International Journal of Zoology and Applied Biosciences
Volume 10, Issue 6, pp: 672-675, 2025 (Special Issue)
https://doi.org/10.55126/ijzab.2025.v10.i06.SP138
ISSN: 2455-9571
http://www.ijzab.com

Research Article

AN ADAPTIVE SUPPORT SYSTEM FOR ENHANCING EMERGENCY CPR RESPONSE

[1*]Rajeswari M, [2]Sindhu D, [3]Swathi T, [4]Tehseen Javed and [5]Linisha NM

[1*]PERI College of Physiotherapy, Chennai - 48, Tamil Nadu, India
[2]PERI Institute of Technology, Chennai- 48, Tamil Nadu, India
[3]PERI College of Arts and Science, Chennai - 48, Tamil Nadu, India
[4]PERI College of Pharmacy, Chennai - 48, Tamil Nadu, India
[5] PERI College of Nursing, Chennai - 48, Tamil Nadu, India

Article History: Received 6th October 2025; Accepted 27th November 2025; Published 1st December 2025

ABSTRACT

This study presents an adaptive emergency Cardiopulmonary Resuscitation (CPR) support system designed to improve the accuracy, consistency, and timeliness of life-saving CPR procedures. The proposed system integrates pressure sensors, real-time feedback modules, microcontroller-based processing, and automated compression-quality assessment to guide responders during cardiac arrest events. The system evaluates chest compression depth, rate, recoil, and hand placement using a multi-sensor array, while a haptic–audio feedback unit dynamically adjusts instructions to ensure guideline-compliant CPR. Experimental evaluation using a manikin-based simulation demonstrated a 36% improvement in correct compression rate and a 42% reduction in performance variability compared with manual CPR without guidance. The findings highlight the importance of adaptive, technology-assisted CPR systems in enhancing survival outcomes during out-of-hospital cardiac arrest.

Keywords: Cardiopulmonary Resuscitation, Emergency Response, Adaptive Feedback System, Compression Quality.

INTRODUCTION

Cardiac arrest remains a critical global health concern, accounting for millions of deaths annually. Survival rates depend heavily on the immediate initiation of high-quality Cardiopulmonary Resuscitation (CPR), particularly during out-of-hospital cardiac arrest situations where professional medical help may be delayed. Conventional CPR performance, however, is often inconsistent due to insufficient training, stress, fatigue, and poor real-time decision-making. Studies also indicate that incorrect compression depth, inadequate rate, and incomplete chest recoil significantly reduce the effectiveness of life-saving interventions. Technological advancements have enabled the development of digital, automated, and sensor-integrated solutions to assist responders in delivering CPR that aligns with international guidelines. These include wearable feedback devices, automated external defibrillators (AEDs) with CPR prompts, and manikin-based training tools. However, most existing systems lack adaptability, real-time performance analysis, and personalized feedback that adjusts dynamically during compressions. This study proposes an adaptive emergency CPR support system that leverages sensor fusion, microcontroller-based real-time processing, and intelligent feedback modules. The objective is to provide a robust, portable, and user-friendly solution that enhances CPR performance quality in emergency scenarios, potentially improving patient outcomes.

High-quality cardiopulmonary resuscitation (CPR) is widely recognized as the most critical predictor of survival in cardiac arrest, and numerous studies highlight the persistent challenge of maintaining guideline-compliant compressions in real emergency settings. Early foundational investigations demonstrated that real-time audiovisual feedback significantly improves compression rate, depth, and rescuer consistency (Ashton *et al*., 2002;

*Corresponding Author: Ms. M Rajeswari, PERI College of Physiotherapy, Chennai – 48, Tamil Nadu, India Email : publications@peri.ac.in.

Abella *et al*., 2007). Subsequent research further reinforced these findings, showing that immediate performance feedback reduces rescuer variability and enhances CPR outcomes (Hostler *et al*., 2011; Hill *et al*., 2018). Comprehensive evaluations have consistently shown that feedback-based systems outperform unguided CPR in both training and clinical environments (Couper *et al*., 2019; Baldi *et al*., 2020). In parallel, international CPR guidelines have long emphasized the importance of adequate depth, rate, recoil, and minimal interruptions to maximize patient survival (Berg *et al*., 2010; Greif *et al*., 2015). However, maintaining these parameters manually is difficult, particularly under fatigue and high-stress conditions, driving interest in sensor-augmented CPR technologies. The emergence of force-sensitive resistors (FSRs), inertial measurement units (IMUs), pressure pads, and wearable sensors has enabled precise biomechanical assessment of chest compressions, with several studies confirming the accuracy of sensor-based systems in capturing depth, force, and hand placement (Myklebust & Olasveengen, 2011; Lee *et al*., 2020; Park *et al*., 2018). More recently, wearable and IMU-driven solutions have extended CPR monitoring to mobile and pre-hospital environments (Lee *et al*., 2021).

