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# Improvement of the quality of cardiopulmonary resuscitation performed with Real CPR Help® device among medical students and medical workers

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## ABSTRACT

**Introduction:** This study aimed to compare the quality of CPR performed with real-time feedback device with CPR delivered without it by medical students and practising medical workers.

**Material and methods:** Studied group consisted of 96 participants. Real CPR Help® technology providing real-time feedback was used. The following parameters were measured: mean depth, mean frequency, adequate depth rate, adequate frequency rate, and general compressions quality. Participants performed one-minute cycles of CPR with and without the feedback.

**Results:** Mean compression depth lowered with the feedback (6.1 ± 1.3 cm *vs.* 5.3 ± 0.4 cm; p < 0.001) and the number of participants with adequate depth increased (25% *vs.* 78,1%; p < 0.001). Mean compression frequency lowered after the use of the device (119.8 ± 16.8 cpm *vs.* 111.9 ± 6.9 cpm; p < 0.001) and the number of participants performing CPR with recommended compression frequency increased (50% *vs.* 86.5%; p < 0.001). Overall quality increased significantly with the feedback (0.0; IQR: 0.0–13.7 *vs.* 55.1; IQR: 31.5–78.8; p < 0.001). Similar CPR quality was observed in the student group *vs.* medical workers without the feedback (0.81; IQR: 0.0–16.2 *vs.* 0.0; IQR: 0.0–12.7; p = 0.27) and after the device implementation (61.26; IQR: 38.16–80.0 *vs.* 49.54; IQR: 30.06–65.84; p = 0.21).

**Conclusions:** The use of the Real CPR Help® device in the simulated test improved the overall quality of CPR. There were no differences concerning CPR quality between students and medical workers after the device implementation.

**Key words:** cardiopulmonary resuscitation, CPR, chest compressions, feedback, training

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## Introduction

Out-of-hospital cardiac arrest (OHCA) remains a relevant health problem in Poland with an incidence estimated as 0.57–1.7 per 1000 inhabitants per year and still unsatisfactory survival [1–4]. Various treatment options, e.g implementation of mild therapeutic hypothermia, have been investigated to improve the patients' survival and clinical outcome [5–7]. Nevertheless, the basic action to improve the survival of patients after OHCA is to introduce cardiopulmonary resuscitation (CPR) as soon as possible. Early bystander CPR forms the basis of the chain of survival along with early recognition and call for help, defibrillation (if needed), and the implementation of advanced resuscitation procedures [8].

Both the American Heart Association [9] and the European Resuscitation Council (ERC) [8] strongly stress the importance of good-quality chest compressions during CPR. The recommended frequency and depth of chest compressions is 100–120 per minute and 5–6 cm, respectively. The American and European guidelines also emphasize full chest relaxation

after each compression to achieve optimal perfusion pressure [8]. Complete chest relaxation helps create a pressure gradient that allows venous blood to return to the right atrium [10]. The importance of good quality CPR is incontestable since only chest compressions performed with adequate depth, frequency, and chest relaxation enhance patient survival [9, 11]. Previous studies revealed that too shallow chest compressions result in poor coronary perfusion and therefore reduce patient survival [11]. On the contrary, too deep compressions are associated with significantly higher rates of complications such as rib fractures [12].

Systematic training is required among the entire community to increase the quality of CPR. Particular emphasis should be put on the CPR training of medical school students, including future physicians, nurses, midwives, physiotherapists, etc. Previous studies showed that the quality of CPR performed with real-time feedback devices was better in comparison to standard resuscitation [13–18]. Furthermore, those devices proved to enhance the learning process of how to perform CPR properly [18–20]. Good quality compressions are essential also for practising medical workers (physicians, nurses etc.) since it is much more likely for them to perform CPR in comparison to the general population.

This study aimed to compare the quality of CPR performed with real-time feedback device with CPR delivered without it by medical students and practising medical workers.

## Material and methods

### The study group

The study group consisted of 63 students from Ludwik Rydygier Collegium Medicum in Bydgoszcz, Nicolaus Copernicus University in Torun and 33 medical workers from Antoni Jurasz University Hospital No. 1 in Bydgoszcz who volunteered for a CPR training session. All participants provided informed consent to use obtained data in the presented study. Students represented various medical fields (medicine, nursing, emergency medical science, laboratory medicine) and different study years. The medical workers' group was heterogeneous and consisted of practising physicians, nurses, and an electroradiology technician.

