period would be extended, allowing for the time it takes a youngster to recognise the need for medical attention and call 111. MPDS is designed for adult use but adjustments for young rescuers could potentially reduce this time and address the uninterrupted period of 600 chest compressions which is also challenging in this age group. MPDS version 12.2 has already shortened the time to CPR.

The majority of youngsters found the dispatcher instructions clear or very clear (supplementary Fig. 6). However, there was a large discrepancy between their perceptions and their true CPR performance. Although only one participant was able to ventilate, 36% believed they did. Similarly, 83% believed they compressed the chest to an appropriate depth or beyond when this was not the case.

Research suggests that although the ability of youngsters trained in CPR to adequately compress the chest is dependent on their age and weight [11,12], those lacking the necessary physique are still capable of learning basic resuscitation principles in the same way as their older peers [11,13]. Our study shows a comparable ability to perform CPR in untrained youngsters such that training, although strongly recommended, should not in our opinion be assumed to be a prerequisite for dispatcher-directed CPR in this age group. However, the MPDS should be simplified for young people by focusing on compression-only CPR and hand positioning, reviewing terminology, and accepting that below a cut-off age of 9 years, compressions administered using the standard technique will have limited effect because of body stature and fatigue. Encouragement is important but instructions should be as simple as possible to minimise interruptions to CPR.

4.1. Limitations

The manikin cannot be expected to provide the same resistance to CPR as a human frame and this study did not replicate the stress and fear experienced in a real OHCA. Youngsters answered the initial call taker questions using the scripted answers provided and it would have been useful to identify how many could have provided their own details in this situation.

We found no accepted definition of ineffectual chest compressions in manikin studies. Compressions less than 10 mm were empirically considered ineffective as they were undetected by the equipment. They would have had a minor impact on compression depth and rate calculations. Only seven participants performed consistently at this level and were stopped early. Their results were included in calculations relating to chest compressions but not interruptions or ventilation attempts.

Although the cohort assessed had received no formal CPR training, the technique is often demonstrated in fictional television dramas. Despite this, the variability in rescuer positioning and performance, the wide range of hand placements used, and the varied approaches to mouth-to-mouth ventilation suggest that the cohort studied had very little familiarity with the technique of CPR.

5. Conclusion

This study supports the performance of compression-only bystander CPR by young people untrained in CPR from the age of 11 and with lean body weights of 40 kg or more. Below that age, compression depth and frequency do not approach the recommended standards and consideration should be given to non-standard CPR techniques that might be of benefit.

Conflict of interest statement

The authors have no conflicts to declare.

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Appendix A. Lean body weight calculations

Body Mass Index (BMI) = [Weight (kg)]/[Height (m)]^2

Gender score: male = 1, female = 0.

Body Fat percentage (BF%) = $1.51 \times$ BMI $- 0.70 \times$ age (years) $- 3.6 \times$ gender $+ 1.4$

Lean body weight percentage (LBW%) = 100 − BF%

LBW (kg) = LBW% $\times$ weight (kg)

Appendix B. Supplementary data

Supplementary material related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2015.02.035.

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