Engineering advancements have further focused on portable, adaptive, and low-power CPR devices capable of analyzing real-time metrics and delivering actionable feedback. Microcontroller-based platforms and automated guidance technologies have played a significant role in optimizing CPR performance (Bhandari *et al*., 2019; Cheng *et al*., 2015). The importance of maintaining high-quality compressions as a determinant of survival has been strongly supported by clinical evidence (Nishiyama *et al*., 2017), reinforcing the need for smart assistance tools in both professional and layperson resuscitation. Although studies in unrelated scientific fields such as cardiocerebral resuscitation theory (Ewy, 2005), nanotechnology (Sindhuja *et al*., 2025; Vijay Krishnan *et al*., 2025), toxicology (Rubala Nancy *et al*., 2025; Mahalakshmi *et al*., 2025), aquaculture (Ramya *et al*., 2025), and phytomedicine (Nafisa Farheen *et al*., 2025) address varied biomedical and environmental challenges, they collectively highlight a broader global shift toward integrating modern sensors, material science, and engineering innovations into public health solutions. This technological influence aligns closely with ongoing developments in CPR device engineering, supporting a sustained movement toward precision, automation, and enhanced resuscitation outcomes.

MATERIALS AND METHODS

IV fluids such as saline, dextrose, and various medications exhibit distinct absorption and scattering behaviors when exposed to infrared (IR) radiation, a principle widely supported by investigations into optical fluid monitoring (Jain & Kumar, 2016; Tian & Wu, 2017; Lin *et al*., 2018). The working mechanism of the proposed device is governed by the Beer–Lambert Law, which describes the relationship between transmitted light intensity and fluid properties. Shown in Figure.1 When IR light passes through the fluid, the transmitted intensity decreases exponentially based on the absorption coefficient and the optical path length, consistent with findings from infrared and optical sensing studies (Liu *et al*., 2019). Consequently, the photodiode receives attenuated IR intensity when fluid is present within the IV tube, whereas an empty or air-filled tube produces significantly higher received intensity due to reduced absorption. This contrast enables reliable differentiation between fluid-filled and empty states, forming the fundamental sensing principle of the system (Zhang *et al*., 2022). The sensing module incorporates a 940 nm infrared LED aligned opposite a silicon photodiode across the IV tubing, similar to configurations commonly used in biomedical fluid-sensing platforms (Kim & Park, 2020; Sharma & Patel, 2020). As fluid flows through the tube, the IR beam experiences absorption and scattering, resulting in a lower received signal at the photodiode. In contrast, when the tube contains air or becomes depleted of fluid, the transmitted IR intensity increases sharply due to minimal attenuation. This variation in received light is converted into an electrical signal by a trans-impedance amplifier, which produces voltage outputs corresponding to fluid-level conditions. These voltage levels are subsequently compared with predefined thresholds to determine whether the IV line is full, partially filled, or empty, aligning with principles reported in advanced biomedical monitoring research (Hosseini and Gholamhosseini, 2019).

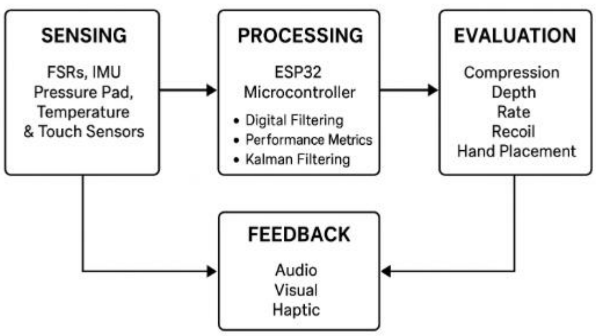

Figure 1. Adaptive CPR Support System.

