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Simulation and education

Smartwatches as chest compression feedback devices: A feasibility study☆

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ABSTRACT

Background: Recently, there have been attempts to use smartphones and smartwatches as the feedback devices to improve the quality of chest compressions. In this study, we compared chest compression depth feedback accuracy between a smartphone and a smartwatch in a hands-only cardiopulmonary resuscitation scenario, using a manikin with a displacement sensor system.
Methods: Ten basic life support providers participated in this study. Guided by the chest compression depths displayed on the monitor of a laptop, which received data from the manikin, each participant performed 2 min of chest compressions for each target depth (35 mm and 55 mm) on a manikin while gripping a smartphone and wearing a smartwatch. Participants had a rest of 1 h between the instances, and the first target depth was set at random. Each chest compression depth data value from the smartphone and smartwatch and a corresponding reference value from the manikin with the displacement system were recorded. To compare the accuracy between the smartphone and smartwatch, the errors, expressed as the absolute of the differences between the reference and each device, were calculated.
Results: At both target depths, the error of the smartwatch were significantly smaller than that of the smartphone (the errors of the smartphone vs. smartwatch at 35 mm: 3.4 (1.3) vs. 2.1 (0.8) mm; $p = 0.008$; at 55 mm: 5.3 (2.8) vs. 2.3 (0.9) mm; $p = 0.023$).
Conclusion: The smartwatch-based chest compression depth feedback was more accurate than smartphone-based feedback.

Introduction

High-quality cardiopulmonary resuscitation (CPR), which includes the correct chest compression (CC) depth (at least 5 cm, but not exceeding 6 cm for adults) and CC rate (at least 100 compressions per minute, but not exceeding 120), affects the survival rates of cardiac arrest patients.[1–4] To provide high-quality CCs, several commercial feedback devices have been developed for such patients.[5–7] However, it is difficult for these devices to be applied in out of hospital cardiac arrest (OHCA) because witnesses with feedback devices are unlikely to be on site.

For the OHCA, many CPR-related apps have been developed with the rise of smartphone penetration. A few apps provide CC feedback using a built-in accelerometer, but their accuracy has not been proven in clinical trials. Several simulation studies have shown that the use of these apps might improve CC parameters; it may be possible to substitute these applications for commercial feedback devices.[8–10] When using a smartphone as a CC feedback device, it should be placed directly on a patient's chest for accurate CC depth feedback. However, it is not used by directly attaching to the chest due to the risk of breakage. To avoid breakage, a smartphone is fitted between a user's hands, but this could lead to inaccurate CC depth feedback because of wasted movement.

Recently, there have been new attempts using smartwatches to solve the disadvantages of the smartphone, which include the inconvenience of gripping the smartphone and the occluding of visual feedback by the gripping hand during the CCs.[11,12] Also, a smartwatch could provide accurate feedback of CC depth because it is closely attached to the wrist and does not make extraneous movements.

In our previous study, we developed a real-time CC depth estimation algorithm for smartphones by double integrating the three-axis acceleration signals from a built-in accelerometer with some signal processing, and we evaluated the accuracy of the

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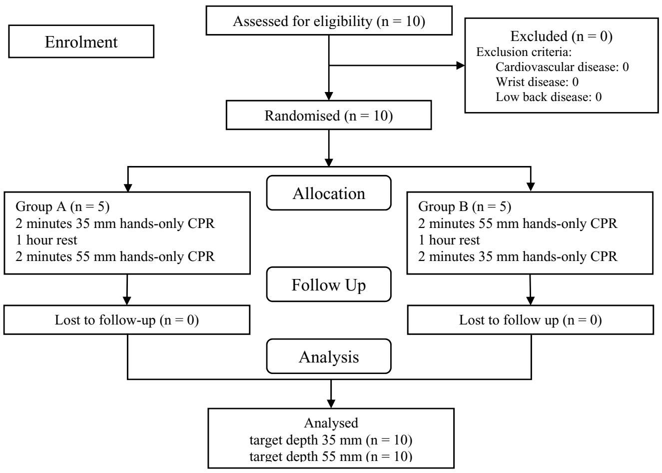

Fig. 1. CONSORT flow diagram for the study.

algorithm using a displacement sensor.[9] In addition, the algorithm was applied to a smartwatch and it was analyzed by a manikin with a displacement sensor system.[11] Our studies showed that the feedback algorithm was tolerable in both the smartphone and smartwatch. However, in our previous study of smartphones, the accuracy of the CC depth feedback was measured by attaching the displacement sensor, and it did not consider the gripping of hands. Smartphones can introduce more errors compared with smartwatches due to not being fixed on the user's body, and they also require the inconvenience of being gripped while the CCs are performed.

