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CPREzy™ improves performance of external chest compressions in simulated cardiac arrest[☆]

Stefan K. Beckers[a,b,*,1], Max H. Skorning[a,1], Michael Fries[a], Johannes Bickenbach[b], Stephan Beuerlein[a], Matthias Derwall[a], Ralf Kuhlen[b], Rolf Rossaint[a]

[a] *Department of Aneasthesiology, University Hospital Aachen, Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen University, Germany*
[b] *Department of Intensive Care Medicine, University Hospital Aachen, Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen University, Germany*

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Summary
Aim of the study: External chest compression (ECC) is an essential part of cardiopulmonary resuscitation and usually performed without any adjuncts. Although different supportive devices have been developed, none have yet been implemented as a standard procedure to guide rescuers in resuscitation. This study investigates the effects of the CPREzy™-pad on ECC performed by first year medical students during simulated cardiac arrest.
Materials and methods: Two hundred and two subjects were randomised and asked to perform 5 min of single-rescuer-CPR. Group 1 (n = 111) was taught classic ECC, followed by ECC with the CPREzy™ and was tested in ECC with the CPREzy™. Group 2 (n = 91) was taught and tested in classic ECC only. One week later each group was divided: Group 1A was tested in ECC with the CPREzy™ again; Group 1B was tested in classic ECC. Group 2A was taught and tested in ECC with CPREzy™; Group 2B was tested in classic ECC again. Primary endpoints were compression rate (90—110/min) and compression depth (40—50 mm).
Results: Comparing groups 1 and 2, ECC was significantly superior with CPREzy™ (correct rate: 93.7% versus 19.8%, $p \leq 0.01$; depth: 71.2% versus 34.1%, $p \leq 0.01$). The group tested with CPREzy™ initially 1 week later (2A; n = 36) improved significantly in correct compression rate (19.8% versus 88.9%, $p \leq 0.01$) and compression depth

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* Corresponding author at: Working Group Emergency Medical Care, Department of Anaesthesiology, University Hospital Aachen, Pauwelsstr. 30, D-52074 Aachen, Germany. Tel.: +49 241 80 88179; fax: +49 241 80 82406.
E-mail address: sbeckers@ukaachen.de (S.K. Beckers).
URL: http://www.anaesthesie.ukaachen.de.

[1] These authors contributed equally to the study.

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(34.1% versus 75.0%, $p \leq 0.02$). The control-group (2B; $n = 55$) without CPREzy™ demonstrated poor performance in both evaluations (correct rate: 19.8% versus 25.5%, depth: 34.1% versus 43.6%).
Conclusion: CPREzy™ as a simple portable and re-usable device is able to improve performance of ECC in simulated cardiac arrest.

Introduction

The initial goal of cardiopulmonary resuscitation (CPR) is to restore an organised, perfusing heart rhythm. External chest compressions (ECC) are a key element of CPR aiming to promote forward blood flow and therefore to maintain heart and brain viability. Even optimally performed manual ECC rarely exceeds 30% of normal vital organ blood flow[1,2] and the haemodynamic effects of ECC are dependent on the compression force,[3] rate[4] and duration.[5] However, the overall importance and haemodynamic significance of consistent, well-performed ECC has recently been reconfirmed by laboratory investigations documenting decreased resuscitability when ECC is interrupted for rescue breathing and rhythm analysis.[6–8]

In contrast, the quality of ECC performed by professional healthcare providers has been called into question, and the performance by laypersons might even be worse.[9,10] The current ILCOR guidelines recommendations[11] cover different facets of ECC performance, summarised in Table 1. Several devices have been developed specifically to support lay rescuers to improve adherence to these recommendations. However, none of these devices has been incorporated into clinical practice.

The CPREzy™-pad (CPREzy™) is an adjunct that has been shown to improve the performance of ECC in two studies with a small number of tested subjects and different study designs. The aim of the present study was to examine if the use of the CPREzy™ is able to improve the quality of ECC in a large population of first year medical students, if effects of training were detectable, and if the device was accepted by the users.