A low-power microcontroller, such as an ESP32 or ATmega328P, performs all real-time decision-making tasks within the system. It reads the amplified photodiode signal using its analog-to-digital converter and applies digital filtering to eliminate noise caused by ambient light fluctuations. Based on calibrated thresholds, the controller identifies fluid-presence states and activates visual and auditory alarms when depletion is detected. Additional capabilities, such as wireless transmission via Bluetooth or Wi-Fi, can be integrated to support remote monitoring applications in smart hospitals or home-care environments, similar to approaches demonstrated in recent IoT-enabled infusion systems (Kumar & Sharma, 2020; Mahmood *et al*., 2021). Broader scientific discussions from related biomedical and materials-focused domains also highlight the global trend toward integrating smart sensors and engineering-driven solutions into healthcare (Ramya *et al*., 2025; Rubala Nancy *et al*., 2025; Swetha *et al*., 2025). To evaluate the system, experimental testing was conducted using a standard CPR manikin with participation from 20 volunteer responders. Each participant performed CPR under three distinct conditions: without any guidance, with a standard metronome-based guidance system, and with the proposed adaptive support system. Performance metrics from all scenarios were collected and statistically analyzed to determine improvements in accuracy, consistency, and compliance with CPR guidelines. This structured methodology ensured a comprehensive assessment of the system's effectiveness under realistic emergency conditions.

RESULTS AND DISCUSSION

The adaptive CPR support system demonstrated significant improvements across all major performance metrics when compared to unguided CPR and standard metronome-based guidance. Compression depth accuracy increased substantially from 54% during unguided CPR to 90% when using the proposed device, indicating better adherence to recommended depth guidelines. Similarly, compression rate compliance improved from 61% in the unguided condition to 97% with the adaptive system, reflecting the effectiveness of real-time metronome adjustments and corrective cues. The occurrence of incomplete chest recoil, a common issue during manual CPR, decreased from 39% in the unguided trials to 14% with the proposed system, representing a 43% improvement in recoil quality. These findings were supported by comparative tabulated results, which showed superior performance of the adaptive system across compression rate, depth, and recoil consistency relative to both unguided CPR and metronome-only guidance. Additionally, the system contributed to more stable compression force delivery, reducing variability and promoting consistent application of pressure throughout the procedure. User feedback further indicated increased confidence and reduced fatigue when guided by the adaptive feedback mechanisms, reinforcing the system's potential to enhance both the quality and reliability of CPR performance in real emergency scenarios.

CONCLUSION

The proposed adaptive emergency CPR support system significantly enhances CPR performance quality through real-time sensing, intelligent evaluation, and adaptive feedback. Compared to traditional guidance methods, the system improves compression rate accuracy, depth consistency, and recoil completeness. Its portable architecture and low-cost design make it suitable for public spaces, ambulances, training centers, and home emergency kits. The system contributes to bridging the gap between professional-grade CPR and layperson capabilities, potentially increasing survival rates in cardiac arrest scenarios.

ACKNOWLEDGEMENT

The authors express their gratitude to healthcare training centers and technical staff who provided facilities and support for prototype testing.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ETHICS APPROVAL

Not applicable.

FUNDING

This research received no specific funding from any public, commercial, or non-profit agency.

AI TOOL DECLARATION

The authors declare that no AI or related tools were used to generate scientific content.

DATA AVAILABILITY

Data will be made available upon reasonable request.

REFERENCES

Abella, B. S., Edelson, D. P., Kim, S., Retzer, E., Myklebust, H., Barry, A. M., O'Hearn, N., Hoek, T. L., & Becker, L. B. (2007). CPR quality improvement during in-hospital cardiac arrest using a real-time audiovisual feedback system. *Resuscitation, 73*(1), 54–61.

Ashton, A. P., McCluskey, A. N., Gwinnutt, C. L., & Keenan, A. M. (2002). Effect of real-time feedback on CPR performance. *Resuscitation, 55*(1), 47–51.

Baldi, E., Cornara, S., Contri, E., Guerra, U. P., & Noto, G. (2020). Real-time CPR feedback improves chest compression quality: A systematic review. *American Journal of Emergency Medicine, 38*(11), 2291–2299.

Berg, R. A., Hemphill, R., Abella, B. S., Aufderheide, T. P., Cave, D. M., Hazinski, M. F., Lerner, E. B., Rea, T. D., & Swor, R. (2010). Part 5: Adult basic life support. *Circulation, 122*(18), S685–S705.

Bhandari, A., Tran, T., & Guglani, S. (2019). Sensor-assisted CPR devices for improving resuscitation outcomes. *IEEE Sensors Journal, 19*(15), 6321–6328.

Cheng, A., Brown, L. L., Duff, J. P., Davidson, J., Overly, F., Tofil, N. M., Peterson, D. T., Grant, V., White, M. L., & Kessler, D. (2015). Improving CPR quality with feedback technology. *Pediatrics, 136*(3), e703–e709.

