Heel compressions quadruple the number of bystanders who can perform chest compressions for 10 minutes

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Objective: The objective of the study is to evaluate whether chest compressions using the heel provide a more effective method than manual compressions for bystanders.

Methods: This is a cross-sectional observational comparison study where each subject acted as his or her own control. A 49-person cohort whose age distribution approximated that of sudden cardiac arrest victims were asked to perform 10 minutes of 5-cm manual compressions on a cardiopulmonary resuscitation manikin at 100 compressions per minute. The compression rate and the endurance of each subject were recorded. The same subject was then asked to perform 10 minutes of heel compressions at the same depth and rate.

Results: Sixteen percent of the cohort performed compliant manual compressions for 10 minutes vs 65% using heel compressions. Twenty-four percent of the subjects were not heavy enough to get compliant depth with manual vs 2% with heel compressions, and 6% could not get down on the floor to attempt manual compressions.

Discussion: Most cardiac arrests occur in private residences. If there is a witness, his or her age usually approximates that of the victim. Heel compressions are useful in situations where a lone rescuer cannot get down on the floor, cannot compress the chest to guideline depth because of an infirmity or lack of weight, or becomes too tired to continue manual compressions. Heel compressions significantly increase the bystander population’s ability to provide effective, uninterrupted compressions until EMS arrival.

1. Introduction

Performance of chest compressions with the foot was reported in 1978 [1] and in 1980 [2] and was listed as an acceptable alternative in the 2005 American Heart Association (AHA) Guidelines [3]. In 2010, the depth guideline minimum increased to 5 cm from 3.8 cm in the 2005 AHA Guidelines. Attainment of that extra depth requires approximately twice the compression force. Heel compression permits the application of greater force to the victim’s chest and is more relevant now than in 2005.

It was clear how the heel method might be helpful for rescuers who could not get down on the floor next to the victim or for those who had problems pushing the chest with their hands. It was not clear whether this method was superior or inferior in terms of stamina.

Objective: The objective is to measure whether there was any difference in the period for which a subject could perform compliant compressions with both methods. Thus, the null hypothesis was that there was no advantage to the heel method for any rescuer who was capable of performing manual compressions.

One in 6 lone rescuers can perform manual compressions for 10 minutes. It is clear that uninterrupted chest compressions of adequate depth, performed from sudden cardiac arrest (SCA) until emergency medical services intervention (along with early defibrillation), are crucial to increasing neurologically intact survival.

The primary goal of this study is to find whether heel compressions significantly improve the percentage of lone rescuers able to achieve 10-minute guideline compliance.

2. Methods

2.1. Study design

The 10-minute trial target limit matches the average time from an arrest until the hands-on arrival of the ambulance crew in Chatham County, GA. This applies in out-of-hospital arrests where the arrest occurred in a private residence (between 69% [4] and 85% [5] of all out-of-hospital arrests) [6].

2.2. Ethics approval

SLICC does not have an institutional review board. This study was an observational study. The study involved observing and recording, while
people compressed the chest of a manikin. The subjects were given a release form before the trials.

2.3. Trial registration

This is not a clinical study. The study is compliant with the guidance of STROBE_checklist_v4_combined_PlosMedicine.pdf to the best of the authors’ knowledge.

2.4. Setting

The equipment required is portable. The trials were held either in the corresponding author’s office, in the subject’s home, at the local fire hall, or at any other convenient place. Some of the trials were conducted in Chautauqua County, NY, and others were conducted in Chatham County, GA. Subjects were recruited progressively throughout the trials. Testing occurred during July to September of 2012.

2.5. Participants

The participants were selected to reflect a roughly equal split between sexes and to approximate the age distribution of SCA victims. The corresponding author recruited the subjects by walking around with a sheet that identified the number of remaining age/sex slots available and asking those he encountered their age. If there were an available slot for someone of that age and sex, that person was asked whether they would participate in a cardiopulmonary resuscitation (CPR) study. He relied on the honesty of the prospective subjects when deciding which age group was appropriate for that subject. See Table: Age distributions: test cohort and cardiac arrest victims.

