

Comparison of the effectiveness of cardiopulmonary resuscitation with standard manual chest compressions and the use of TrueCPR and PocketCPR feedback devices

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Abstract

Background: High effectiveness of chest compressions is an important element of cardiopulmonary resuscitation (CPR), improving survival and reducing neurological deficits resulting from sudden cardiac arrest.

Aim: Evaluation of the effectiveness of standard manual chest compressions (SMCC) and CPR with the use of two CPR feedback devices: TrueCPR and PocketCPR.

Methods: 167 paramedics participated in the study. The participants were randomised to perform SMCC, CPR using the TrueCPR device, and CPR using a smartphone with the PocketCPR application in a crossover fashion.

Results: Comparison of SMCC, TrueCPR and PocketCPR showed differences in the effectiveness of chest compressions (40.3%, 85.5% and 28.8%, respectively), compression depth (49.5, 56.5 and 50.3 mm, respectively), and compression rate (118.5, 105.1, and 89.5 min⁻¹, respectively).

Conclusions: During simulated CPR, TrueCPR device significantly increased the effectiveness of chest compressions compared to SMCC and the use of PocketCPR smartphone application. Further studies are required to confirm these findings in clinical practice.

Key words: resuscitation, chest compressions, effectiveness, paramedic, simulation

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INTRODUCTION

Out-of-hospital cardiac arrest is a major cause of death and neurological dysfunction in Europe [1, 2]. Survival in out-of-hospital cardiac arrest ranges from 4.3% to 10.7% [1–5]. Effective chest compressions are the mainstay of cardiopulmonary resuscitation (CPR) and increase the likelihood of surviving cardiac arrest [6–10]. Proper hand position, and appropriate rate and depth of compressions are among the most important parameters during chest compressions [11]. Studies indicate that effective CPR continues to be a challenge for healthcare personnel [12, 13].

With advances in medicine and technology, an increasing number of devices that may be used to support CPR by providing feedback information is available on the market.

These include TrueCPR (Physio-Control, Redmond, WA, USA) and CPRmeter (Laerdal, Stavanger, Norway) devices, and numerous smartphone applications such as PocketCPR (ZOLL Medical Corporation, Chelmsford, MA, USA) [14]. These devices provide information on the number of chest compressions per minute or, with the use of sophisticated algorithms, the depth of chest compressions.

The aim of the present study was to compare the effectiveness of CPR during standard manual chest compressions (SMCC) and with the use of TrueCPR and PocketCPR feedback devices. Monitoring manikin software (StatAdult CPR Manikin, Simulaids, Saugerties NY, USA) was used to provide data to evaluate parameters of chest compression.

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METHODS

The study was approved by the Board of the International Institute of Rescue Research and Education (Approval No. 4.2014.11.21) and was conducted from May to July 2014.

All subjects volunteered to participate in the study following explanation of the study purposes. Paramedics who took part in the study were selected randomly among the participants of training courses run by the International Institute of Rescue Research and Education (Warsaw, Poland). Overall, the selected study group included 167 paramedics (103 men, 64 women) who had no previous experience with TrueCPR and PocketCPR feedback devices during CPR.

Study design

The study was performed with the use of a StatAdult CPR manikin. The following methods to monitor the effectiveness of chest compressions were used:

1. TrueCPR™ CPR Assistant — allows precise measurements of the depth of chest compressions regardless of the surface the patient is placed on, using unique technology based on three-dimensional induction of magnetic field. This technology uses magnetic field and advanced mathematic computations for precise determination of the momentary distance between a sensor on the anterior chest surface and another sensor placed below the back, thus showing the actual depth of chest compressions in the anteroposterior plane. In addition to chest compression depth, it also indicates the rate of compressions and the timing of rescue breaths. Compression depth and rate are displayed real-time on a clearly visible panel located on the anterior chest sensor. A build-in metronome is also a useful feature for paramedics.
2. PocketCPR application by ZOLL Medical Corporation — an application developed for Android smartphones, provides real-time information on chest compression depth and rate. Parameters of chest compressions are calculated using special algorithms that analyse changes of the telephone location during CPR.

The control group used SMCC.