Table 1 Summary of recommendations concerning external chest compressions

Hand positioning	Lower half of the sternum
Compression rate	100/min
Compression depth	40–50 mm
Ratio compression:decompression	1:1 (with complete release during decompression)
Compression–ventilation ratio	30:2

Materials and Methods

Equipment

The CPREzy™ is a re-usable, portable device designed to improve the performance of rescuers delivering ECC during CPR. It consists of a solid plastic exterior shell weighing 260 g. The external dimensions are 55 mm × 180 mm × 50 mm and a 9 V battery is necessary to power the device. A diagram on the lower part of the device indicates where it should be placed on the patient's sternum and where to apply compression force (Figure 1). After turning the device on, a series of lights in the upper part illuminate with each compression, and switch off after releasing pressure adequately. The number of lights activated depends on the force generated by each compression force 23 kg illuminates 1 light and is suitable for a child, 2 lights generate 32 kg suitable for a small adult, 3 lights generate 41 kg suitable for an average adult, 4 lights generate 50 kg suitable for a large adult and 5 lights are equal to 54 kg (caution). The corresponding, approximate, body weights are indicated adjacent

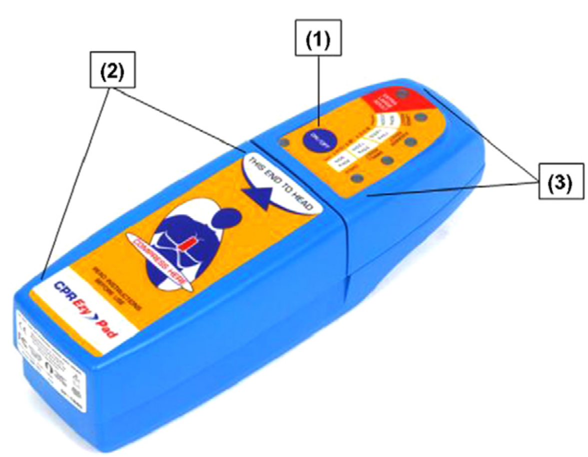

Figure 1 The CPREzy™-pad with the on/off-button (1), the compression surface (2) and the series of lights indicating the amount of compression pressure (3).

Table 2 Overview ''four-step-approach''

Step 1	Demonstration of the skill by the instructor in real time without explanations
Step 2	Repeat demonstration of the skill with dialogue informing learners of the rationale for actions
Step 3	Repeat dialogue, describing the skill by one or several learners with their own words
Step 4	Repeat demonstration of the skill by the learner, and practice of the skill by all learners

to the lights; these are not the same as the force generated.

An integrated metronome beeping at a rate of 100 times per minute indicates the correct rate of compressions. At a distance of 30 cm from the device the audible signal has a volume of 60 dB.[12,13]

Subjects

First year medical students were asked to take part in the study during their initial weeks at the medical school of the University in Aachen, Germany. These students had no specific previous medical education after leaving secondary school. Students who passed any medical emergency-training before the beginning of their studies were excluded from the study.

All students were informed that their performance would be evaluated and used for scientific purposes. The sex and age of each student, but no personal data were collected. Therefore, the institutional ethical committee waived the need to obtain informed consent from each person.

Study protocol (Figure 2)

In a prospective randomised study, subjects were evaluated twice on the same manikin (Skillreporter ResusciAnne®, Laerdal, Stavanger, Norway) in a mock cardiac arrest scenario. Prior to the first evaluation all subjects received a tutorial in Basic life support — including classic ECC — by certified Advanced Life Support Instructors of the European Resuscitation Council (ERC). To assure consistent instructions for all participants, a standardised and common teaching methodology of the ERC, the ''four-step-approach''[14,15] was used (Table 2). The subjects were then randomly divided into two groups (1 and 2) for the first evaluation. Group 1 received additional teaching of approximately 5 min about how to use the CPREzy™, also employing the ''four-step-approach''. Group 2 received no additional instructions. Both groups were directly assigned for their first evaluation on the same day. All individuals were tested using the following standardised protocol (Figure 2):