2.6. Variables

The primary measurement was length of time that the subject could perform compliant compressions using each of 2 methods. “Compliant” was defined as between 25 and 30, 2-in compressions for each 15-second period, that is, at a rate of 100 to 120 compressions per minute.

2.7. Data sources/measurement

A CPR manikin (CPR Prompt model, 32nd percentile adult chest stiffness) was modified to click at 2 in of compression. An audible rate prompt was provided as needed during the first 30 seconds of both trials. The number of clicks (compliant compressions) was recorded for each 15-second interval. When the number of clicks fell below 25 for 2 successive 15-second periods, the trial was terminated, and the time during those sub-25 periods was not counted. Isolated excursions below the 25 compressions per 15 seconds criterion did not cause the entire 15-second segment to be deleted. No data were excluded for excess rate.

2.8. Bias

The design intentionally provided for performance of manual compressions first to avoid the possibility that the performance of heel compressions would reduce manual stamina. The design likely was biased against any potential advantage of heel compressions. The test subjects were not told the nature of trial 2 (heel compression stamina), until they had performed trial 1 (manual compression stamina.) The subjects were tested privately, so that no subject as of yet tested would witness the second trial. Communication about the trial between a subject who had been tested and a subject who had not was not preventable. Each subject was asked whether they knew what the test was about, and none reported that they knew what the trial was about. There is no way of verifying the honesty of their responses. The corresponding author recorded all data, except for 1 subject where he supervised the data recording by another volunteer.

2.9. Study size

The number of subjects was calculated using a Web-based calculator, specifically http://powerandsamplesize.com/Calculators/Compare-2-Means/2-Sample-Non-Inferiority-or-Superiority A sample of 44 will yield sufficient power and values if an increase of 25% in compression duration with heel compressions is observed. A greater difference in stamina between the 2 compression methods was expected based upon earlier work. The cohort size was originally intended to be 100 to permit statistically significant comparisons between sexes in age groups 2 and 3. Recruiting subjects proved to be more difficult than anticipated.

2.10. Discrete and quantitative variables

- Discrete: the method of performing compressions (manual or heel).
- Quantitative: the length of time that subject could produce compliant compressions using each of those 2 methods.

2.11. Statistical methods

Each of the 49 subjects served as their own control in that each first attempted to reach 10 minutes using manual compressions and then was asked to attempt to reach 10 minutes using heel compressions. This required a paired t-test to evaluate the power of the findings. Evan Miller’s tool was used (see http://www.evanmiller.org/ab-testing/t-test.html). The difference of mean calculation yielded an α < .001. See Fig: 1: Miller’s tool and the result.

The data describing the endurance of the cohort members, both for the manual compression trial and for the heel compression trial as well as the actual data are available online. The data for each individual are at http://www.slicc.org/Heel-Manual.

3. Results

3.1. Participants

Fifty-two participants were recruited by age and sex. At the time of the actual trials, 3 of the 52 were excused: 2 for refusing to participate in the trials and 1 for not taking the trials seriously. The participants did not receive a stipend.

The participants were recruited with the major effort being to find participants whose age distribution approximately matched the age

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (y)</th>
<th>Males</th>
<th>Females</th>
<th>Total</th>
<th>% of Cohort</th>
<th>Distribution of that age in CARES</th>
<th>Manual: males at 10 min</th>
<th>Manual: females at 10 min</th>
<th>Heel: males at 10 min</th>
<th>Heel: females at 10 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35–49</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>12%</td>
<td>13.1%</td>
<td>100.0%</td>
<td>0.0%</td>
<td>100.0%</td>
<td>66.7%</td>
</tr>
<tr>
<td>2</td>
<td>50–64</td>
<td>3</td>
<td>11</td>
<td>14</td>
<td>29%</td>
<td>30.2%</td>
<td>33.3%</td>
<td>9.1%</td>
<td>100.0%</td>
<td>81.8%</td>
</tr>
<tr>
<td>3</td>
<td>65–79</td>
<td>16</td>
<td>8</td>
<td>24</td>
<td>49%</td>
<td>28.8%</td>
<td>12.5%</td>
<td>12.5%</td>
<td>68.8%</td>
<td>50.0%</td>
</tr>
<tr>
<td>4</td>
<td>≥80</td>
<td>4</td>
<td>5</td>
<td>9</td>
<td>10%</td>
<td>22.3%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>26</td>
<td>23</td>
<td>49</td>
<td>100%</td>
<td>94.4%</td>
<td>Of total 23.1%</td>
<td>Of total 8.7%</td>
<td>Of total 65.4%</td>
<td>Of total 65.2%</td>
</tr>
</tbody>
</table>