### Measurements

The training was carried out using a ZOLL® R Series® defibrillator with Real CPR Help® technology that provided real-time feedback, triggering a monitor alert whenever chest compression depth or frequency were beyond values recommended in the ERC guidelines [8].

All participants performed CPR twice on a training manikin. The first no-feedback round was followed by a second attempt with the implementation of real-time feedback on the depth and frequency of chest compressions. The effectiveness of the resuscitation, as assessed by adequate depth and frequency of compressions, was measured in one-minute periods for each person. The following parameters of chest compression quality were recorded: mean depth (cm), mean frequency [compressions per minute (cpm)], adequate-depth compression rate (%), adequate-frequency compression rate [%] and adequately-delivered compression rate (%) (only when both the depth and frequency were within the guideline-recommended ranges a compression was considered to be adequately delivered). The study was conducted by the Declaration of Helsinki.

### Statistical analysis

Statistical analysis was performed using IMB SPSS Statistics version 23. Testing for normality of data distribution was performed with the Shapiro-Wilk test. Continuous variables were presented as means ± standard deviation (SD) or medians with interquartile range (IQR) and categorical variables as counts with percentages. Statistical analysis for continuous variables was performed using the t-Student or Mann-Whitney U test as appropriate according to data distribution. Differences between categorical variables were calculated with the chi-square test. Differences were considered significant at p < 0.05.

## Results

A total of 96 participants were included in the study, with the majority of medical students 65.6% (n = 63). Median age of the study group was 24.0 (IQR: 23,0–37,0) with older participants among medical workers group (46.0; IQR: 36.5–54.0 *vs.* 23.0; IQR: 22.0–24.0; p < 0.001). Females predominated in the group (n = 72; 75.0%) with no differences between medical workers and medical students (69.8% and 84.8% respectively; p < 0.139). Both groups differed in regard to participants profession (p < 0.001) with the majority of medicine students in the students' group (n = 53; 84.1%) and nurses in the medical workers group (n = 21; 63.6%),

