Enhancing Basic Life Support Training: Development of a Real-Time Feedback Manikin

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INTRODUCTION

Background: Basic Life Support refers to the care provided to anyone experiencing cardiac arrest, respiratory distress or an obstructed airway[1]. Immediate and effective Cardiopulmonary Resuscitation (CPR), a form of Basic Life Support, can double or triple survival rates[2]. Figure 1 shows steps for bystander CPR. A Real-Time Feedback (RTF) manikin is defined as a manikin that provides feedback based on trainee performance on CPR metrics. Recent literature demonstrates that training on Real-Time Audiovisual Feedback manikins results in improved CPR quality for both laypersons and experienced healthcare professionals[3]. However, commercial RTF manikins are expensive or provide feedback on only a few metrics[4]. An affordable RTF manikin that provides feedback on each stage of CPR would make training more accessible and has the potential to drastically increase bystander CPR quality.

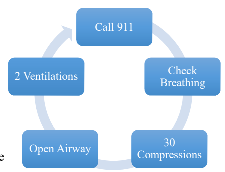

Figure 1. Bystander Basic Life Support Steps

Objective: We designed and constructed an affordable (<$100) open-sourced RTF manikin that aims to improve functional outcomes in CPR training. This manikin provides feedback on seven key metrics: compression force, compression rate, chest recoil, ventilation volume, ventilation rate, hands-off time, and airway occlusion feedback. This information is collected using electronic sensors, interfaced to an Arduino microcontroller, and displayed to trainees using text on a Liquid Crystal Display (LCD).

METHODS

This manikin is equipped with six sensors interfaced to an Arduino microcontroller. Each sensor has been calibrated with the guidance of Professor Paula Owens, a CPR-certified instructor.

- A force-sensitive resistor in the lower half of the sternum measures the force and pace of chest compressions and displays real-time feedback interfaced through the Arduino microcontroller onto the LCD. This resistor also measures any interruptions in chest compressions and percentage of full chest recoils after compressions.
- A tactile switch implanted into the manikin's nostril senses nasal airway closure.
- An accelerometer measures head-tilt angle.
- A thermistor in the mouth of the manikin detects the temperature change when hot air is delivered through mouth-to-mouth ventilations.
- A MicroSD card reader MP3 Player Module provides auditory feedback to reduce the necessity of looking at the LCD while performing CPR.
- An electronic metronome buzzes at the proper rate for CPR providing valuable audio feedback for the trainee in the stressful environment of CPR.

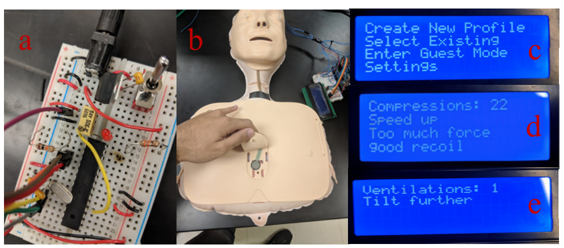

Figure 2 (a-e). Figure 2a displays a portion of the circuit; Figure 2b displays the force-sensitive resistor placement within the manikin; Figure 2c shows the initial options available to users; Figure 2d shows example feedback displayed on the LCD during compressions; Figure 2e shows an example of feedback displayed on the LCD during ventilations.

This device also allows for the creation of different user profiles for each different trainee and stores information about each session. Thus, trainees can only not only obtain real-time feedback but also review their progress over the course of weeks/months of training. A large number of profiles can be created and analysis of all prior sessions and suggestions for improvement are displayed on the LCD.

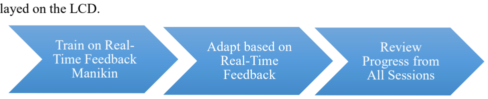

Figure 3. Recommended RTF Manikin Protocol

RESULTS

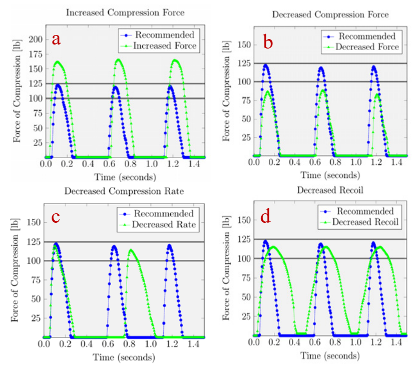

Figure 4(a-d): Data Generated from Manikin's Force Sensor. In each graph above, the blue line represents the recommended AHA guideline, while the gray lines represent upper and lower bounds for these metrics[1]. The green lines plot data from manikin sensors during training. Figure 4a displays excess compression force; Figure 4b displays insufficient compression force; Figure 4c displays insufficient compression rate; Figure 4d displays insufficient chest recoil.

