CPR TRAINING TOOL FOR HEALTH CARE PROVIDERS

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ABSTRACT: The heart is one of the vital organs of the human body whose pumping action ensures the supply of blood to every single cell of the body. This supply may be interrupted because of cardiac arrest which directly affects the drainage of blood from the heart to other body parts causing arrhythmias and is one of the underlying causes of cardiovascular death. However, this effect can be reversed by Cardiopulmonary resuscitation which is a life-saving technique. CPR is done on patients manually to revive the blood flow & pumping action of the heart, enabling it to pump effectively. To avoid the potential negative impacts of applying excess pressure on ribs during CPR which may cause rib fracture to the individual, a complete understanding of delivering CPR is required. Having this idea, we design a cost-effective CPR Controller Manikin to train health care providers & nursing students about CPR to improve their efficiency in lesser time. This training tool can take account of all the basic parameters of Quality CPR(QCPR) including no. of compressions, force delivered, depth of compressions, no. of breath, correct hand position, and air pressure delivered & displaying them on software. The gadget is distinctive as it not only aids in the training of the health care providers but also ensures that the procedure is up to the mark in delivering QCPR to the patient.

Keywords: *Heart, Cardio Pulmonary Resuscitation (CPR), Cardiac Arrest, Rib Fracture.*

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INTRODUCTION

Cardiovascular death is one of the common causes of cessation of life globally with cardiac arrest(CA) as the prominent factor (Ahern *et al.*, 2022) . The onset of CA directly affects the flow of blood by terminating the circulation due to which the heart stops its electrical activity. The kinetic energy delivered in the form of chest compression is the only way to overcome the inertial forces of major arteries of the thoracic cavity for regaining the blood flow. This occurs under Newton's law of motion that the compressive force applied during CPR results in accelerating the ceased flow of blood (Pathman J, 2015**)**. The continuation rate in patients with heart aspiratory capture out of the medical clinic is generally low, a few patients can recuperate after proper resuscitation including the early way to deal with emergency care, early CPR, early defibrillation and early development cardiovascular life uphold (Travers *et al.*, 2010).

Many studies reveal the significance of delivering compression in this life-threatening situation as it unanticipatedly elevated the flow of blood (*Maier et al.,* 2015**,** Ewy, 2016**)**. However, this is only possible when a rescuer with knowledge of Basic Life Support(BLS) is around with expertise in the chest compressions and rescue breathe /Resuscitation procedure (Travers *et al.*, 2010). As the onset of Cardiac Arrest is more frightening if it occurs away from the health care centers because the chances of survival of an individual decrease due to the unavailability of medical staff. Prioritizing this, in 2005, the International Liaison Committee on Resuscitation bring to the fruitful end on broad arrangement for out of medical clinic resuscitation, specifying that the most significant originator of endurance from unexpected heart failure is the presence of a trained individual who is prepared, capable, and equipped to act. Moreover, the committee also focused on Quality CPR with the set parameters including no. of compressions and ventilation for adults and infants ("The International Liaison Committee on Resuscitation (ILCOR) Consensus on Science With Treatment Recommendations for Pediatric and Neonatal Patients: Pediatric Basic and Advanced Life Support", 2006).

CPR represents Cardiac Pulmonary Resuscitation. It's a procedure that is performed whenever an individual has heart failure which occurs due to interruption inflow of blood from the heart to the brain. When an individual has heart failure, the usual practice is to perform chest compression and mouth-to-mouth breathing, which is also called rescue breathing. There are 30 compressions and 2 mouth-to-mouth breaths per cycle, with 100 to 120 compressions for every minute (Meaney *et al.*, 2013**)**.