The manikin was placed in supine position on the floor dressed with a zippered jacket. Two physi-

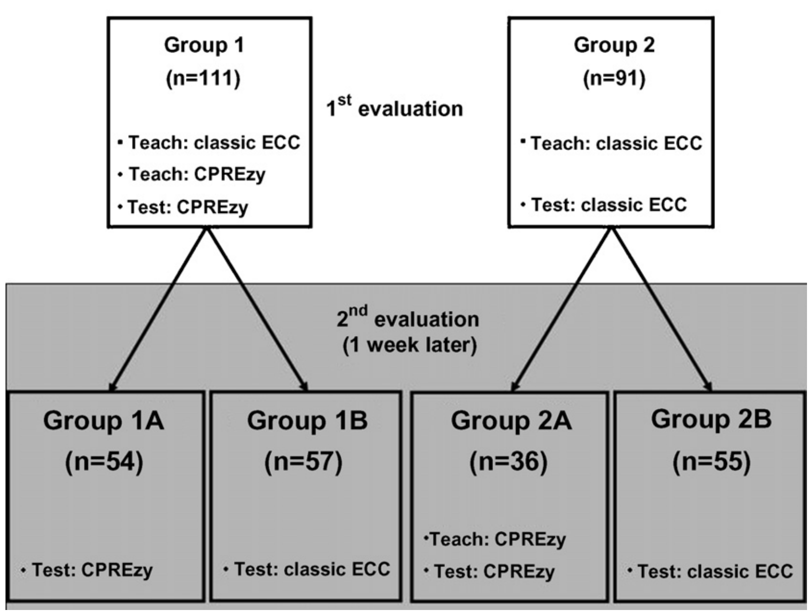

Figure 2 Overview of the study protocol.

cians skilled in providing and teaching Advanced Life Support (certified instructors of the ERC) were present during the performance of each student and recorded data. Each subject was tested individually and was not able to observe the other participant's performance. They were instructed with the following sentence:

''This manikin represents a normal sized adult who collapsed just in front of you. Please assess the patient.''

While checking vital signs the following instructions were given to the subjects each time in the identical manner:

''The patient is not breathing and has no signs of circulation. You have directed another bystander to perform an emergency call. Please perform basic life support until paramedic personnel arrive on the scene.''

The procedure was always carried out as single-rescuer-CPR (ECC in combination with mouth-to-mouth ventilation in a 15:2 ratio). Subjects allocated to use the CPREzy^{TM} were asked to use the device, placed beside the manikin. The evaluation was terminated after 5 min.

One week later the subjects were divided into two subgroups (A and B) for the second evaluation: group 1A was tested in ECC with CPREzy^{TM} again and group 1B was tested in classic ECC only. Group 2A received the same standardised training in the use of CPREzy^{TM}, as group 1, and was tested afterwards using CPREzy^{TM}, while group 2B was tested in classic ECC again and therefore served as a control-group. Testing procedures during the second evaluation were the same as the standardised protocol described for the first evaluation.

Data analysis

Primary end-points

The primary end-points were — adapted to at that time current guidelines[16,17] — an average compression depth within 40 and 50 mm and a targeted rate of ECC between 90 and 110/min. This rate refers to the rate of compressions, not the absolute amount of compressions produced per minute because of interruptions for ventilation.

Secondary end-points

Incorrect hand positioning and incomplete release of pressure between compressions also were recorded during ECC performance. In each case, a fraction of more than 20% of compressions with one of these failings was assumed not to be acceptable.

We decided to analyse sex-specific differences concerning each aspect of ECC.

Because of the potential interaction between ECC and rescue breaths while performing single-rescuer-CPR, we also recorded data of ventilation volumes and the number of rescue breaths achieved during the evaluations. As recommended in the guidelines current at that time an average volume of 700—1000 ml was assumed to be effective.[16,17]

After the first use of the CPREzy^{TM} each participant was asked to complete a questionnaire (Table 5) addressing the ease of use and their personal level of confidence while using the device.

