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Article

Portable equipment and interface to train in CPR based on monitoring the applied force

Equipo portátil e interfaz para el entrenamiento en RCP basado en la monitorización de la fuerza aplicada

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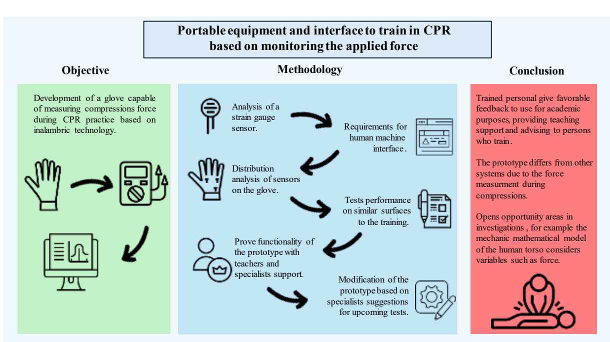
Abstract

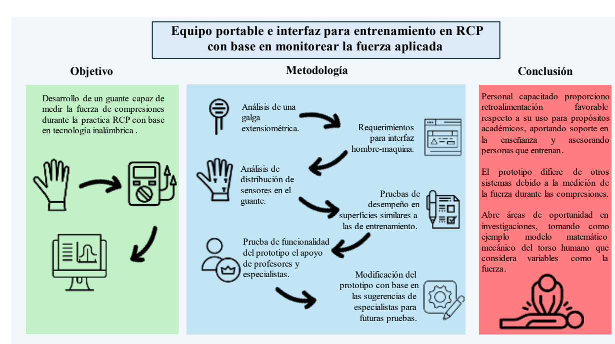
A percentage of sudden cardiac arrests that occurred outside the hospital, there were no present people to assist in, so it is necessary that people need to be easily trained with equipment capable to feedback concisely to their performance, due to apply a quality CPR may increase survival to persons who suffers cardiac arrests. This article shows the development of training CPR equipment, based on measuring the force during compressions. For the prototype, two strain gauges were used to measure force, also having an embedded system to recollect data to subsequently send them to a graphic interface to be interpretated by persons who are training. The force variation from each sensor is due to their position, therefore, an average of measurements was made, resulting in a variation range between 220 N and 340 N for the applied force during compressions. This equipment can be useful as base for data acquisition



Cardiopulmonary Resuscitation, Data acquisition, Training

Resumen

En un porcentaje de paros cardiacos que suceden fuera del hospital no hay personas que auxilien, es necesario que las personas tengan facilidad de capacitarse con equipo que retroalimente concisamente su desempeño, ya que aplicar una RCP de calidad provoca que las posibilidades de supervivencia crezcan ante un paro cardiaco. Este artículo presenta el desarrollo de equipo para entrenamiento en RCP, basado en medir fuerza durante compresiones. Para el prototipo se utilizaron dos sensores tipo galgas extensiométricas para medir fuerza, contando con un sistema embebido que recaba datos para posteriormente mandarlos a una interfaz gráfica para su interpretación por personas que usen el equipo. La variación de fuerza detectada por cada sensor se debe a su posición, por lo tanto, se hizo un promedio dando como resultado una variación de 220 N a 340 N para la fuerza ejercida durante compresiones. El desarrollo del equipo puede servir como base para adquisición de datos.



Resurrección cardiopulmonar, Adquisición de datos, Entrenamiento

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Introduction

Sudden cardiac arrests are a substantial problem because they represent a percentage of worldwide deaths. The first minutes after suffering a cardiac arrest are very important due to while more the time passes, the possibility of surviving will decrease if CPR is not applied. CPR can duplicate or triplicate the survival of a person who is facing a cardiac arrest, for which is necessary to count with trained staff in its application.

When a person is trained in CPR, it should be considered different parameters that defines the quality of the practice. The most important parameters are the necessary force to compress the torso at least 5 cm, letting a complete thoracic expansion in a period of 100 to 120 compression per minute, also it's indispensable to minimize the quantity of interruptions between compressions (Lavonas, et al., 2024).

Research and technological developments have been released to improve the technique and learning of CPR, in addition, there are portable equipment capable of performing automated CPR (Patent No. WO 2010/148529 A1, 2010), and devices similar to the human torso to simulate CPR techniques (Patent No. WO 2010/136626 A1, 2010; Patent No. WO 2010/147129 A1, 2010; Patent No. WO 2010/130754 A1, 2010). Thanks to those developments, there are equipment to train or test skills (Patent No. WO 2012/141586 A1, 2012; Patent No. US 2013/0330698 A1, 2013), moreover they provide visual assistance referent the CPR development (Patent No. WO 2013/093757 A1, 2013), they also measure the heart rate or blood flow of people receiving CPR (Patent No. WO 2017/013278 A1, 2017).