After participant recruitment, a 30-min training on adult CPR was performed in accordance to the 2010 CPR guidelines of the Polish Resuscitation Council [6]. The training also included the use of CPR monitoring and feedback devices such as TrueCPR and PocketCPR. After the training, appropriate adult CPR (30:2) was demonstrated by the instructors, including SMCC for 2 min, followed by CPR using the TrueCPR device for 2 min and CPR using the PocketCPR smartphone application for another 2 min.

The participants were then allowed to practice standard manual CPR and CPR using monitoring and feedback devices, each during a 2-min period.

During the study, the effectiveness of chest compression was evaluated during standard manual CPR and CPR using the two CPR monitoring and feedback devices, each performed

for 10 min. The Research Randomiser software was used to determine the order of the evaluated CPR approaches in the study group [15]. The study participants were divided into three groups, each performing CPR efforts at the randomly determined order. A 20-min rest period was provided after the CPR effort. Details of the randomisation procedure are shown in Figure 1.

The parameters of chest compression effectiveness (compression depth, compression rate, incomplete chest relaxation rate, inappropriate hand position on the chest surface) were monitored using software compatible with the training manikin used. During CPR, the participants were not provided any information recorded by the manikin monitoring system and were guided only by their own experience and data provided by the CPR monitoring and feedback device used (TrueCPR, PocketCPR). Following each CPR effort, the participants were asked to rate the usefulness of CPR monitoring and feedback devices from 1 (definitely useless) to 5 (definitely useful).

Statistical analysis

All analyses were performed using the R for Windows package (version 3.0.0). Results were expressed as mean values and standard deviations (\pm SD) and numbers and percentages. Analysis of variance (ANOVA) *post hoc* tests with the Bonferroni correction for metric data were used for univariate analysis to compare the three study groups. The Kruskal-Wallis test was used to compare non-normally distributed data. Multivariate ANOVA was also used. Results were considered significant at $p < 0.05$.

RESULTS

Study population

Overall, 167 paramedics (64 women, 103 men) participated in the study. None of the participants had previous experience with the TrueCPR device or PocketCPR application. Sixty-four participants (43 women, 21 men) worked in a hospital emergency department, and 99 participants (21 women, 78 men) worked in emergency medical services. The mean duration of professional experience was 8.3 ± 4.6 years.

Mean chest compression depth [mm]

The mean chest compression depth varied between study groups and was 49.5 ± 8.8 mm during SMCC, 56.5 ± 4.7 mm with the use of TrueCPR, and 50.3 ± 18.2 mm with the use of PocketCPR (Table 1). Significant differences were found between TrueCPR and SMCC ($p = 0.002$) and between TrueCPR and PocketCPR ($p = 0.026$).

Too deep chest compressions were most common during SMCC (18.7%; Table 1). The highest proportion of too shallow chest compressions was noted with the use of PocketCPR (35.2%; Table 1).

Mean chest compression rate [min^{-1}]

The mean chest compression rate was $105.1 \pm 4.7 \text{ min}^{-1}$ with the use of TrueCPR, $89.5 \pm 11.8 \text{ min}^{-1}$ with the use of PocketCPR,

