Digitalizing CPR Skills Training: A Low-Cost Smart Manikin System with Real-Time Feedback

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High-quality cardiopulmonary resuscitation (CPR) is a critical lifesaving intervention that requires accurate compression depth, compression rate, complete chest recoil, minimal interruptions, and correct hand placement to maximize patient survival. However, CPR training in many medical and allied health educational institutions continues to rely on conventional spring-based manikins and instructor observation, resulting in subjective assessment and limited real-time feedback for trainees. Although commercially available smart CPR simulators provide objective performance evaluation, their high-cost limits widespread adoption, particularly in resource-constrained training environments. This study presents ResQ, a low-cost retrofit smart CPR training system with an estimated prototype cost of approximately LKR 35,000, designed to convert existing CPR manikins into intelligent training platforms while preserving the realism of conventional CPR practice. A prototype was developed by integrating Digital Barometric Pressure Sensors (HX710B) and Linear Magnetic Hall Effect Sensor (KY-024) with an embedded processing unit (ESP32-C3 32-bit RISC-V single-core processor) and wireless communication to continuously acquire CPR compression data. The system processes sensor inputs to generate quantitative outputs including compression depth, compression rate, chest recoil, hand placement, compression consistency, and interruptions, which are presented through dedicated real-time dashboards for both trainees and instructors. Initial functional validation demonstrated successful acquisition, processing, and visualization of these parameters during simulated CPR sessions, enabling immediate feedback to support trainee self-correction and instructor monitoring. Prototype evaluation conducted at the Nursing Skills Laboratory of the Faculty of Allied Health Sciences indicated that the physical appearance and chest compression response of the prototype closely resembled the CPR training manikins currently used in practical sessions, suggesting that the integration of sensing mechanisms preserved the tactile realism required for effective skills training. Quantitative validation against instructor assessment and established CPR training guidelines is currently underway to evaluate measurement accuracy and clinical applicability. The proposed system offers an affordable and scalable engineering solution for objective CPR skills assessment while enhancing simulation-based medical education and expanding access to data-driven CPR training in resource-limited healthcare institutions.

Keywords: Cardiopulmonary Resuscitation (CPR) training, real-time feedback, medical simulation, embedded sensing, performance analytics