Delivering Quality CPR is critical for the survival of an individual. The prominent parameter of quality CPR is the proper delivery of chest compression and ventilation. Continuous chest compressions with reduced interruptions are required for the oxygenation of tissues thus achieving the blood flow (Abella *et al.,* 2007). Sufficient Compression Depth is also a critical factor of Quality CPR. The 2010 Guidelines of the American Heart Association instructed the critical value for compression depth of ≥ 2 inches for adults in with each compression. Ventilations of adequate volume also ensures the continuity of life (Li *et al.,* 2017). This life-saving mechanism also requires the information of the pressure applied and the correct position of the hand on the chest of the sufferer along with proper training to revive the blood flow. Moreover, the clinical students and the nursing staff cannot play out their practices on the real body because it is damaging as the ribs can be broken in this kind of practice (Weidenauer *et al.,* 2018).

Currently, the CPR regulator manikin is accessible for these practices ("SimTalkBlog", 2022**)**. These sort of manikins are useful for the training of clinical understudies and nursing staff as they upgrade the deficiencies in delivering Quality CPR. This Mechanical chest compression equipment are intended to convey compressions of reliable rate and profundity and give a chance to decrease the recurrence and length of delays in compressions. Manikin training with mechanical chest compression equipment has exhibited upgrades in CPR quality (Esibov *et al.,* 2015**)**.

Different types of manikins are already available for the training of health care providers. A proposed study on nursing students was conducted to evaluate the performance of diverse categories of manikins. It indicates that three different groups began preparing with Mini Anne. Mini Anne is an idea that incorporates viewing intuitive recordings while training on an inflatable doll with a head and chest. The training followed the Swedish Resuscitation Council's 2005 rules, which meant 30 compressions at a pace of 100/min at a depth of 4 to 6cm. Two ventilation, each with a volume of 500 to 600 ml follows compression. Group 1 has an experienced person, who guides them during training. Gatherings 2 and 3 utilize similar ideas for preparing, however, there are no instructors. Group 1 was of manikin without any feedback, while group 2 was of the manikin with graphical feedback and group 3 was of voice advisory manikin. The point of this examination was to assess the impacts of various kinds of input/feedbacks on CPR abilities among nursing students. The outcome demonstrates that self-preparing with Mini-Anne and manikin with graphical feedback (Group 2) gave the good caliber of CPR skills as compare to other groups i.e. Group 1 and Group 3 thus indicating the significance of this training tool. Moreover, it is also evident that the manikin with feedback or with some set testing parameters is better than manikin without feedback (Hedberg and Lämås, 2013**)**.

Recent advances have done a lot of work for the purpose, like we have True CPR™ guidance gadgets from physical control, CPR-EZY™, Q-CPR™ (2022), accessed in the market, but it is very expensive, so many institutes do not have this device.

A.E. Tomlinsonet al., make use of load cell along with displacement sensor for the monitoring of significant parameters of CPR which includes compression force and depth (Tomlinson *et al.,* 2007).

Stanely et al. utilize more hardware parts and complicated circuitry including pneumatic damper and valves which increases the overall cost of the CPR manikin as compare to our design making it inaccessible to every health care organization, especially in the third world countries. Moreover, the damper present in the system absorbs the energy delivered by the trainee in every delivered compression, therefore the compressive forces to deliver the QCPR up to the optimal depth needs more effort, thus decreasing the motivation of a trainee to learn this procedure properly due to the fatigue (Stanley *et al.,* 2012).

In comparison to the above-mentioned devices, the proposed manikin can be used for training as well as for testing purposes. Moreover, this device is user-friendly, cost-effective, and can perform quality CPR procedures and it can adjust in manikin easily to reveal results on the output screen. If the health care professional finished two cycles as per set parameters, at that point the palpitations will occur which tells that the health care professional carried out their responsibilities impeccably. In this way, the proposed manikin is unique from different available manikins.

MATERIALS AND METHODOLOGY

Proposed Architecture: The proposed design of CPR-controlled manikin comprises several components comprising sensors, vibrators, and counters. Figure 1 shows the complete working principle of the proposed system. An airflow sensor is used for measuring the air volume in the air passage path and for detecting the hand position on the chest, position sensors are used, which helps to show the accuracy of the hand placement position for CPR. A ventilation bag is placed inside the manikin for giving mouth-to-mouth breath. FSR sensor will detect the force of hands during the compression of the manikin and provide a signal to the Arduino UNO. If the health care provider performed two cycles of CPR that is 60 compression and two mouth-to-mouth breaths in one minute, then palpitations will occur otherwise it will display ‘failed’ on the screen.