Mean depth was 6.1 ± 1.3 cm without the feedback and 5.3 ± 0.4 cm after implementation of the feedback device (Fig. 1). The number of participants who performed compressions with adequate depth was 3-fold higher in the feedback group (25%; n = 24 *vs.* 78.1%; n = 75; p < 0.001). Only half of the participants (n = 48) without the feedback performed CPR with the recom-
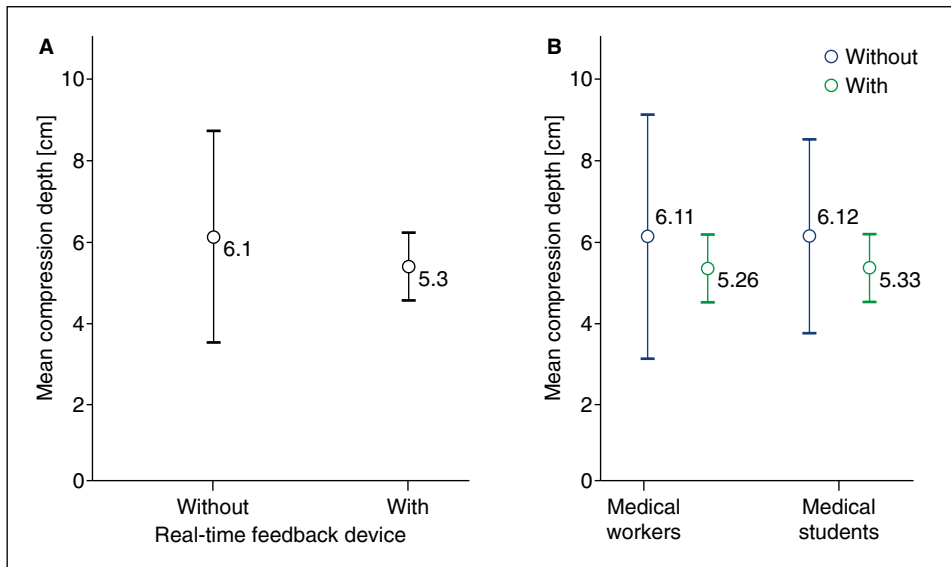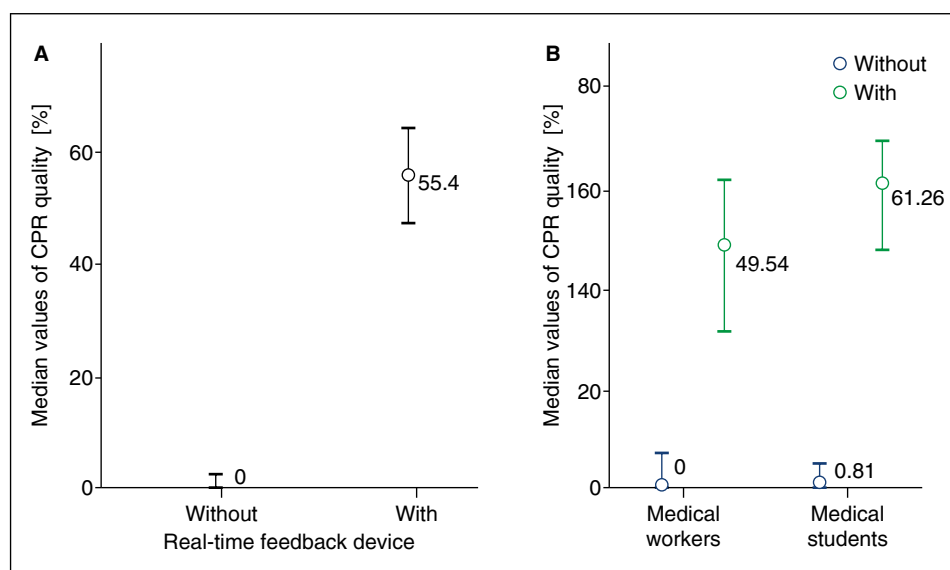
**Figure 1.** Mean compression depth with and without feedback for the entire study group (**A**) and separately for medical workers and medical students (**B**). Error bars show ± 2 standard deviations
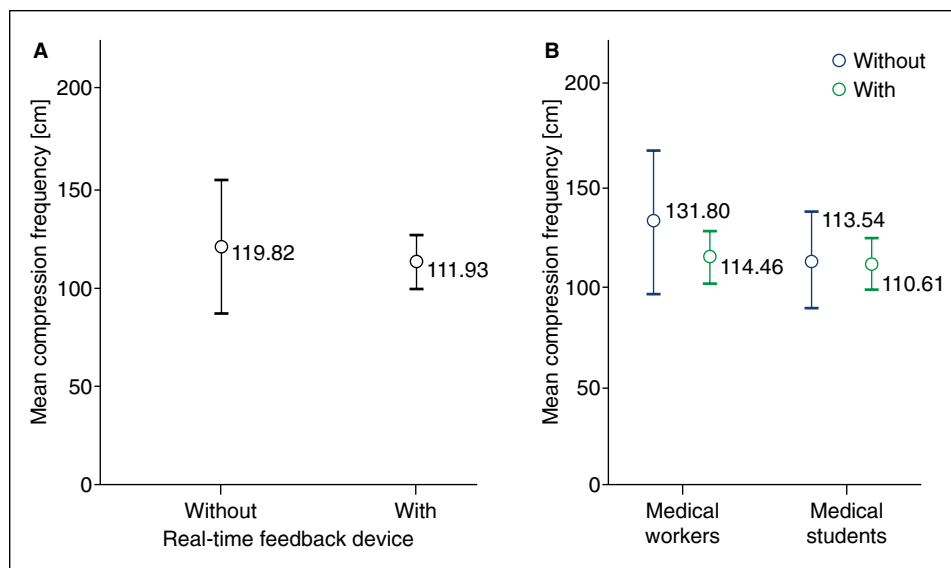


**Figure 2.** Mean compression frequency with and without feedback for the entire study group (**A**) and separately for medical workers and medical students (**B**). Error bars show ± 2 standard deviations

mended compression frequency in comparison to 86.5% (n = 83) with the feedback device (p < 0.001). The feedback group demonstrated a significantly lower average frequency of chest compressions (Fig. 2), as well as significantly higher rates of adequate compression depth (11.06; IQR: 0.0–38.91 *vs.* 70.81; IQR: 51.12–84.92; p < 0.001), adequate compression frequency (54.96; IQR: 6.35–84.33 *vs.* 83.32; IQR: 65.61–94.75; p < 0.001) and adequately delivered compressions (Fig. 3).