About 150 thousand to 250 thousand cardiac arrests occurred every year in México, with survival rate less than 12 %, nevertheless if you apply a quality CPR then the survival rate may increase (Celaya Cota, 2024; Previdi, et al., 2024). Hence, having equipment to train people in quality CPR, could improve the survival rate. Notwithstanding, there is equipment to train people in CPR, a considerable quantity of them do not show specific data about the technique performed during the training to understand if the CPR was performed effectively.

Some equipment only focused to simulate human torsos without considering feedback with base in measuring the variables that defined the performance of the person undergoing training (Patent No. WO 2010/148529 A1, 2010; Patent No. WO 2010/136626 A1, 2010; Patent No. WO 2010/130754 A1, 2010). Notwithstanding there are multiple equipments based on CPR through augmented and virtual reality, they do not provide physical data that could approximate in a real practice or emergency (Cheng, et al., 2024). Other equipments are destined to monitor the performance during CPR in a patient, however, they do are not destined to be used in during training (Patent No. WO 2017/013278 A1, 2017; Patent No. US 11348686 B2, 2022). Almost all the devices that capacitate and train in CPR do not consider specific data to provide complete feedback in the performance (Patent No. WO 2012/141586 A1, 2012; Patent No. WO 2013/093757 A1, 2013; Patent No. US 2013/0330698 A1, 2013; Patent No. WO 2017/013278 A1, 2017; Patent No. US 11348686 B2, 2022). Several devices are based on collecting data use accelerometer to measure displacement, some examples are the equipments based on smartphones and theirs integrated sensors (Gruenerbl, Pirkl, Monger, Gobbi, & Lukowicz, 2015).

There are technologies based on triboelectric nanogenerator which provide physical health monitoring, they could serve as support in the recovery of people who suffered sudden cardiac arrest (Pandey, Maharjan, Seo, Thapa, & Sohn, 2024; Tang, Fu, & Xu, 2024). Nevertheless, it is still necessary to count with trained personnel in case complications arise during recovery.

This article shows the development of an equipment for the capacitation in CPR training, considering measurement of the force applied during compressions, as well as a graphic interface to show feedback to allow knowing the performance and opportunity areas.

Materials and Methods

As a first point, the strain gauge BF350 function was analyzed, which works based on encapsulated meters, temperature compensation and fluency. This is necessary to know the necessities of data acquisition through analog to digital converter.

In addition, it was reviewed the conditioning circuit requirements of the signal to obtain a value that would show the force.

Those points with the purpose of performing tests and analyzed the strain gauge behavior, evaluate under wrist conditions and positions its response, as well as develop a graphical interface to data acquisition, Figure 1.

This first test stage defines the interface to obtain proper readings and utility parameters, as well as versatile in its visualization.

Box 1

a)

b)

Figure 1
a) Graphic interface starting screen b) Screen to show dynamic graphs

Through a test circuit and serial communication to a personal computer, Figure 2, we seek to realize a data parameterization, evaluating the strain gauge performance.

Box 2

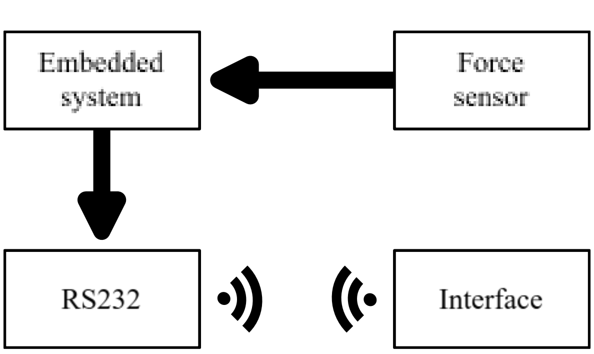

Figure 2
Testing circuit connection scheme

Being of vital importance to noticed that evaluating only one point it is faced the necessity to distribute the measurement through the palm, determining the adequate points of measurements, the points where it is applied the force during CPR.