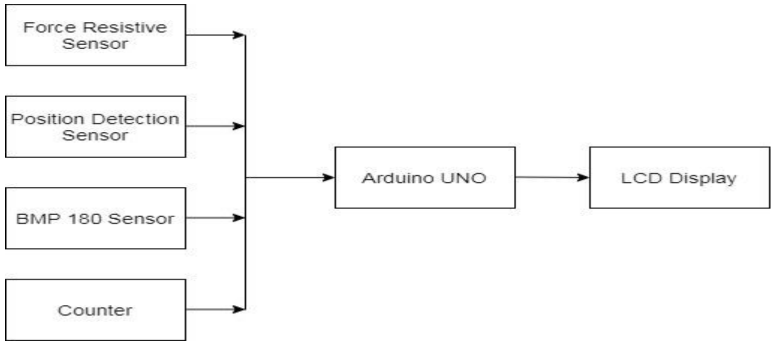

Figure 1. Block Diagram of CPR-Controlled Manikin

Mechanical Assembly: In the proposed design, there are different sensors such as airflow sensor, position detection sensors, and FSR sensor are attached to manikin for the monitoring CPR operation and to provide a complete controlled prototype for the learning perspective among trainees or health care staff. In this design, economical manikin having soft and plastic material is used, which has the features such as long chest and easily movable structures like head and chin for the procedural activities. Other than plastic material, there are many materials used in different manikins, but they are usually expensive. Figure 2 indicates the assembling of all the electronic components integrated with mechanical parts in the manikin.

Figure 2. Proposed CPR Training Tool

Mathematical Modeling of the Manikin:
This training model is a simplified mass spring system whose mathematical equation can be derived from Newton's law of motion as:

$\sum F = Ma$ (1)

On expanding acceleration in terms of displacement, equation 1 can be written as:

$F_{app} - F_k = M\ddot{x}$ (2)

$F_{app} - kx = M\ddot{x}$ (3)

$F_{app} = M\ddot{x} + kx$ (4)

where $\sum F$ = sum of all forces
M = Mass
a= acceleration
F_{app} = Applied force
F_k = Opposing force generated by spring
k = spring constant
x = displacement

CPR-controlled manikin workflow: To detect and analyze the pressure parameter in the process of CPR, FSR is used which calculate the force exerted by the trainee or health care staff on the chest in Newton. The sensor was placed in the middle of the chest. Whenever the trainee or health care staff applied force on the sensor, there was a change in resistance and conductance of the sensor, as a result, force is calculated and shown on the LCD in Newton. In FSR, the pressure applied is inversely proportional to the therefore, due to the increase in pressure, the resistance is decreased. This is the basic phenomenon for the measurement of force. The sensor is integrated with the Arduino Uno board to convert the analog values into digital ones and show them on the LCD. The value of force is displayed on LCD from the FSR in Newton. When there is no pressure, the value of the resistance reaches up to 1MHz. A voltage divider is created to produce a variable voltage which was read by the microcontroller.

Table 1. Random Force Measurement from the Proposed Design.

FORCE (N)	RESISTANCE (K ohms)	VOLTAGE (volts)
450	100	4.090909
460	97	4.129264
470	88	4.21147
480	77	4.308797
490	67	4.398564
500	60	4.464286
510	55	4.513274
520	51	4.553415
530	44	4.616725
540	23	4.795737
550	20	4.824561

Table (1), shows the data collected by the random force measurement from the prototype. The range of a force is selected according to the American Heart Association recommendation in which pushing force to compress the torso around 3.8 to 5cm, which requires 450 to 550 Newton of force.

Figure 3 shows the relationship between the force versus resistance and voltages which concludes that as force increases both parameters decrease linearly.