To use a smartwatch or smartphone as a CC depth feedback device in a clinical setting, it is necessary to confirm its accuracy in a similar environment. In this study, we compared CC depth feedback accuracy between a smartphone and smartwatch in a hands-only CPR scenario using a manikin with a displacement sensor system as the reference.

Methods

Setting and participants

This prospective, randomised, controlled study was approved by the University of Ulsan (Ulsan, Republic of Korea) Institutional Review Board (1040968-A-2015-009), and experiments were conducted at the Hanyang University Hospital (Seoul, Republic of Korea) on 13th November 2015. Healthcare workers who had qualified as adult basic life support (BLS) providers were recruited voluntarily by notice on a bulletin board from 4th to 11th October 2015. Participants who had cardiovascular, wrist, and/or low back disease were excluded. Each potential participant received written information about the study. All participants provided written consent.

Three BLS providers participated in the pilot experiment that was conducted to determine an optimum sample size. The sample size was analyzed using G-power 3.1.2® (Heine Heinrich University, Germany) with an α error of 0.05 and power of 0.8. For the experiment, we recruited ten BLS providers in consideration of a potential 10% dropout rate. We used two kinds of target depths for representative of shallow and adequate CCs. As shown in Fig. 1, participants were randomly assigned to either group A (target CC depth 35 mm → 55 mm) or group B (target CC depth 55 mm → 35 mm) in a 1:1 ratio using a random number generator (www.random.org).

Table 1
Demographics of participants.

	Participants (n = 10)
Age, years; mean (SD)	32.0 (3.5)
Gender, male; n (%)	10 (100%)
Height, cm; mean (SD)	173.6 (3.6)
Weight, kg; mean (SD)	81.4 (5.6)

Materials and methods

In our previous study, we developed a real-time CC depth estimation algorithm and implemented it on an Android-based smartphone [9] and smartwatch [11]. Both of the apps were registered on Google Play for the CC training in the names of UCPR [13] and W-CPR [14], and they were used in this experiment. It provided guidance for the CC rate by metronome or vibration and visual feedback of the current CC depth and rate. A Galaxy S3™ smartphone (Samsung Electronics Co., Republic of Korea) and a Galaxy Gear™ Live smartwatch (Samsung Electronics Co., Republic of Korea) were used for our experiment. To evaluate the accuracy of the CC depth feedback, we installed a displacement sensor (RDP-100S, Radian Co., Republic of Korea) inside a Little Anne® CPR training manikin (Laerdal Medical Co., Norway). The data from the manikin's displacement sensor were used as the reference to compare accuracy between the smartphone and smartwatch.

As shown in Fig. 2, according to the CC depths depicted on the monitor of the laptop, each participant performed two minutes of hands-only CPR (only CCs) for each target CC depth on a manikin with a displacement sensor system while gripping the smartphone in his hands and wearing the smartwatch on his wrist. Participants were allowed one hour of resting time between each instance of CPR to minimize their fatigue.

Data collection and analysis

We recorded background information about the participants, including their age, sex, height, and weight. Each CC depth datum from the smartphone, smartwatch, and manikin with displacement system was recorded. The CC depth feedback errors of the smartphone and smartwatch were represented as the absolute values of the differences between the reference value and that of each device.

All data were analyzed using the Statistical Package for the Social Sciences 18.0 KO for Windows (SPSS Inc., USA). We generated descriptive statistics and presented them as the means with standard deviations (SDs) because all data exhibited normal distributions. The errors in the CC depth data were compared between the smartphone and smartwatch using a paired t-test. A p-value less than 0.05 was considered statistically significant.

Results

All 10 participants completed the study. The demographic data are summarized in Table 1. The results for the errors in CC depth from the smartphone and smartwatch feedback are shown in Table 2. At both target depths, the error associated with the smartwatch is significantly smaller than that for the smartphone,

Table 2
Errors of smartphone and smartwatch feedback with target depth.

Target depth	Error of smartphone, mm; mean (SD)	Error of smartwatch, mm; mean (SD)	p-Value
35 mm (n = 10)	3.4 (1.3)	2.1 (0.8)	0.008[a]
55 mm (n = 10)	5.3 (2.8)	2.3 (0.9)	0.023[a]

[a] Indicates a significant p-value < 0.05 in a paired t-test.