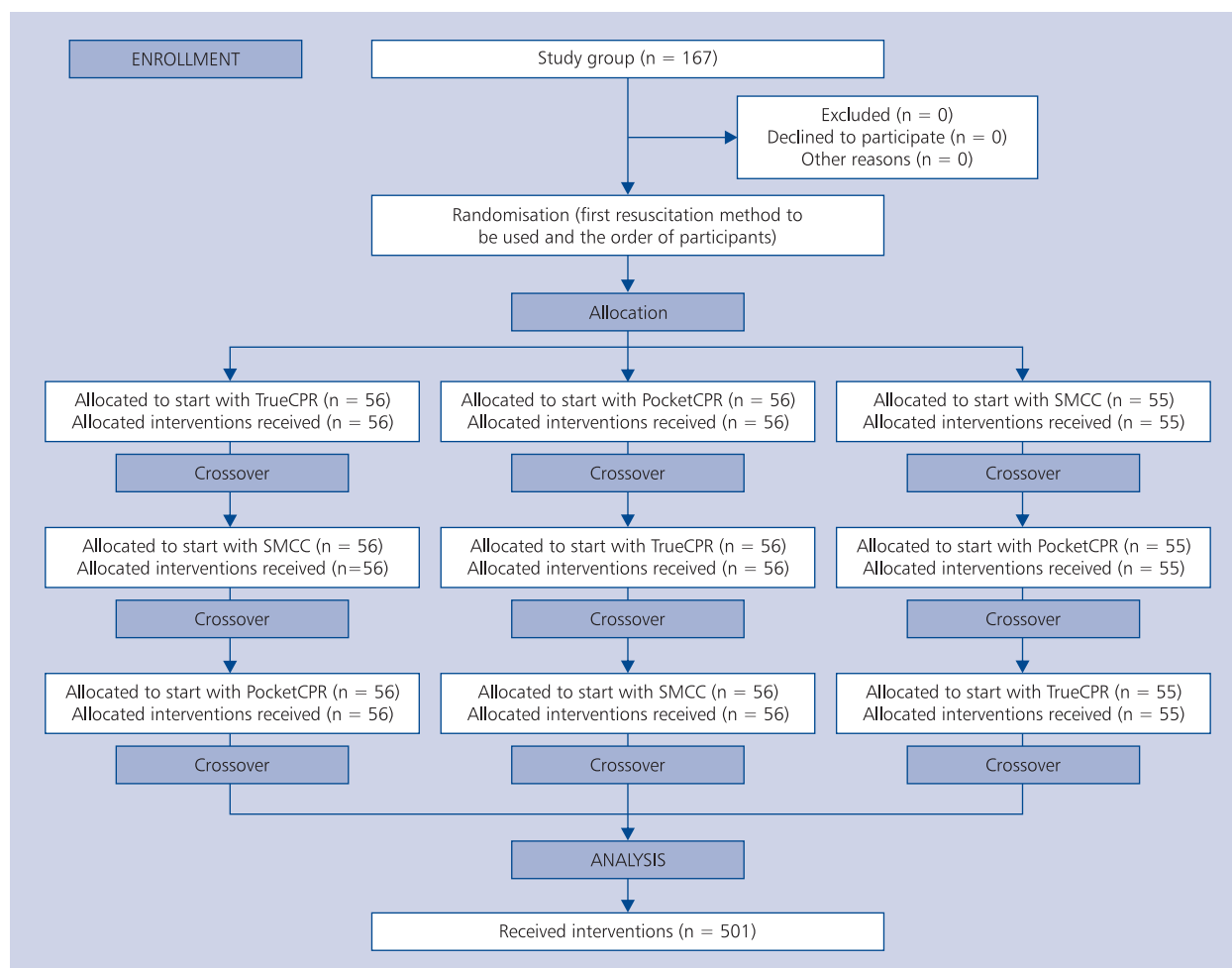


Figure 1. Study design; SMCC — standard manual chest compressions

and $118.5 \pm 14.2 \text{ min}^{-1}$ during SMCC. Significant differences were found between SMCC and TrueCPR ($p < 0.001$) and between SMCC and PocketCPR ($p < 0.001$).

Chest compression

The most effective chest compression, defined as appropriate compression depth (50–60 mm) with appropriate hand position and complete chest decompression, was observed with the use of TrueCPR ($85.5 \pm 11.8\%$). During SMCC, the proportion of effective chest compression was $40.3 \pm 31.5\%$. The least effective was CPR with the use of PocketCPR ($28.8 \pm 21.2\%$). Significant differences were found between SMCC and TrueCPR ($p < 0.001$), between SMCC and PocketCPR ($p = 0.036$), and between TrueCPR and PocketCPR ($p < 0.001$).

Use of TrueCPR allowed the highest proportion of appropriate chest compressions among all CPR methods studied. This proportion was the highest both at initiation of CPR (91%) and at 10 min of CPR (63.54%), as illustrated in Figure 2.

Incomplete chest relaxation [%]

Incomplete chest relaxation ranged from 17.6% with the use of TrueCPR to 43.5% with the use of PocketCPR ($p < 0.001$). During SMCC, incomplete chest relaxation was 26.5%.

Inappropriate hand position [%]

Significant differences were found in inappropriate hand position during the three studied approaches to CPR. The proportion of participants showing inappropriate hand position was 2.5% with the use of TrueCPR and was lower compared to PocketCPR (8.9%; $p < 0.001$) and SMCC (8.2%; $p < 0.001$).