The sensors are connected to the micro-controller. The micro-controller is the dynamic gadget which is controlling the entire program and afterward, it gives the yielded output on the LCD screen. When trainee or health care staff will play out the pattern of CPR as per the set standard parameters (YES), at that point the palpitations will happen underneath the ear on the neck, and if the pattern of CPR won't perform as per the parameters extend (No), at that point, the alert will begin ringing. Figure 4. shows the process flow diagram of the proposed design.

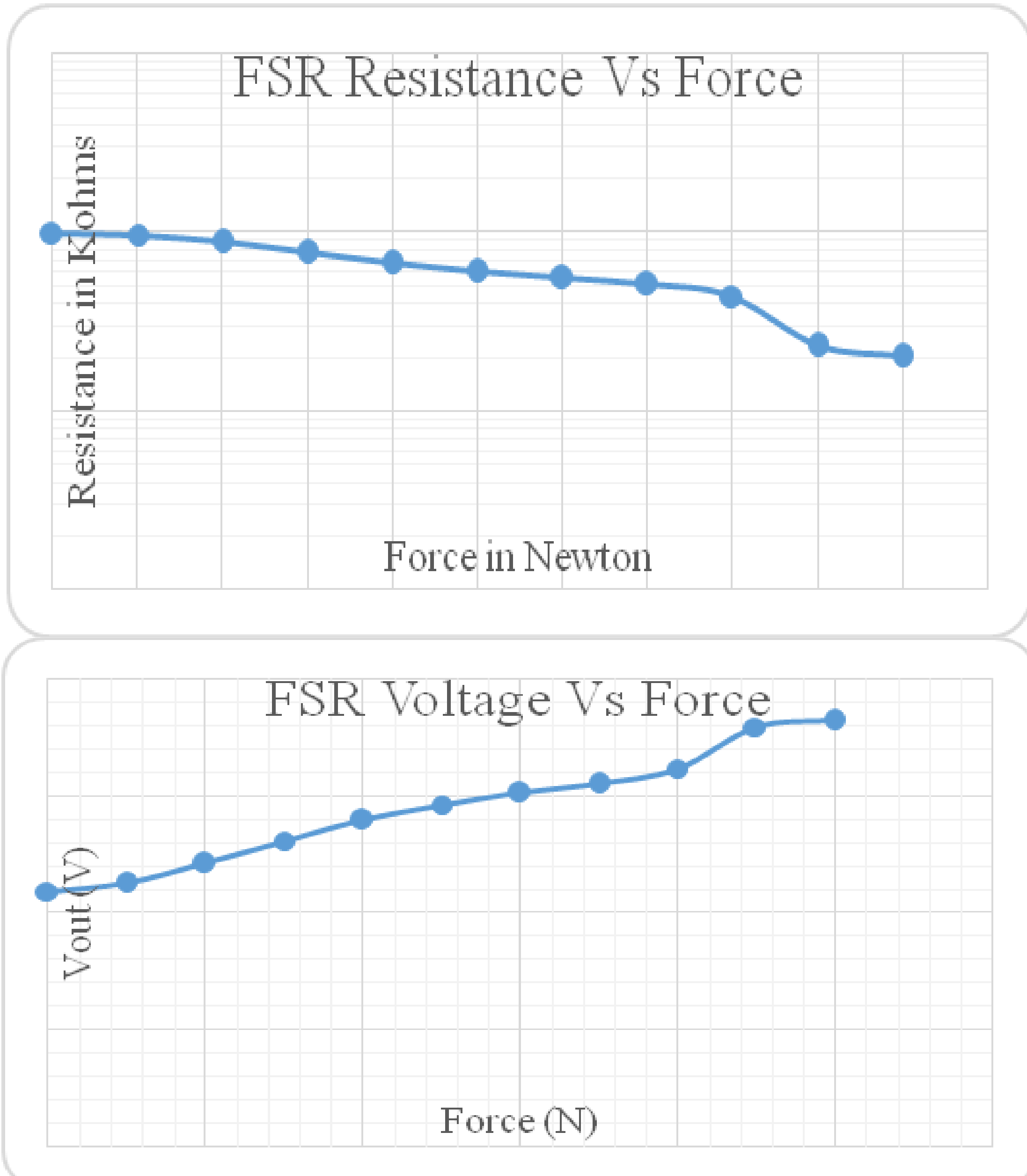

Figure 3. Graphical Representation of Random force measurement from the proposed design