Box 3

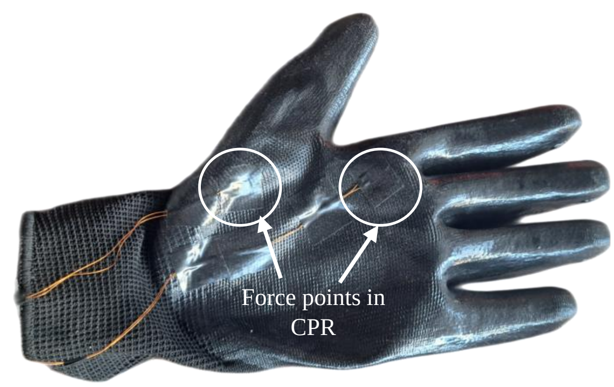

Figure 3
Distribution and position of the strain gauges over the testing glove

It is worth mentioning that those measurement points were suggested by trained personnel in the medical care area of the educational institution, ENSAIN.

Hence, we will proceed to obtain databases with values from different tests, in order to optimize the variable management and the glove performance.

Methodology

Tests were performed on similar surfaces to the training equipment, in order to obtain a database with the previously values collected by the prototype. With this data it will be optimized the management of variables, afterwards it could be interpreted in a database.

Box 4

Table 1
Sensor 1 behavior data

V out (V)	Mass (kg)	Force (N)
0	0	0
0.06636363	0.058	0.568806
0.17454545	0.145	1.422015
0.24545454	0.296	2.902872
0.35454545	0.346	3.393222
0.41545454	1.003	9.836421
0.44272727	2.335	22.899345
0.48272727	3.15	30.89205
1.04727272	4.668	45.779076

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Box 5

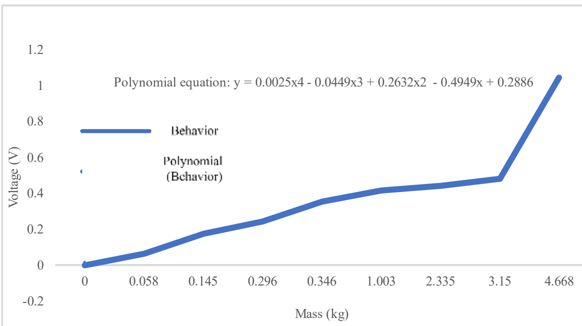

Figure 4
Sensor 1 behavior and response

With the database obtained during the tests, data collected data from diverse compressions, the same ones that were applied with a fixed pressure to evaluate fixed data, subsequently compressions and force applications will vary.

The data was graphed with the purpose of achieving a polynomial regression equation and obtain the sensor response through different variations. Those equation would allow to be embedded in a microcontroller for them processing in CPR application. The steps with the sensor 1 response were equally applied to the sensor 2. Obtaining characteristic curves and equations from the two proposed points.

Box 6

Table 2
Sensor 2 behavior data.

V out (V)	Mass (kg)	Force (N)
0	0	0
0.080769231	0.204	2.000628
0.106923077	0.262	2.569434
0.188461538	0.405	3.971835
0.213076923	0.608	5.962656
0.290769231	0.911	8.934177
0.508461538	1.307	12.817749
0.530769231	2.006	19.672842
0.625384615	3.526	34.579482

Box 7

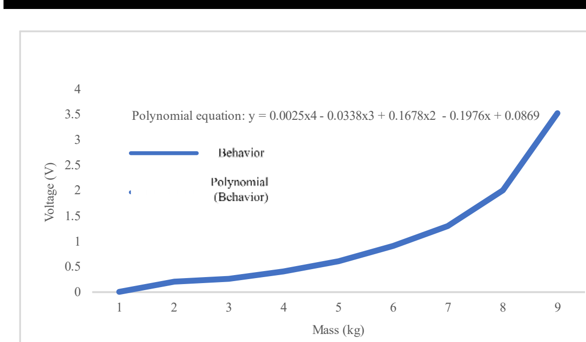

Figure 5
Sensor 2 behavior and response

Initially, with the prototype assembled for testing, tests were carried out to prove its functionality, debug errors and improve initial prototype aspects. In order to achieved with what was proposed, teachers and specialists in the ENSAIN facilities of the UAQ Nursing Faculty provided help during the process. Inside the facility, training equipment (manikin) was provided to practice and train in CPR.