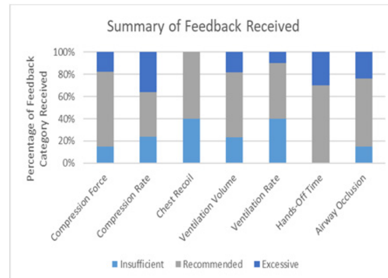

Figure 5. Trainee data collected from manikin sensors for an individual over three training sessions. At the conclusion of training, this data is presented to the trainee for each metric. For example, the trainee above had a low percentage of compressions within the recommended range of Compression Rate.

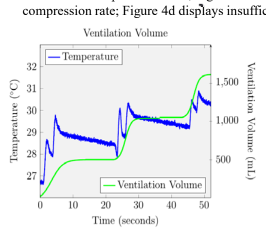

Figure 6. The thick blue line indicates the temperature measured by the manikin's thermistor, while the thin green line indicates the ventilation volume delivered, approximated from the temperature changes.

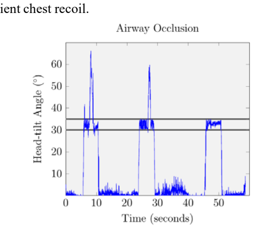

Figure 7. The thin blue line depicts airway occlusion during ventilations measured by the accelerometer; AHA guidelines recommend a head-tilt angle between 30 degrees and 35 degrees[1].

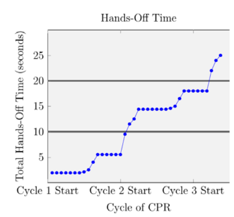

Figure 8. The blue line displays total hands-off time, defined as the cumulative time spent not performing chest compressions or ventilations in a single cycle. AHA guidelines recommend total hands-off time remains below 10 seconds[1].

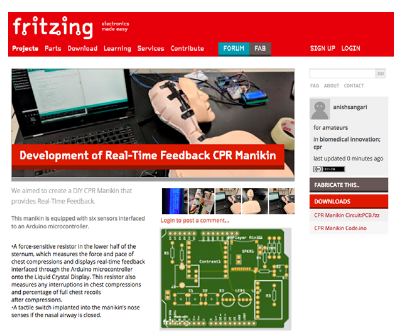

Figure 9. The RTF manikin is open-source on Fritzing, allowing anyone to create this manikin at an affordable price and convenient manner.

Figure 10. The fully operational manikin is displayed with all sensor equipment hidden under the mask and chest cavity. The enclosure above the manikin hosts the Arduino, LCD, and function selection buttons.

DISCUSSION

This manikin is open-source; every aspect of the project, including the code, printed circuit boards, a list of sensor elements, and detailed instructions on how to assemble the manikin, has been posted on Fritzing. This allows interested individuals to purchase the circuit board, download the code, and read the instructions. We approximate the manikin can be assembled by an amateur in an hour for less than $100. Therefore, this has the potential to be very appealing to low-budget universities or CPR training courses.

Table 1. Comparison of Commercially Available Manikins and Their Features

	Open-Sourced RTF Manikin	Laerdal QCPR	HeartiSense Kit	AmbuMan Next Generation	Prestan Adult Manikin	CPR Savers Basic Buddy	Nasco CPR Prompt
Compression Depth	X	X	X	X	X	X	X
Compression Rate	X	X	X		X		
Chest Recoil	X	X	X	X			
Hand Position		X	X	X			
Ventilation Volume	X	X	X	X			
Ventilation Rate	X	X	X				
Hands-off Time	X	X	X				
User Profiles	X	X	X				
Audio Feedback	X						
Airway Occlusion Feedback	X						
Under $100	X					X	X

This manikin includes several novel features when compared to commercially available manikins. First, neither audio nor airway occlusion feedback is provided on more expensive RTF manikins. Second, this manikin can be constructed at a fraction of the price of commercially available feedback devices, offering a low-cost alternative.

CONCLUSION

We have successfully created an open-source RTF manikin for less than $100. Our manikin measures seven metrics key to effective CPR: compression force, compression rate, chest recoil, ventilation volume, ventilation rate, hands-off time, and airway occlusion. Each sensor delivers accurate feedback based on AHA guidelines. We believe this product represents an attractive alternative for low-budget CPR training courses including CPR courses held in community colleges, K-12 schools, or zero-cost public training. The next step of this research is to conduct an IRB approved experiment to compare multiple commercially available RTF manikins with our open-source manikin to measure training improvement. Once the study concludes, three additional manikins will be manufactured and donated to the CPR class at Augusta University.

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