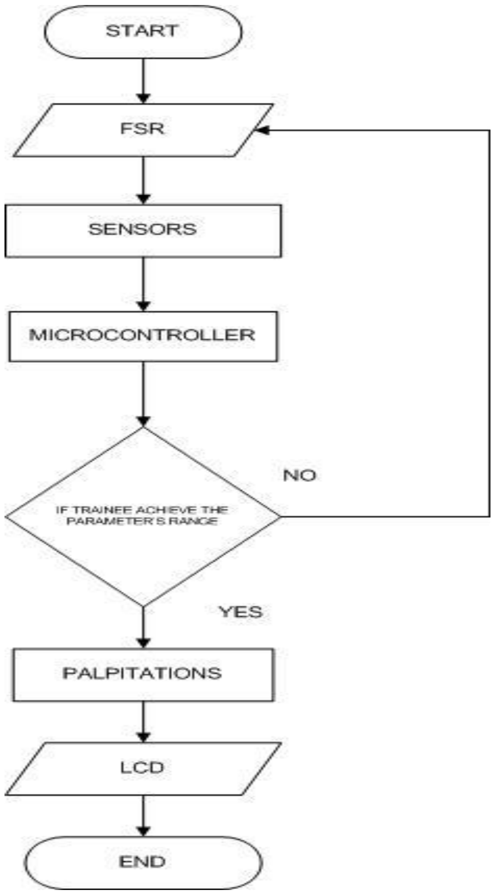

Figure 4 Process Flow diagram of the proposed design

RESULTS

The design counts the force of CPR and breathe, also it can measure the force of compression in Newton. In CPR there are 30 compressions at the rate of 100/minute and 1 mouth-to-mouth breathes per cycle and when you reach the 30th compression the breath green bar changes into the red for reminding you to give mouth-to-mouth breathing. There is also a bar that indicates the depth and release of compression. When we give mouth-to-mouth breath to the patient then it also measures the air pressure and counts the mouth-to-mouth breathe. When we achieved two cycles (60 compressions and 2 mouth-to-mouth breathe) then it will show the "target achieved" on the output screen and palpitations will occur. It can also detect the correct hand position.

To evaluate the performance and verify the results of the proposed design, the data has been gathered by the 10 Trainee/health-care staff. The purpose of this test is to identify the mistakes of participants during training, the mistake was observed is to compress the chest too fast or too slow. This can be identified by comparing the standard range of 100 to 120 compressions per minute of CPR in a duration of fewer than 10 seconds. Table II includes the demographic data of the test performed by 10 participants, every participant performs CPR operation at least 10 times to verify the accuracy of the design.

In table II, C1 is the number of participants (trainee/health care staff), C2 is the normal range of CPR compression rate, C3 is the compression rate tested in the proposed design, C4 is the mean value of the compression rate of testing design, C5 is the duration and C6 is the mean value of duration perform in seconds also it included the feedback consists of two questions of individual participants which are labeled in C7 and figure 5 represent the graphical analysis of the proposed design.

Table 2. Demographic Data from the Proposed Design.