Uses the CARES registry data as the age distribution of SCA victims. The CARES reference appears in the citations.
distribution of SCA victims as reported by Cardiac Arrest Registry to Enhance Survival (CARES) [4]. The specific age categories used were dictated by the way the CARES report classified the cardiac arrest death statistics by age. Table shows that the most significant distortion can be found in the overrepresentation in group 3 and the underrepresentation in group 4. For obvious reasons, recruiting for age group 4 (age ≥80 years) presented a significant challenge.

The initial temptation was to have the cohort’s sex distribution include twice as many females as males because the sex distribution of the rescuers is more likely to be the inverse of the SCA victims. It was decided to attempt to achieve a 50/50 split, however, because of a concern with the possibility that the cohort would lack sufficient numbers of females to support statistically significant comparisons within age groups.

3.2. Descriptive data

A mixture of income and health levels populated both recruitment venues. The only participants for whom full test data are lacking are the 3 that were excused. Health issues were not recorded, except for the subject that reported problems with his prosthetic lower leg.

The exact form of heel compressions that was published in JAMA in 1978 was not used due to a concern about inadvertent separation of the xiphoid process from the sternum in the event of a positional drift of the heel. The form used has the shoeless rescuer standing straddling the victim’s head, facing the victim’s feet, with the rescuer’s toes near the top of the victim’s ears. A chair, doorframe, walker, table, or any convenient object is used for rescuer stability. The heel of either foot is then placed at the “CPR” point (intranipple line at the longitudinal centerline). The reason for positioning the toes of the stationary foot at the top of the ears is to force the ball of the active foot upward, so that the ball of the foot cannot press on the xiphoid process. A video demonstration of this technique is available online at http://www.slicc.org/ClassVideo/2014CV_AdultCPR.mov.

The subjects were recruited randomly in 2 communities based on of sex and age. There are no missing data.

3.3. Outcome data

Nearly 4 times as many males as females could reach 10 minutes with manual compressions. Approximately equal percentages of males and females could reach 10 minutes with heel compressions. See Table: Total cohort stamina manual vs heel switching to heel compressions erased the sex gap in the context of a CPR manikin.

The sample size of the individual age group/sex cells prevents making any significant comparison among them.

None of the group 4 subjects were able to perform compressions for 10 minutes with either compression method.

3.4. Main results

Few subjects were able to perform manual compressions for 10 minutes. See Fig. 2: Suitability of manual compression method.

More than half the cohort passed the 10-minute mark with heel compressions. See Fig. 3: Suitability of heel compression method.

More than 3 times as many of the cohort reached 10 minutes with heel compressions. See Fig. 4: Comparative suitability of heel and manual methods.

3.5. Confounders and how adjustments were made

Any effect of effort expended in the first trial influencing effort available for the second trial might have been a confounder had the order of
the manual and heel trials been randomized. The manual trial came first for all subjects, thus introducing a bias against the heel method and ensuring that there was no related bias against the manual method. No attempt was made to correct for this bias.

Advance knowledge of the purpose of the study and what trial 2 consisted of before performing trial 1 could also have been a potential confounder. This potential was largely eliminated by not disclosing the nature of the second trial until after the first trial, by testing the subjects in isolation from others waiting to be tested and by asking each subject at the time of the trials whether they had heard or seen anything about the nature of the trial.

3.6. Other analyses

Three subjects could not get down on floor for various reasons. This eliminates the possibility of their performing manual compressions.

One subject (female, group 1) stopped at 9:38 because she misunderstood the question “If this were ‘for real’ could you perform compressions for another 10 minutes?” and thus could not be counted as having reached the 10-minute goal.

One subject could not press the chest to compliant depth with either method because of low body weight. Heel compressions increase the portion of the rescuer’s body weight available to be translated into compression force.

