Training and education

Is a homemade cardiopulmonary resuscitation (CPR) trainer non-inferior to a commercially available CPR mannequin in teaching high-quality CPR? A non-inferiority randomized control trial

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Abstract

Introduction: Studies demonstrate that feedback devices help students achieve mastery of critical CPR skills and shorten the time from demonstration to competence. CPR feedback devices are costly and may not be available in low resource settings or in the context of online classes. We have developed a homemade feedback enabled CPR trainer. This trainer consists of a lid with two toilet rolls stacked on top. We have shown it is feasible to generate high quality CPR using this trainer, however the ability for this trainer to successfully be used in skill acquisition is unknown. Our main objective was to assess if learning CPR on a homemade toilet paper trainer was non-inferior to a commercially available mannequin when comparing post-training CPR scores.

Methods: We conducted a parallel non-inferiority randomized control trial using a variable block randomization to a 10-min training session on either a toilet paper or commercial mannequin trainer. Primary outcome was mean overall CPR score as determined by high fidelity mannequin software. A sample size of 62 per group was calculated based on a 90% power to assess for the lower limit of a two-sided 95% confidence interval above the non-inferiority limit of 10%.

Results: 125 participants were randomized to the toilet paper (n = 64) or commercial mannequin trainer (n = 61). There was no difference between groups in age, sex, height, weight or previous CPR training. There was an absolute difference of 2% (CI 95% 3.3 to 7.3%) in mean overall CPR score between groups (toilet paper = 82% (SD 15.9%), commercial mannequin = 84% (SD 15%)).

Conclusion: A homemade CPR trainer was non-inferior to a commercially available trainer. This study provides preliminary evidence supporting the use of a homemade, easily accessible trainer for basic compression-only CPR skill acquisition.

Keywords: Compression-only CPR, Homemade CPR trainer, Remote learning

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2666-5204/Crown Copyright © 2021 Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Introduction

Hands-on cardiopulmonary resuscitation (CPR) education with real-time feedback is essential for skill acquisition. Studies demonstrate that feedback devices help students achieve mastery of critical CPR skills and shorten the time from demonstration to competence. However, feedback devices are costly and may not be available in low resource settings. Thus, further increasing the gap in CPR education between low and high resource settings. There are many barriers to in person CPR education which may contribute to a community’s low level of bystander CPR. Classes are in person therefore childcare requirements and work commitments limit accessibility. CPR education programs are most often paid programs therefore further limiting accessibility to those in low-income settings. Online courses offer a potential alternative to traditional in person teaching. However due to the cost of feedback devices they lack a core tool for skill acquisition.

In order to increase equitable access to high quality CPR education we have developed a free online program aimed at school aged children and seniors. As part of this program, we developed a homemade feedback enable CPR trainer. This device consists of a screw top mason jar lid with two toilet paper rolls placed directly on top (Fig. 1). To the best of our knowledge this is the first home-made feedback enabled CPR trainer.

The toilet paper trainer has been provisionally validated using a Zoll X series defibrillator with a CPR feedback sensor. Full compression of inner tubes was equivalent to 5 cm compression and opening of the inner tubes signified full recoil. When the trainer is compressed, the screw top mason jar lid generates audio feedback, a “click”, reinforcing appropriate compression, depth and rate.

There are fidelity differences in the feedback that is provided from a commercially available mannequin versus the toilet paper trainer. The toilet paper trainer requires minimal effort to compress versus a commercially available mannequin. It also lacks the realism of a human chest. However, the homemade trainer has the potential to allow real time training on a feedback enabled trainer that is low cost and readily available to all laypersons.

Our main objective was to assess if learning CPR on a homemade toilet paper trainer was non-inferior to a commercially available mannequin when comparing overall CPR scores as tested on a feedback enabled CPR mannequin.

Methods

We conducted a non-inferiority randomized control trial of general public visitors over the age of 12 attending Science North, a science centre in Sudbury, Ontario, Canada that hosts 250,000 visitors annually. Participants were approached from July-August 2020 if they interacted with the CPR training exhibit at Science North. A research associate explained the study and obtained informed consent from each participant. Participants were randomized to the trainers using opaque sealed envelopes 1:1 to a 10-min training session on a toilet paper or commercial (Laerdal Mini Anne) trainer. We used a variable block randomization with block sizes of 4, 6 or 8. The randomization list was generated by principal investigator (RO) with an online random number generator (Research Randomizer Version 4.0). This study was approved by the local research ethics board.