C1	C2	C3										C4	C5										C6	C7	
																								Q1	Q2
A	100	100	110	110	120	110	160	110	120	140	120	120	0.5	0.8	0.3	0.4	0.5	0.3	0.3	0.3	0.4	0.4	0.42	2	1
B	102	110	120	110	130	100	100	130	99	89	70	106	0.4	0.8	0.3	0.3	0.4	0.8	0.3	0.3	0.4	0.4	0.44	1	1
C	104	110	130	110	120	130	120	80	120	120	130	117	0.5	0.3	0.3	0.3	0.4	0.3	0.4	0.3	0.8	0.5	0.41	2	1
D	106	120	120	80	100	110	130	140	120	130	140	119	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.8	0.3	0.43	2	1
E	108	110	160	140	100	120	100	100	110	120	130	119	0.3	0.5	0.5	0.5	0.5	0.5	0.3	0.5	0.3	0.3	0.42	2	2
F	110	160	120	120	110	110	100	120	120	130	120	121	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.8	0.4	0.8	0.41	1	1
G	112	150	70	50	80	80	100	100	100	100	100	93	0.4	0.5	0.3	0.3	0.3	0.5	0.3	0.5	0.5	0.4	0.4	1	1
H	114	130	130	140	130	110	100	100	120	100	140	120	0.5	0.5	0.3	0.3	0.3	0.5	0.4	0.5	0.3	0.5	0.41	2	1
I	116	120	100	160	100	100	100	100	140	139	120	118	0.5	0.8	0.3	0.4	0.5	0.3	0.3	0.3	0.4	0.4	0.42	2	1
J	120	100	100	100	130	110	130	100	120	130	140	116	0.3	0.3	0.3	0.4	0.5	0.3	0.5	0.5	0.5	0.5	0.41	3	2

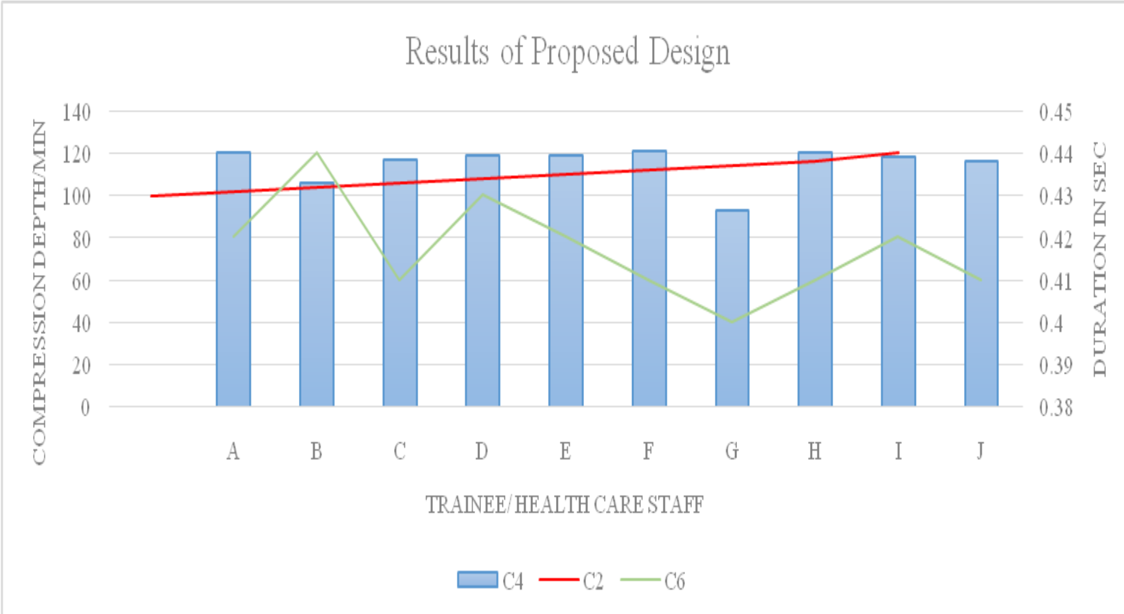

Figure 5 Graphical Reprsentation of the proposed design

Figure 6, depicts that almost all test results were under the normal range, which verifies the accuracy and precision of the proposed design. In the feedback, two questions were asked orally to the individual participants. All questions were rated in three categories: 1= Good, 2=Average, and 3=Unsatisfactory. The first question comprises the feedback related to the interface of the proposed design, and the second question comprises the self-evaluation of the individual trainee in the perspective of gaining a complete understanding of the CPR operation. Figure 6 shows the graphical representation of the feedback conducted for the proposed design in which most of the trainers were satisfied with the training of the CPR and also suggests the improvement for the interface.