## Students *vs.* medical workers

Implementation of the feedback device was associated with a decrease in the mean depth and frequency of compressions as well as with a significant improvement in CPR quality in both groups (Fig. 1–3). Improvement was observed in adequate compression depth rate (9.4; IQR: 0.0–32.4 *vs.* 76.3; IQR: 51.03–86.1; p < 0.001) in the student group with the feedback device. The difference in adequate compression fre-

**Figure 3.** Median values of CPR quality with and without feedback for the entire study group (**A**) and separately for medical workers and medical students (**B**). Error bars show 95% Confidence Interval

**Table 1.** Comparison of CPR performance among students and medical workers with and without real-time feedback

|  | Students | Medical workers |  |
|---|---|---|---|
|  | **Mean ± SD / Median (IQR)** | | |
|  | **Without real-time feedback** | | **P-value** |
| Mean depth [cm] | 6.12 ± 1.20 | 6.11 ± 1.52 | 0.981 |
| Mean frequency [cpm] | 113.54 ± 12.06 | 131.80 ± 18.1 | < 0.001 |
| Quality [%] | 0.81 (0.0–16.19) | 0.0 (0.0–12.72) | 0.265 |
| Adequate depth rate [%] | 9.4 (0.0–32.36) | 12.71 (0.0–49.97) | 0.660 |
| Adequate frequency rate [%] | 73.17 (18.68–88.29) | 10.53 (0.0–76.77) | < 0.001 |
|  | **With real-time feedback** | | |
| Mean depth | 5.33 ± 0.41 | 5.26 ± 0.41 | 0.238 |
| Frequency | 110.61 ± 6.89 | 114.46 ± 6.38 | 0.009 |
| Quality | 61.26 (38.16–80.0) | 49.54 (30.06–65.84) | 0.210 |
| Depth [%] | 76.34 (51.02–86.09) | 66.67 (49.77–79.07) | 0.227 |
| Frequency [%] | 85.32 (67.37–96.26) | 77.98 (57.89–92.55) | 0.093 |

quency rate was also significant, but less marked in this group (73.2; IQR: 18.7–88.3 *vs.* 85.3; IQR: 67.4–96.3; p = 0.001). Similar results were found in the group of medical workers — increase in the rates of adequate compression depth (12.7; IQR: 0.0–50.0 *vs.* 66.7; IQR: 50.0–79.1; p < 0.001) and adequate compression frequency (10.5; IQR: 0.0–77.8 *vs.* 78.0; IQR: 57.9–92.6; p < 0.001).

The rate of adequate compression frequency (73.17; IQR: 18.68–88.29 *vs.* 10.53; IQR: 0.0–76.77; p < 0.001) without the feedback was higher in the stu-

dent group in comparison with medical workers (Tab. 1). Furthermore, medical students performed CPR with a significantly lower mean compression frequency at baseline (Fig. 2.) After the implementation of the real-time feedback device medical workers still performed CPR with a significantly higher mean compression frequency, however, both results were following current guidelines (110.61 ± 6.89 *vs.* 114.46 ± 6.38; p = 0.009). There were no differences regarding other measured parameters between students and medical workers when the device was used (Tab. 1).

## Discussion

In the presented study, implementation of the real-time feedback device significantly improved all measured parameters of CPR (mean compression depth, mean compression frequency and the rates of proper-quality CPR, adequate compression depth and adequate compression frequency) for the total study cohort and each of the investigated subgroups. Despite the improvement in the overall quality of CPR, the results remained unsatisfactory since the median rate of proper-quality CPR in terms of compression depth and frequency was merely 55.4%. When performing CPR without the feedback device, the medical students failed to achieve the recommended depth but successfully maintained the recommended frequency of chest compressions, while medical workers tended to overdo, both in terms of compression depth and frequency, with the mean frequency exceeding 130 compressions per minute. However, the overall quality of CPR at baseline was similar in both groups. The implementation of the feedback device resulted in the improvement of CPR quality in either of the groups.