Intervention

Both groups received 10 min of one-on-one education on how to correctly perform compression-only CPR. The training included demonstration of high-quality CPR (~1 min) followed by three periods (~2 min each) of hands-on practice/education that concentrated on each core component of compression-only CPR: depth, rate and recoil. With a final 3-min period of practice with feedback. The participants received feedback from the trainer they were assigned (commercial trainer with a green light indicating high quality CPR or the toilet paper trainer as described previously) in addition to verbal feedback from the instructors in regards the quality of their CPR.

Fig. 1 – Example of toilet paper trainer.
(a) Complete compression (5 cm) is demonstrated by full compression of the toilet paper inner tubes and click of the jar lid. (b) Full recoil is demonstrated by re expansion of the inner tubes. Note: the inner tubes only re-expand to an elliptical shape; they will not re-expand to a circle.
The toilet paper rolls used were of an average diameter of 11.4 cm. The inner tube had an average diameter of 3.8 cm. This represents the most common dimensions of toilet rolls that are available on the market. New toilet rolls were used for each participant. We have not conducted formal testing, but we found that after 5 min of compression the toilet rolls do not recoil sufficiently to enable a 5 cm compression depth.

The instructors were high school students that had undergone a Heart and Stroke credentialed Basic Life Support program. Our local organisation which provides free CPR education (“Northern City of Heroes”) is based on peer led teaching. The students underwent instructor training within our organisation and were observed educating 10 participants by an emergency medicine physician/certified CPR instructor.

**Outcome**

Our primary outcome was mean overall CPR score as determined by the high-fidelity mannequin software. This score is calculated using an algorithm developed in collaboration with members of the American Heart Association (AHA) and Emergency Cardiovascular Care Subcommittee and co-authors of the 2013 AHA Consensus Statement. It uses a combined weighted score for depth, rate, full release, hand position, no flow time, and compression number per cycle. Overall CPR score was assessed on a separate feedback enabled mannequin after participants were trained on either the toilet paper or commercial trainer. Participants underwent a 1-min CPR test immediately after completing the education session. Secondary outcomes included the proportion of participants who achieved a passing >70% score, proportion of participants who were successfully predicted to pass, willingness to perform CPR on a stranger or family post training and adequate rate, recoil and depth achieved on the respective trainer prior to testing.

For the toilet roll trainer adequate depth was signified by complete compression of the two inner tubes and adequate rate was judged based on the lid click matching the rate of an accompanying song of 100–120 bpm or metronome.

**Statistical methods**

A sample size of 39 per group size was calculated based on a 90% power to assess for the lower limit of a one-sided 95% confidence interval above the non-inferiority limit of 10%, based on a standard deviation of total CPR score of 15%. This standard deviation was based on pilot data obtained prior to trial commencement and was not included in the study. In order to account for a higher standard deviation, we inflated our sample size to account for a standard deviation as high as 19%, resulting in a conservative sample size of 62 per group. The non-inferiority margin is difficult to define as depending on the resource setting a higher non inferior margin may be acceptable if no alternative trainer is available. Therefore we chose a non-inferiority margin that was based on similar studies assessing non-inferiority of different training methodologies for CPR.

We calculated the absolute frequencies for categorical variables and the mean and standard deviation (SD) for the continuous variables. Categorical variables were analysed using a Chi-square and continuous variables using a T-test. Statistical analysis was performed using SAS 9.4 University edition.

**Results**

We recruited a total of 125 participants that were randomized to either the toilet paper (n = 64) or commercial mannequin trainer (n = 61). There was no participant cross over (Fig. 2). The average age was 26.4 (SD 12.8), height 170 cm (SD 12.1), and weight 70.1 (SD 16.5).
There was no difference between groups in age, sex, height, weight or previous CPR training (Table 1). Post training similar proportions of participants achieving adequate rate (100—120 compressions/minute) was seen in toilet paper (95.3%) vs. commercial (82.5%) mannequin group. Participants demonstrated an adequate depth of compression more often on the toilet paper (95.3%) vs the commercial mannequin (82.5%) but lower rates of adequate recoil (59.4% vs. 72.1%) (Table 1). Mean overall CPR scores were 2% (CI 95% – 3.3 to 7.3%) higher in the commercial mannequin group (Table 2, Fig. 3). There was an absolute 4% (CI 95% – 17.1 to 9%) difference in passing CPR score (>70%) between groups (Table 2). There was an absolute 7% (CI 95% 6.2%–21.3%) difference in accuracy of prediction of pass between groups (Table 2). Participants in the toilet paper group were more likely to perform CPR on stranger post training than the commercial mannequin group (82.8% vs. 78.7% P < 0.004). There was no difference in a participant of the toilet paper or commercial mannequin groups’ willingness to perform CPR on a family member post training (90.1% vs. 91.8% P < 0.4).