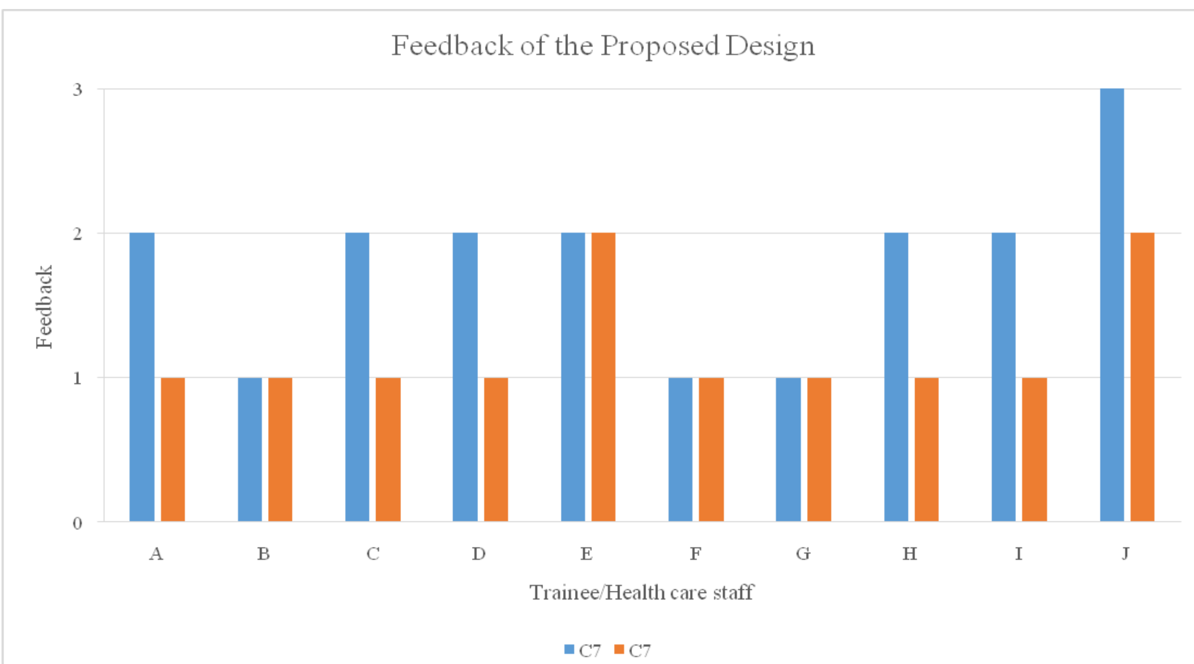

Figure 6 Feedback of Design

Conclusion: CPR controller manikin is a gadget for clinical students through which they can learn this life-saving technique with precision. The principal challenge for clinical care staff is to give the most ideal therapy.

This can be best accomplished by both learning and practice. For figuring out how to be proficient, instructive targets must be characterized and training must have a quantifiable, positive effect on health care provider's clinical practice. This reveals the significance of the monitoring of training procedure in delivering QCPR to ensure that/so that the appropriate pressure is applied on the chest of the patients and proper ventilation is provided for the revival of blood flow. For the quantification of the training of the QCPR, feedback systems accelerate the performance of an individual.

In the proposed gadget, at the point when the health care provider performs chest compression and mouth-to-mouth breath, the microprocessor used its internal instrumentation to quantify the learner's pressure and ventilation performance. CPR controller manikin is to provide instant feedback and software data for objective scoring of trainee's performance. Through this manikin, the learner can play out all the parameters accurately as per their ranges. We can accomplish all the targets which we referenced previously.

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