Satisfaction level

The participants rated the three approaches to CPR in terms of their preference regarding use of each method in clinical practice. The participants rated their preferences from 1 (method definitely useless) to 5 (method definitely useful). The TrueCPR device was considered the most useful (score 4.6 ± 2.1), while use of PocketCPR was scored 2.1 ± 1.3 . A significant

Table 1. Parameters of chest compression (mean ± standard deviation)

Chest compression parameter	TrueCPR	PocketCPR	SMCC	P
Effective compression* [%]	85.5 ± 11.8	28.8 ± 21.2	40.3 ± 31.5	TrueCPR vs. PocketCPR < 0.001 TrueCPR vs. SMCC < 0.001 PocketCPR vs. SMCC = 0.031
Compression depth [mm]	56.5 ± 4.7	50.3 ± 18.2	49.5 ± 8.8	TrueCPR vs. SMCC = 0.002 TrueCPR vs. PocketCPR = 0.026 Other: NS
Too deep compression (> 60 mm) [%]	4.2 ± 11.5	8.4 ± 7.5	18.7 ± 5.4	TrueCPR vs. PocketCPR = 0.033 SMCC vs. TrueCPR < 0.001 SMCC vs. PocketCPR < 0.001
Too shallow compression (< 50 mm) [%]	11.6 ± 7.9	35.2 ± 15.4	29.1 ± 9.8	PocketCPR vs. TrueCPR < 0.001 PocketCPR vs. SMCC = 0.021 Other: NS
Compression rate [min ⁻¹]	105.1 ± 4.7	89.5 ± 11.8	118.5 ± 14.2	SMCC vs. TrueCPR < 0.001 SMCC vs. PocketCPR < 0.001 Other: NS
Incomplete chest relaxation [%]	17.6 ± 7.4	43.5 ± 22.4	26.5 ± 13.2	TrueCPR vs. PocketCPR < 0.001 Other: NS
Inappropriate hand position [%]	2.5 ± 5.7	8.9 ± 13.5	8.2 ± 5.4	TrueCPR vs. PocketCPR < 0.001 TrueCPR vs. SMCC < 0.001 Other: NS

*Effective compression was defined as appropriate compression depth (50–60 mm) with appropriate hand position and complete chest decompression; NS — non-significant; SMCC — standard manual chest compressions

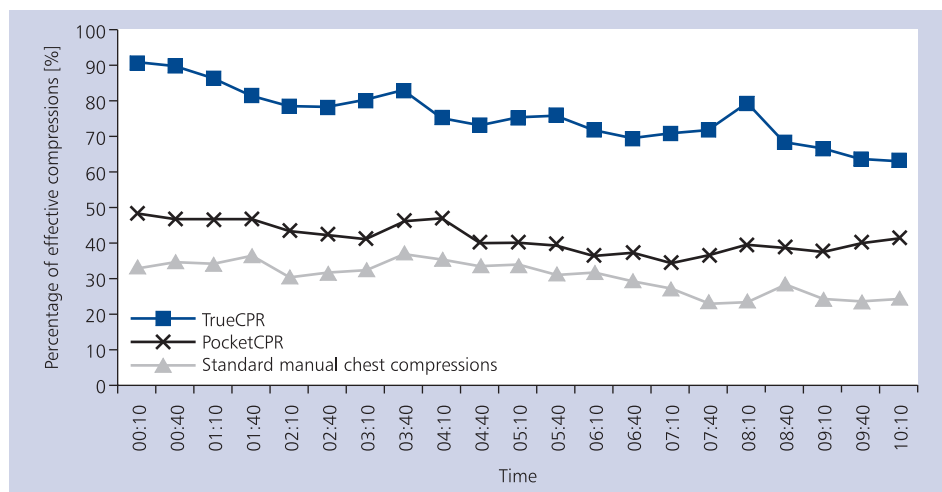


Figure 2. Effectiveness of chest compression in relation to duration of cardiopulmonary resuscitation

differences was noted between these TrueCPR and PocketCPR scores ($p < 0.001$).