Our results are consistent with some previously published studies which demonstrated improvement in CPR quality with the use of real-time feedback devices [13–18]. OHCA remains one of the most challenging medical conditions due to a very low survival rate. Previous reports showed that return of spontaneous circulation was achieved in 33% of cases, however, only 8% survived until hospital discharge [21]. Two main components of adequately performed CPR are compression depth and frequency. The adequate depth range recommended in the guidelines is 5-6 cm [8]. In a meta-analysis by Wallace et al. [22], it was demonstrated that deeper chest compressions improved the prognosis of patients after cardiac arrest. Similar results were reported in another meta-analysis by Talikowska et al. [23], who showed that deeper chest compressions were related both with a greater chance of return of spontaneous circulation and survival. Vadeboncoeur et al. [24] investigated 593 cases of OHCA and found incremental odds of survival with an increase in compression depth by each 5 mm (aOR: 1.29; 95% CI 1.00–1.65). Deeper chest compressions were also proven to improve haemodynamics (assessed with coronary perfusion pressure, carotid and renal blood flow) in the animal model [25]. However, in a study by Stiell et al. [26] an inverse association between the depth and compression rate was found. In the present study, the mean compression depth without the feedback was slightly higher than the range recommended in the guidelines, but it reached the appropriate range ($5.3 \pm 0.4$ cm) after the implementation of the feedback device.

The importance of performing chest compressions with an adequate frequency was demonstrated in several previous studies. Current guidelines recommend maintaining the pace between 100 and 120 compressions per minute [8]. In the above-mentioned meta-analysis by Talikowska et al. [23] the frequency of 100–120 cpm was associated with survival till hospital discharge. Of note, even within this range, a higher frequency was observed in the non-survivor group [23]. The analysis of data collected from a monitor-defibrillator recording of 10 371 OHCA patients revealed the greatest survival odds for rates of 100–119 cpm in comparison with the other four analysed rate ranges (< 80, 80–99, 120–139, and $\geq$ 140) [27]. Furthermore, increasing compression frequency was found to be accompanied by a simultaneous significant decrease in compression depth. Similar results were presented by Monsieurs et al. [28], who investigated compression depth for 3 rate categories (< 80/min, 80–120/min, and > 120/min) in 133 patients undergoing CPR. Rates >120 cpm were associated with decreased compression depth, hoverer in this study the deepest compression was 4.5 cm at the frequency of 86/min, therefore was insufficient in terms of the current guidelines. On contrary, Lee et al. [29] reported a proportional relationship between chest compression depth and frequency, however, the frequency > 120 cpm was associated with the highest rate of incomplete chest relaxation. Both higher frequency and deeper compressions are related to a greater chance of injury including ribs and sternum fractures [11, 12]. In the present study, the mean compression frequency remained within the recommended range regardless of the feedback present or absent, however, it significantly decreased when the device was used ($119.8 \pm 16.8$ vs. $111.9 \pm 6.9$; $p < 0.001$). Without the feedback, over half of all compressions were performed with the recommended frequency, but only in 11% of cases, the compression depth was adequate.

In this study, an increase in the quality of feedback-assisted CPR was present for both investigated groups analysed either together or separately. After the implementation of the feedback device, a significantly higher mean compression frequency was observed in the medical workers' group, however, both results were following current guidelines. Besides the above-mentioned, no differences were found between those groups. Without it, the major difference between students and medical workers concerned compression frequency, in favour of the student group. However, the overall quality of CPR was similar in both groups. During their courses, medical students more often can perform CPR training in a controlled setting, when they are supervised by the instructor. On the other hand, medical workers perform CPR in a real-life setting, which is a major source of stress and there is no supervision

available. Those conditions can potentially lead to higher compression frequency and therefore impaired quality of CPR. The introduction of post-cardiac arrest debriefing sessions has been proven to improve the CPR parameters (ventilation, frequency, and depth of chest compressions) and the chances to achieve ROSC [30]. Presented results also support the need for continuous CPR training for all social groups. Performing CPR with real-time feedback devices should also be considered a part of medical training to support the education process and improve the quality of CPR training [18–20].

## Limitations

The study has several limitations to be mentioned. Firstly, it was conducted under simulated conditions. However, a similar study performed on real patients after OHCA might be related to unacceptable risk for their life and health. Furthermore, simulated conditions allowed proper standardization of the study. Secondly, no data on chest relaxation were provided, making the analysis of this CPR-vital parameter impossible. Thirdly, CPR duration was confined to two one-minute runs, thus eliminating the effect of exhaustion-related CPR quality deterioration seen with prolonged real-life CPR.

## Conclusions

The use of the Real CPR Help® real-time feedback device in a simulated test improved CPR quality. Even with real-time feedback, the overall CPR quality remains unsatisfactory, mandating additional training for CPR skills improvement. There were no differences concerning CPR quality between students and medical workers after the implementation of the real-time feedback device.

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