Nine subjects could not perform 5-cm compliant compressions manually. This appeared to be a body weight issue.

Three subjects terminated a trial because of pain.

4. Discussion

4.1. Key results

Heel compressions benefit most bystanders.

Heel compressions permit greater stamina: 2.7 times as many males and 7.5 times as many females reached 10 minutes of compliant compressions using their heels, all in the context of a 32nd percentile of adult chest stiffness CPR manikin.

Heel compressions permit persons who are not able to get down on the floor, who are marginally not heavy enough to produce compliant compressions, or who cannot push hard enough with their hands, to perform compliant compressions.

4.2. Limitations

Other physical problems can limit the advantage of heel compressions. For example, 1 subject had balance and stability problems while performing heel compressions because he wears a prosthetic lower leg.

One cannot expect this result to be useful in forecasting the percentage of cardiac arrest victims who can receive guideline compliant compressions. The CPR manikin used was at the 32nd percentile of adult chest stiffness. It takes 105 lbs to compress a 32nd percentile manikin.

The heel method is not useful in single-rescuer 30 and 2 protocols because of the impracticality of interrupting heel compressions to get down on the floor to perform ventilations. The AHA’s Scientific Advisory of 2008 [7] and the European Resuscitation Consortium’s 2010 Guidelines [8] have made continuous chest compression the bystander standard.

5. Conclusions

For those able to perform heel compressions, heel compressions should be the preferred bystander compression method in situations where one will need to perform compressions for more than a few minutes, where one has hand/arm or flexibility/pain issues that interfere with performing manual compressions, or when one’s weight is insufficient to perform 2-in (5-cm) deep compressions. Furthermore, given the superior endurance of the cohort members when using the heel compression method, it is logical that bystanders begin with heel compressions. Finally, given that none of the group 4 (≥80 years) was able to reach 10 minutes with either method, couples of ≥80 years should consider whether they want to have a personal Automated Electronic Defibrillator (AED) in their home.
Health care providers on an ambulance or in a health care facility should not use this compression method because those are 2 environments where heel compressions cannot be performed safely. Standing in a moving ambulance to perform chest compressions is dangerous. Similarly, the patients in health care facilities are on carts or in bed on CPR backboards.

The authors were not successful in locating any CPR studies where endurance was measured and where the age distribution of the cohort approximated that of cardiac arrest victims.

Except for special populations—below knee amputees, for example—the heel technique is generalizable to the population of bystander rescuers.

Conflicts of interest

Neither author has any relevant conflict of interest.

The only parties who have anything to gain by the publication of this work are SCA victims whose arrest is witnessed by a bystander.

The roles of the funding source are president of SLICC and corresponding author.

Ethics and subject consent

Each subject either signed or verbally agreed to a release that read “On this ____ day of ____ 2012, intending to be legally bound hereby, the undersigned agrees and does hereby release from liability and to indemnify and hold harmless Saving Lives In Chatham County, Inc, and any of its officers, directors, employees, advisors, or agents as regards to CPR chest compression endurance testing. This release is for any and all injuries (including death) and property losses or damage occasioned by or in connection with any activity or accommodations for this event.”

Each subject’s vital signs were taken before commencement of the trials, between the trials, and after the trials. If the subject were not obviously okay after the second trial, the subject was retained and monitored, until the vital signs returned to pretest levels.

Most of the subjects were photographed holding a page containing their subject number in front of their face. Some subject’s photographs have been misplaced. The consent and data forms have names on them.

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A volunteer proofread the manuscript.

The funding for this project—less than $50 in total—was provided by the corresponding author and may or may not eventually be reimbursed by the nonprofit organization, a 501(c)(3) public charity at which both authors serve as unpaid volunteers. See http://www.slicc.org.

Both authors made substantial contributions to the conception and design of the study, to the analysis and interpretation of data, and to the drafting and critical revision of the article. Both authors approved the final version of the article. The corresponding author collected the data. No one other than both authors participated in the writing of the article. Another volunteer helped with the proofreading. No other writing assistance was used.

The corresponding author had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

The corresponding author conducted and is responsible for the data analysis.

References