Statistical analysis

Categorial variables (e.g. correct rate of compressions) were analysed using Fisher's exact or McNemar-test, respectively depending whether results were compared within or between groups.

Absolute data (e.g. ventilation volume) were compared using a *t*-test for connected and disconnected items. A p-value of ≤ 0.05 was considered to indicate statistical significance. For analysis, statistical software SPSS 12.0 (SPSS Inc., Chicago, IL) was used.

Results

Study population

Seventy-one percent of the tested subjects ($n = 202$) were female and 29% male with a mean age of 20.7 years (range 18—31 years). We excluded 28 subjects prior to the study, because of a history of medical education (17 emergency medical technicians and paramedics and 11 specialised nurses). A few students had to be eliminated from the study because of failure to attend the 2nd test due to organisational problems. The result was an unexpected reduction in group 2A compared to the other subgroups.

First evaluation

Group 1 showed significantly better results than group 2 for the correct rate (93.7% versus 19.8%, $p \leq 0.01$) and the correct depth of compression (71.2% versus 34.1%, $p \leq 0.01$). There were no significant differences in the number of incomplete releases between compressions ($p = 0.722$) and incorrect hand positioning ($p = 0.244$) detected among the groups. Further details are displayed in Table 3.

Table 3 Results of the 1st evaluation

	Group 1 ($n = 111$)				Group 2 ($n = 91$)				p-Level
	Male ($n = 38$)	Female ($n = 73$)	Total		Male ($n = 21$)	Female ($n = 70$)	Total		
			n	%			n	%	
Compression rate 90–110/min	34	70	104	93.7	2	16	18	19.8	≤0.01
Compression depth 40–50 mm	32	47	79	71.2	13	18	31	34.1	≤0.01
Incomplete release between compressions (>20%)	1	1	2	1.8	3	0	3	3.3	0.722
Incorrect hand positioning (>20%)	5	8	13	11.7	2	11	13	14.3	0.244

Comparison of subgroups from first to second evaluation

Group 1A, tested with the CPREzy™ demonstrated only a marginal increase of the primary and secondary endpoints in both evaluations, but without any significance between the times of testing.

The subjects tested on the first evaluation with the CPREzy™ and on the second evaluation without the device (group 1B) performed significantly worse regarding the rate of compressions ($p \leq 0.01$), whereas compression depth, correct release and hand positioning remained unchanged.

Group 2A, tested with the CPREzy™ initially in the second evaluation, produced a significant improvement in the correct rate of compression (from 19.8% to 88.9%, $p \leq 0.01$) and a significant increase in the average compression depth (from 34.1% to 75.0%, $p \leq 0.02$), without an influence on release and hand positioning. In group 2B, a consistently poor performance during both evaluations occurred. Further details are displayed in Table 4.

Comparison of subgroups within the second evaluation

The subjects accomplishing ECC with the CPREzy™ (groups 1A and 2A) showed similar results without any significant difference in all end-points. Comparing the subjects carrying out classic ECC, group 1B performed significantly better than group 2B in respect of the correct depth of compression (71.9–43.6%, $p \leq 0.01$), whereas the rest of the observed variables showed just marginal differences without any significance. Further details are displayed in Table 4.

Table 4 Results comparing subgroups in the 2nd evaluation

	Group 1A ($n = 54$)		Group 2A ($n = 36$)		p-Level
	n	%	n	%	
Compression rate 90–110/min	51	94.4	32	88.9	0.372
Compression depth 40–50 mm	45	83.3	27	75.0	0.151
Incomplete release between compressions (>20%)	1	1.9	3	8.3	0.204
Incorrect hand positioning (>20%)	6	11.1	4	11.1	1.00
	Group 1B ($n = 57$)		Group 2B ($n = 55$)		p-Level
	n	%	n	%	
Compression rate 90–110/min	21	36.8	14	25.5	0.196
Compression depth 40–50 mm	41	71.9	24	43.6	≤0.01
Incomplete release between compressions (>20%)	1	1.8	3	5.5	0.301
Incorrect hand positioning (>20%)	12	21.1	6	10.9	0.145