Box 8

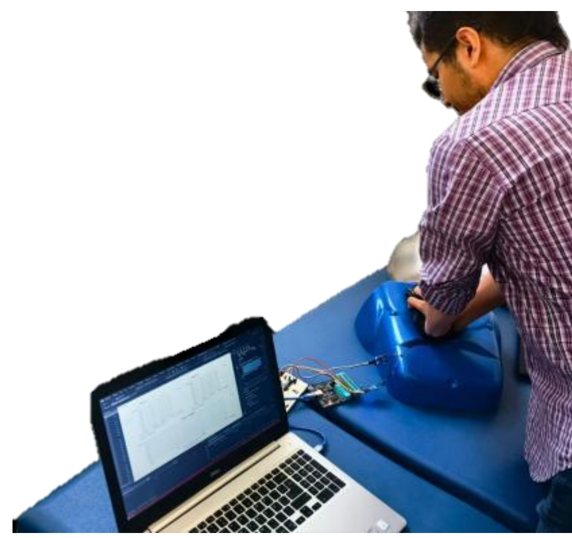

Figure 6
Tests of the training CPR equipment prototype.

During rehearsals, a brief training was received about a correct compression application for CPR practice. With this it was confirmed the prototype functionality to the tests to be carried out by specialists.

The teachers and specialists provided feedback respect to the equipment size, proposing a smaller circuit design for the data reception by the sensors. A second observation was about the sensors' location to measure the compressions force. The updated key points were increased by one where all the body force is applied during compressions, those points are indicated in the Figure 7.

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Box 9

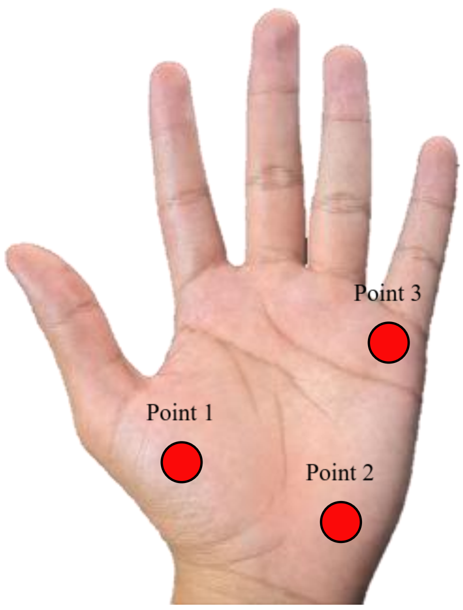

Figure 7
Force evaluation points updated

Corrections, modifications and improvements were suggested and proposed, the prototype was modified for the upcoming tests that will be carried out in the ENSAIN facility.

Results

The proposals modifications are shown in the Figure 8. They consist of the development and mounting of a PCB, in which the embedded system is mounted. In addition, a power supply with lithium-ion rechargeable batteries and a voltage regulator were added. Finally, the sensors were mounted in two of the key positions to measure the force, the selected points are in the section where maximum force is applied during compressions.

Box 10

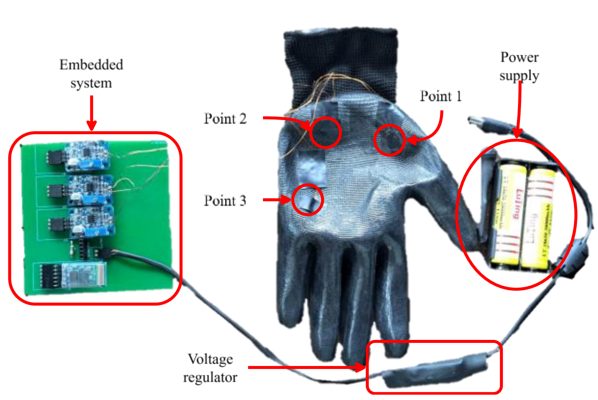

Figure 8
Prototype with embedded system

Subsequently, final tests were performed in ENSAIN facility along trained staff in CPR practice.

Behavior data by the sensors in the last tests was obtained to prove its functionality when performing compressions. The data obtained from the first and second sensor is shown graphed in Figures 9 and 10, which are in the positions 1 and 2 shown in Figure 7, respectively. It is possible to deduce that the first sensor performance is more sensitive to detect force during compressions due to the multiple peaks that appear. The force range, that is possible to notice in the behavior peaks of the first sensor, vary between 600 N to 640 N.