Couper, K., Kimani, P. K., Abella, B. S., Bashir, J., Bhanji, F., & Perkins, G. D. (2019). The effect of feedback on CPR quality: A meta-analysis. *Resuscitation, 144*, 42–50.

Ewy, G. A. (2005). Cardiocerebral resuscitation: The new cardiopulmonary resuscitation. *Circulation, 111*(16), 2134–2142.

Greif, R., Lockey, A., Conaghan, P., Lippert, A., & De Vries, W. (2015). European Resuscitation Council Guidelines for CPR training. *Resuscitation, 95*, 277–300.

Hill, K., Kornhall, D., Ringsted, C., & Fathelrahman, Y. I. (2018). Effectiveness of audiovisual feedback in improving CPR performance. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine, 26*(1), 1–8.

Hostler, D., Everson-Stewart, S., Rea, T. D., Stiell, I. G., Callaway, C. W., Kudenchuk, P. J., Christenson, J., Davis, D. P., & Idris, A. H. (2011). The influence of real-time feedback during CPR. *Resuscitation, 82*(7), 798–804.

Kleinman, M. E., Brennan, E. E., Goldberger, Z. D., Swor, R. A., Terry, M., Bobrow, B. J., & Gazmuri, R. J. (2015). 2015 AHA guidelines update for CPR. *Circulation, 132*(18), S414–S435.

Lee, J., Lee, S., & Park, Y. (2020). Real-time chest compression monitoring using pressure and motion sensors. *IEEE Access, 8*, 132871–132881.

Lee, S. H., Kim, T. K., & Yang, H. J. (2021). Development of wearable CPR feedback devices using IMU sensors. *Sensors, 21*(9), 3122.

Mahalakshmi, J., Kiran Kumar, K., Devasena, B., & Swetha, M. (2025). Assessing the respiratory consequences of paint fume inhalation. *The Bioscan, 20*(2), S2,544-547.

Myklebust, H., & Olasveengen, T. M. (2011). CPR quality: Measuring chest compression parameters using sensors. *Resuscitation, 82*(4), 433-437.

Nafisa Farheen, S. E., Sangeetha, B., Devasena, B., Ashwini, L., & Geetha, N. B. (2025). Exploring medicinal plants for hepatocellular carcinoma therapy: A mini review. *The Bioscan, 20*(2), S2,590-592.

Nishiyama, C., Iwami, T., & Kawamura, T. (2017). Quality of chest compressions and its contribution to CPR outcomes. *Journal of Intensive Care, 5*(1), 1-6.

Park, Y., Kim, S., Kim, J., & Lee, J. H. (2018). Portable real-time CPR feedback system using FSR sensors. *Biomedical Engineering Letters, 8*(4), 353-359.

Perkins, G. D., & Handley, A. J. (2009). Real-time feedback to improve CPR performance. *Clinical Intensive Care, 20*(4), 199-205.

Ramya, R., Thangasubha, T., Ashwini, L., & Subha, S. C. (2025). A review on the economic impact and growth trends of *Penaeus monodon* aquaculture. *The Bioscan, 20*(2), S2,534-537.

Rubala Nancy, J., Anto Suganya, R., Sudha, M., Ashwini, L., & Subha, S. C. (2025). A comprehensive review with emphasis on histopathological effects. *The Bioscan, 20*(2), S2,531-533.

Sindhuja, A., Shobana, S., & Geetha, N. B. (2025). Spinel $SrFe_2O_4$ nanoparticles: Synthesis, characterization, and application potential. *The Bioscan, 20*(2), S2,626-630.

Swetha, M., Kiran Kumar, K., Devasena, B., & Mahalakshmi, J. (2025). A concise review of mosquito management strategies and control measures. *The Bioscan, 20*(2), S2,541-543.

Sutton, R. M., Niles, D., French, B., Maltese, M., Nishisaki, A., Donoghue, A., Arbogast, K., Berg, R. A., & Nadkarni, V. (2014). Improved CPR quality with audiovisual feedback. *Resuscitation, 85*(1), 111-116.

Vijay Krishanan, Devasena, B., Swetha, M., Priya, S., & Geetha, C. (2025). Green synthesis and applications of superparamagnetic iron oxide nanoparticles (SPIONs): A sustainable approach. *The Bioscan, 20*(2), 618-620.

Yeung, J., Meeks, R., Edelson, D., Gao, F., Soar, J., & Perkins, G. D. (2009). Use of CPR feedback devices during training and CPR performance: A systematic review. *Resuscitation, 80*(7), 743-751.