Table 5 Questionnaire in respect of the subjects using the CPREzy™ ($n = 147$)

	Yes		No		Not able to judge	
	n	%	*n*	%	*n*	%
Would you use the CPREzy™ in a real cardiac arrest situation?	111	75.5	36	24.5	—	—
Would you agree that CPREzy™ helped in performing CPR?	109	74.1	23	15.6	15	10.2
Did you feel more confident in performing CPR using the device?	106	72.1	41	27.9	—	—
Did the feel disturbed in performing CPR using the device?	27	18.4	119	81.0	—	—
Would you carry CPREzy™ in your first-aid-kit?	118	80.3	27	18.3	—	—

Sex-specific differences

There were significant differences regarding the correct depth of compression between males and females in group 1 (84.2% versus 65.3%, $p \leq 0.01$) as well as in group 2 (61.9% versus 25.7%, $p \leq 0.01$) during the first evaluation. Such differences could not be observed during the second evaluation.

Effect on ventilation

In group 1, significantly more rescue breaths reached the correct ventilation volume than in group 2 (43.2% versus 30.8%, $p \leq 0.02$), but we could not find any significance comparing the subgroups on the second evaluation.

The total number of rescue breaths delivered during the evaluations was comparable between groups and subgroups without any statistical significance.

User satisfaction with the CPREzy™

A total of 147 participants used the CPREzy™ and completed the questionnaire. The majority *stated that they* would use the device in a real cardiac arrest situation and agreed that the CPREzy™ helped them in performing CPR. Only a few of the subjects felt disturbed using the device. Complete results of the questionnaire are shown in Table 5.

Discussion

It is accepted that good quality ECC is of particular importance in CPR. While evidence about the best method is rare, it is suspected that the guidelines' recommendations represent a feasible compromise.

Recently published data shows weak performance of healthcare professionals especially for the rate and the depth of compressions. Wik et al. reported from out-of-hospital resuscitation a mean compression depth of 34 mm and just 28% of compressions with a depth of 38—51 mm.[10] These observations were also confirmed by Aufderheide et al. in simulated cardiac arrest: they obtained poor results with healthcare professionals for compression depth in an assessment of different alternative manual chest compression—decompression techniques as well.[18]

For in-hospital-resuscitation Abella et al. detected a correct rate of ECC — between 90 and 110/min — in only 31.4% of the observed time during resuscitation attempts.[9] Additionally, they found that a higher compression rate correlated with a higher rate of ROSC. The survivors had a mean compression rate of 90/min, whereas the non-survivors received compressions at a mean rate of 79/min.

Based on these findings we made the presumption that the abilities of non-healthcare professionals performing ECC were going to be poor, too. In fact the results of our control-group confirmed this statement, because even in the second evaluation only 43.6% obtained the correct compression depth and only 25.5% the correct compression rate.

Our main finding is the remarkable improvement of compression rate and depth with CPREzy™ during simulated cardiac arrest. Another important result is the fact that CPREzy™ is able to achieve an enduring effect after it has been used in resuscitation training because it gives immediate and consistent feedback of the depth of compressions to the individual student.

In respect of the compression rate, our data confirmed the effect of an audible signal in producing the correct rate of compressions, but no lasting effect for this endpoint was detectable. Kern et al. demonstrated the improvement of compression rate by using a metronome during ECC.[19] Additionally, positive effects of audible tone guidance were described by Milander et al.[12] and build the basis for related guidelines' recommendations in 2000.[20] After a few minutes, quality of ECC deteriorates because of fatigue,[21] and so strategies to prevent this effect seem worth thinking about.