Multivariate analysis

Multivariate analysis was performed using ANOVA. Independent sociodemographic variables included age (in age ranges), gender (men, women), education (university-level, vocation-

al), duration of professional experience (in age ranges), and place of work (hospital emergency department, emergency medical services). The dependent variable was the effectiveness of chest compression in relation to the CPR approach (Table 2). Higher effectiveness of chest compression correlated with the duration of professional experience when performing SMCC ($p = 0.017$) and during CPR with the use of PocketCPR

Table 2. Effect of selected sociodemographic variables on the effectiveness of resuscitation

Effectiveness of chest compression	Statistical parameter	Sociodemographic variable				
		Age	Gender	Education	Duration of professional experience	Place of work
TrueCPR	Beta	0.04828	0.04723	0.042877	0.03845	0.03822
	P	NS	NS	NS	NS	NS
PocketCPR	Beta	0.03254	0.03857	0.038532	0.04028	0.03184
	P	NS	NS	NS	0.031	0.033
SMCC	Beta	0.04285	0.03874	0.03468	0.03381	0.03678
	P	NS	NS	NS	0.017	0.038

NS — non-significant; SMCC — standard manual chest compressions

($p = 0.031$). Specifically, participants with a higher duration of professional experience were significantly more effective at performing SMCC compared to those with a shorter duration of professional experience. The place of work correlated significantly with a higher effectiveness of CPR with the use of PocketCPR ($p = 0.033$) and during SMCC ($p = 0.038$). Participants who worked as members of emergency medical service teams were more effective at performing chest compression compared to those who worked in a hospital emergency department.

DISCUSSION

Chest compressions at a rate below 100 per minute but less than 120 per minute are recommended in the European Resuscitation Council guidelines [6]. Deschilder et al. [16] showed that the currently recommended CPR at a rate of 30 chest compressions to 2 rescue breaths is more exhaustive for the rescuer than CPR at a rate of 15:2. Thus, prolonged resuscitation may result in fatigue of the rescuers, reducing the effectiveness of chest compression and the likelihood of surviving cardiac arrest. In these circumstances, devices to increase the effectiveness of chest compression might be helpful.

The first device to support CPR was developed in 1992, when Kern et al. [17] reported chest compressions using a metronome. Since that time, multiple devices were developed to enhance the effectiveness of CPR [18–20]. These include both automatic chest compression devices such as LUCAS 2™ [21] and AutoPulse™ [22], devices that still require manual chest compressions by the rescuer but provide feedback information on compression rate and depth, the degree of chest relaxation, or appropriate timing of rescue breaths [23], and numerous smartphone applications [24].

In our study, we attempted to evaluate the effectiveness of chest compressions using three approaches — SMCC, TrueCPR, and PocketCPR. During CPR scenarios, multiple parameters affecting the effectiveness of chest compressions were recorded, including compression depth and rate, appropriate hand position on the chest surface, and the degree of chest relaxation. We defined effective chest compressions

as appropriate compression depth (50–60 mm) with appropriate hand position and complete chest decompression. This definition served as a basis to compare the three evaluated chest compression approaches.

In our study, compression depth differed between the evaluated chest compression approaches. During chest compressions with the use of TrueCPR device, it was 56.5 ± 4.7 mm, slightly higher compared to that reported in the study by Beesems and Koster (54.4 ± 1.8 mm) [23]. During chest compressions with the use of PocketCPR application, the mean compression depth was 50.3 ± 18.2 mm, while during SMCC it was 49.5 ± 8.8 mm. In other studies, chest compression depth during standard basic life support was 43 mm in the study by Sutton et al. [25], 46 mm in the study by Ettl et al. [26], and 55 mm in the study by Zapletal et al. [27].

Chest compression rate also showed some differences between TrueCPR, PocketCPR, and SMCC. The mean compression rate using these approaches was 105.1 min^{-1} , 89.5 min^{-1} , and 118.5 min^{-1} , respectively. Also in the studies by Zapletal et al. [27] and Blomberg et al. [28], a higher chest compression rate during CPR was noted for standard manual compressions compared to device-guided CPR. A lower chest compression rate during standard manual compressions was reported by Sutton et al. (104 min^{-1}) [25]. However, this value was still within the range recommended by the European Resuscitation Council ($100\text{--}120 \text{ min}^{-1}$) [6].