### Discussion

We demonstrated that compression-only CPR skills acquired using a homemade CPR trainer were non-inferior to a commercially available trainer. This study provides preliminary evidence supporting the use of an affordable homemade, easily accessible tool for basic compression-only CPR skill acquisition during online or in person training.

The World Health Organization (WHO) endorses that every child over 12 be taught CPR annually until graduation. The American Heart Association (AHA) recommends the use of feedback enabled mannequins for skill acquisition.

The recommendation for use of a feedback-enabled mannequin has the potential to place significant barriers to widespread adoption of the WHO CPR recommendations. CPR mannequins, although reusable, require a significant upfront cost to schools and community initiatives. Our study proposes an easily accessible and cost-effective alternative. In addition, using everyday household items as training tools increases accessibility allowing for spaced repetition learning and skill maintenance when practiced at home.

There is little published literature regarding homemade CPR trainers. One small study exists testing a trainer consisting of a t-shirt pulled through an inner tube of a toilet roll and a towel placed over this. It demonstrated that a brief video-based lecture coupled with this trainer improved hand position, rate and recoil, but no improvement on compression depth.11 Although not formally assessed in this study it is possible that this trainer can be compressed more times without losing recoil over. However, there is no feedback mechanism to aid in skills acquisition.

There are intrinsic structural differences in the toilet paper trainer and the commercial mannequin trainer that could affect skill acquisition. Commercially available trainers require 48 kg of force to compress to a depth of 5 cm.12 Smaller sized adults and children may not be able to generate the required force to compress a commercial mannequin due to body habitus, thus impairing their ability to learn hands-only CPR. We found that participants learning on the toilet paper trainer demonstrated better compression depth compared to those learning on the commercial mannequin trainer. The toilet paper trainer allows for individuals of all sizes to practice adequate compression depth with less force required. We also found that at the end of training adequate recoil was lower in the toilet paper trained group. The toilet paper trainer has lower intrinsic recoil, therefore in order to allow the inner tubes to open, participants must

| Table 1 – Characteristics of included participants. |
|----------------------------------------------------|
| Toilet paper trainer (n = 64) | Commercial mannequin trainer (n = 61) |
| Female | 33 (51.7) | 25 (41) |
| Height (cm, SD) | 170 (13.7) | 171 (10.2) |
| Weight (kg, SD) | 70.7 (15.8) | 69.5 (17.3) |
| Age (years, SD) | 28.2 (14) | 24 (11) |
| Previous training (n, %) | 22 (34.4) | 17 (27.9) |
| Years since CPR training (years, SD) | 6 (7.8) | 3.5 (4.6) |
| Likely to perform CPR on stranger (n, %) | 35 (54.7) | 31 (50.8) |
| Likely to perform CPR on family (n, %) pre training | 46 (71.9) | 41 (67.2) |
| Adequate CPR at the end of training (n, %) | | |
| Depth (n, %) | 61 (95.3) | 52 (85.2) |
| Rate (n, %) | 56 (87.5) | 54 (88.5) |
| Recoil (n, %) | 38 (59.4) | 44 (72.1) |

| Table 2 – Comparison of outcomes between participants trained on the toilet paper versus the commercial mannequin. |
|-------------------------------------------------------------|
| Toilet paper trainer (n = 64) | Commercial mannequin trainer (n = 61) |
| Mean overall CPR scores | 82 (15.9) | 84 (15) |
| Achieved a score >70% | 52 (81.2) | 52 (85.2) |
| Accurately predict a score of >70% | 57 (89) | 53 (86.9) |
| Post training willing to perform CPR on a stranger | 53 (82.8) | 48 (78.7) |
| Post training willing to perform CPR on a family member | 58 (90.6) | 56 (91.8) |

CPR = cardiopulmonary resuscitation.
trainer. This study provides preliminary evidence supporting the use of a homemade, easily accessible tool for basic compression-only CPR skill acquisition.

**Author contribution**

Dr. Ohle was responsible for study design, analysis and manuscript preparation. Ms Moskalyk, Ms. Boissonneau, Ms. Bilgasem and Ms. Tissot were responsible for data collection and manuscript editing. Dr. Mcisaac provided methodology input and oversight in addition to manuscript editing. Dr. Ohle acts as guarantor for accuracy and integrity of the manuscript.

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**Conflicts of interest**

All of the authors have neither commercial nor personal associations that might pose a conflict of interest in the subjects discussed in this manuscript.

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**Appendix A. Supplementary data**

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resplu.2021.100134.

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