Looking at the secondary end-points of our study, we were able to demonstrate that there are at least no negative side-effects during the use of CPREzy^{TM} in terms of other requirements for ECC such as hand positioning and decompression. Also there is no adverse influence on rescue breathing.

Not to our surprise, the compression depth depends on personal features so females had more problems to reach the correct depth during the first evaluation. But given the profound improved compression depth in males we would not suggest the CPREzy^{TM} for women only.

Elding et al. described the CPR-Plus, a similar non-invasive device, which was able to reduce the amount of incorrect compressions as well as to reduce fatigue effects during ongoing CPR.[22] Although this paper stated that devices may have the same effect on real-life victims, no efforts were attempted to translate these results into practice until now.

The CPREzy^{TM} was described by Boyle et al. first.[13] They tested a small number of non-medical hospital staff (n = 32) after CPR-training, asking then to perform 4 min of two-person CPR in simulated cardiac arrest and found results comparable to ours, a significant improvement of compression rate and depth, especially during the last minute of CPR. Additionally, they stated that the device might be able to reduce ''injury from incorrect position of ECC'', because of an increase in correct hand positioning with the device, contrary to our results.

Perkins et al. tested the device during simulated cardiac arrest on a hospital bed and observed the performance of 20 certified BLS/AED instructors.[12] After instructions and familiarisation with the device they performed 3 min of continuous ECC with, and without the CPREzy^{TM}. Overall they detected, even in this group of well-trained and specialised subjects, a significant improvement of compression depth, whereas a larger amount of incorrect hand positioning with the CPREzy^{TM} (mainly too low compressions) in contrast to our findings were observed. Moreover in contrast to our study 95% of the CPREzy^{TM} users complained discomfort and pain in hand and wrist. From our 147 subjects assigned to use the new device all were able to provide ECC and only one subject reported pain in the thumb. Eighteen subjects expressed concern about the design, e.g. ''surface too slippery'' or ''unfavourable shape''; suggestions the manufacturer should consider for technical improvement of the device in future.

Considering possible limitations we have to clarify first of all, that CPREzy^{TM} is not comparable to mechanical devices for cardiopulmonary resuscitation as Cardiopump^{TM}, Lifestick^{TM} or other recent technical developments.[23] These devices provide additional mechanical benefits, which are not generated by the CPREzy^{TM}. The CPREzy^{TM} is simply a device that helps the performer to carry out quality ECC as recommended.

The groups are not representative concerning sex (male 29%, n = 59; female 71% n = 143) and age (20.7 years, range 18—31), but are comparable between groups. Although the evaluated subjects were not chosen at random from the total population, they represent a group of young and inexperienced laypersons, because in Germany students usually start medical school directly after graduation from secondary school. For this reason we argue that they are laypersons concerning CPR and not representative of other healthcare professionals.[24] But as other studies have already considered, participants may not be free from external or internal motivation factors[25,26] just because they are going into medicine.

Moreover, all models of the manikin used in studies representing an unconscious, apoxic and pulseless victim are unable to simulate a human perfectly. Following this limitation it is debatable if simulation of a complex performance can convert into clinical practice, but as a testing instrument for this purposes it is appropriate and has been described on several occasions previously.[13,22,24,27—29]

Conclusions

The CPREzy^{TM} is a new device that is easy to use after brief instruction and is able to improve laypersons' performance of ECC in simulated cardiac arrest. In addition, it seems to enhance the quality of classic ECC later, even if the device has only been used in resuscitation training.

With increasing evidence that ECC is becoming a more and more important part of CPR, a device helping users to meet the guidelines during ECC performance is worthy of further study.

In order to validate these findings in vivo, clinical studies are essential to translate this into clinical practice. Another step is to gather data about help for professionals to improve their CPR performances, and to demonstrate an improvement in the outcome of patients with cardiac arrest.

Conflict of interests

The authors declare that Health Affairs Ltd., United Kingdom, provided training devices for the investigators of the study, and they confirm, that no additional governmental nor commercial financial support that could influence the work was granted to any of the listed authors.

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