Studies by Park [29] showed significant differences between SMCC and CPR with the use of a feedback smartphone application. This study showed a higher compression depth and a higher proportion of appropriate CPR during SMCC.

Inappropriate hand position during CPR is a major problem, resulting in modification of the force applied to the chest. In addition, inappropriate hand position on the chest surface during CPR may be complicated by rib fracture. In our study, the proportion of chest compression with inappropriate hand position was lowest with the use of TrueCPR (2.5%), followed by SMCC (8.2%), and the highest proportion was noted with the use of PocketCPR (8.9%). Zapletal et al. [27] showed significant differences in inappropriate hand position

between SMCC or CPR with the use of TrueCPR and CPR using a smartphone application.

Analysis of our data indicated a large proportion of incomplete chest decompression. This is also a major problem as incomplete chest decompression decreases the effectiveness of resuscitation by precluding complete myocardial relaxation, which results in reduced venous return and subsequent fall in cardiac output produced by CPR. During SMCC, every fourth compression was associated with incomplete chest relaxation, compared to 43% with the use of PocketCPR and 17.6% with the use of TrueCPR. These findings are consistent with the findings of Zapletal et al. [27] who also showed that CPR using a smartphone application was associated with an increased proportion of incomplete chest decompression.

Our multivariate analysis showed that only the use of TrueCPR was not associated with an effect of age, gender, education, duration of professional experience and place of work on the effectiveness of chest compressions. This indicates that this device may be equally effectively used by all paramedics regardless of their experience in resuscitation.

In summary, the highest effectiveness of chest compression was found for TrueCPR, and the lowest for PocketCPR. Our findings are consistent with the results reported by Zapletal et al. [27]. Also the assessment by participating paramedics indicated that they preferred CPR with the use of TrueCPR device.

Limitations of the study

Our study had a number of limitations. First, it was performed in simulated conditions using a training manikin. However, studies undertaken using manikins allow repeating CPR efforts without any harm to a cardiac arrest victim, and provide unified CPR conditions for all study participants. Second, the study was performed in a small professional group of paramedics. To confirm our findings, another study would have to be conducted among other healthcare professionals.

CONCLUSIONS

During simulated CPR, TrueCPR device significantly increased the effectiveness of chest compressions. Further studies are required to confirm these findings in clinical practice.

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Conflict of interests: none declared

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Porównanie skuteczności bezprzrządowego uciskania klatki piersiowej z monitorami TrueCPR i PocketCPR

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Streszczenie

Wstęp: Wysokiej efektywności uciśnięcia klatki piersiowej stanowią istotny element resuscytacji krążeniowo-oddechowej (CPR), zwiększając szanse na przeżycie i zmniejszając deficyty neurologiczne wynikające z nagłego zatrzymania krążenia.

Cel: Celem pracy była ocena efektywności uciskania klatki piersiowej podczas wykonywania standardowego (bezprzrządowego) uciskania klatki piersiowej (SMCC) oraz z wykorzystaniem urządzeń do monitorowania skuteczności uciskania klatki piersiowej: TrueCPR i aplikacji PocketCPR.

Metody: W badaniu uczestniczyło 167 ratowników medycznych. W sposób randomizowany wykonywali uciśnięcia klatki piersiowej, stosując SMCC, TrueCPR i telefon z aplikacją PocketCPR.

Wyniki: Wyniki badań poddano analizie statystycznej. Najlepszą efektywność uciskania klatki piersiowej odnotowano w przypadku TrueCPR (85,5%), była ona statystycznie istotnie wyższa niż w przypadku SMCC (40,3%; $p < 0,001$) i PocketCPR (28,8%; $p < 0,001$).

Wnioski: Wstępne wyniki wskazują, że zastosowanie TrueCPR podczas resuscytacji poprawia skuteczność uciskania klatki piersiowej. Zastosowanie aplikacji PocketCPR znacząco zmniejsza efektywność uciśnięć klatki piersiowej w porównaniu z SMCC. Należy przeprowadzić dalsze badania potwierdzające te wyniki w praktyce klinicznej.

Słowa kluczowe: resuscytacja krążeniowo-oddechowa, ratownik medyczny, efektywność, TrueCPR, PocketCPR, symulacja
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