Box 11

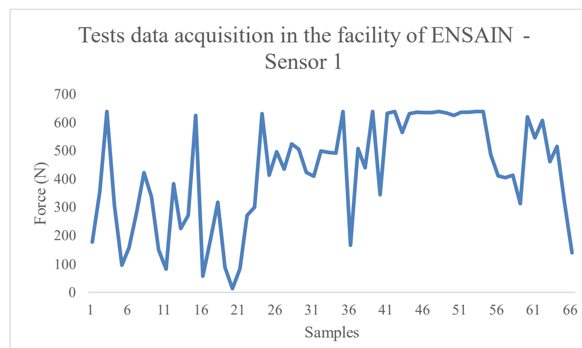

Figure 9
First sensor data obtained from tests.

It is deduced that the second sensor is less sensitive to detect the force changes between compression due to its graphed behavior. The range in which the applied force on the second sensor varies during tests is from 10 N to 60 N, due to that it is difficult to detect changes between compressions. Until the end of the tests, where it was decided to apply more load over the second sensor, it is possible to noticed there is two peaks that vary between 100 N and 150 N, approximately.

Box 12

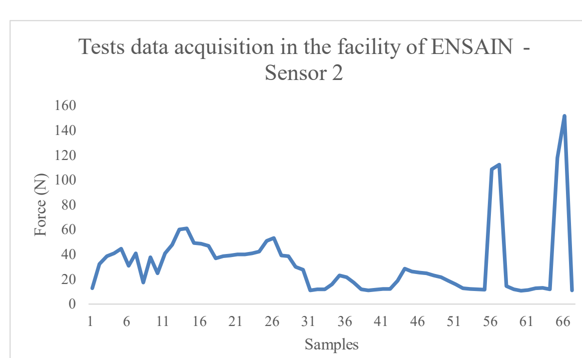

Figure 10
Second sensor data obtained from tests

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The difference between both sensors measurements is due to the hand outline is not a uniform surface, therefore, each sensor undergoes distinct strain on different hand points, triggering a different variation in the applied force on each sensor.

The average behavior between both sensors is shown graphed in Figure 11, acquiring a similar behavior to the first sensor but reducing its varying force range due to the small sensitivity of the second sensor. The peaks values range between 220 N to 340 N in this case.

Box 13

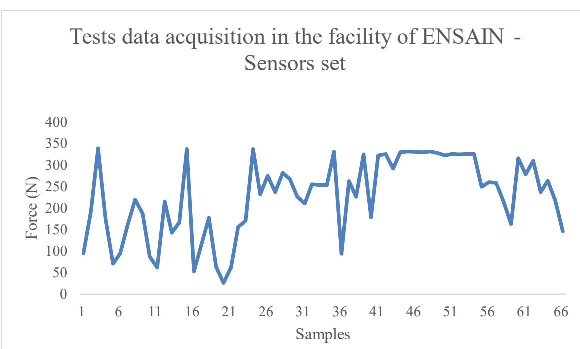

Figure 11
Avarage data obtained from tests

Graphical interface is characterized by measuring the applied force in real time and showing its behavior in dynamic graphs during compressions to interpret through CPR practice capacitation, as well as it can store force data collected in a text file.

Conclusions

Similar to the first tests, there were still areas for improvement and suggestions by trained personnel, in addition it was provided favorable feedback regarding the feasibility of using the equipment for academic purposes, providing teaching support and advising to people who want to introduce themselves to CPR practice.

Prototype development is of great importance due to the educational aspect provides a real time feedback to the persons who trains. Regarding the part of collecting data, the prototype differs from other systems due to it is not based on the torso displacement during the compressions, instead it measures the applied force to achieve a compression.

Having a resource to measure force during compression in CPR practice opens opportunity areas due to there exist investigations in which it is proposed a mechanic mathematical model of the human torso that considers variables such as compressions frequency, compression displacement, recoil and applied force.

Mathematical model of the human torso can be related to a machine that performs the action of CPR automatically, based on the data acquisition that was developed in this article, due to it may help in controlling the performance of some systems to do the compressions.

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Seseña, Hiram: Contributed to the project idea and development of the prototype.

Zuñiga, Mariana: Contributed to the redaction of this article.

Nápoles, Elías: Contributed to the redaction of this article.

Martínez, Moisés: Contributed to the research method and contact to CPR specialists.

Availability of data and materials

The data of each sensor behavior response was obtained through experimentation, it is shown in Table 1 and 2.

The data obtained of each sensor behavior during tests could be obtained through e-mail contact.

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Abbreviations

CPR Cardiopulmonary Resuscitation

ENSAIN Enfermería en Salud Integral

UAQ Universidad Autónoma de Querétaro

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Antecedents

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Discussions

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