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Quality of chest compressions performed by school-age children — a quasi-experimental simulation-based study

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ABSTRACT

Introduction: Most of the research worldwide mentions that cardiopulmonary resuscitation (CPR) training should be conducted among children. The knowledge of life-saving practices of CPR should be made available to various groups of society, including children. The present study shows the results of such experiments done with children, especially with regard to out-of-hospital cardiac arrest (OHCA). Children are apt learners and thus can be of great help in case of sudden OHCA, to their grandparents, for example.

Material and methods: This study aimed to find out if children aged 7–12 have the ability to perform quality chest compressions (CC), which is one of the most important activities in CPR. The study involved 447 children from public elementary schools who never had practical classes in cardiopulmonary resuscitation before. The following parameters were defined as primary outcomes: chest compression fraction (CCF), session time, mean depth, rate of compressions, percentage of compressions at the correct depth, recoil, and the correct rate of compression.

Results: The results showed that the compression rate improves with training; however, the mean depth of compression still remains a great problem.

Conclusions: Although children aged 7–12 are not really in a position to perform a high-quality CPR, the importance and role of CPR training cannot be neglected. Such training results in the betterment of the quality of CPR.

Key words: cardiopulmonary resuscitation, community health education, simulation study, chest compressions, simulation training

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Introduction

Although the knowledge about the basics of first aid is continuously spreading among society, out-of-hospital cardiac arrest (OHCA) still remains one of the leading causes of death all over the world, including in Europe. It could be said that it is a major health problem [1]. A retrospective study of sudden cardiac arrest (SCA) in Europe demonstrates that there are over 10000 cases per year and over 7000 attempts of cardiopulmonary resuscitation (CPR) [2]. These numbers show how vital this issue is even in today's times. Unfortunately, OHCA is associated with a poor survival rate. According to a meta-analysis performed by Sasson et al., 76.2% of victims die before they get admitted to the hospital, and 92.4% die in hospital [3]. It is frequently argued that early initiation of CPR performed by bystanders before the arrival of Emergency Medical Service (EMS) can lead to improvement of the number of survivals up to 2–4 times [4]. People who receive bystander CPR are also less likely to suffer from brain damage or death during the first year after OHCA as compared to people receiving no bystander CPR [5, 6].

It is a well-known fact that children, especially those living in developed countries, often spend their time with grandparents who belong to an at-risk group for

OHCA. Moreover, the majority of cardiac arrests happen at patients' homes [7]. This is why we should focus on developing CPR skills among schoolchildren. They are an incredibly teachable group that might save the lives of many OHCA victims by performing proper CPR in the future. Research held by multiple departments from Germany reveals that after 3- or 6-year training carried out by teachers, pupils achieved high results for knowledge about both chest compression (CC) and the ventilation rate. Even after a 3-year pause in training, skills of pupils after the 3-year course remained stable (in comparison to those with 6 years annual training program) [8]. Latest studies revealed that CPR courses are not flawless, yet they should be regularly conducted by trained teachers or BLS instructors [9].

This study aimed to evaluate whether schoolchildren aged 7-12 possess the ability to conduct correct and effective CC. An additional purpose was to evaluate the effectiveness of training on the quality of performed compressions.

Material and methods

Legal aspects

The study protocol was approved by Institutional Review Board (No KB337/21).

Parents of all participated children in the study provided written informed consent.

Population

The study involved 447 children from public elementary schools in Poznan County. Only children who never had practical classes in cardiopulmonary resuscitation before were eligible for the study.

Study design and protocol

This study was designed as a quasi-experimental simulation study without a control group. Participants took part in free first aid training. The training lasted 2 hours and covered such elements as calling for help, recognizing sudden cardiac arrest, and hands-only CPR. The classes were conducted based on the 2015 ERC guidelines. The training groups consisted of a maximum of 6 children.

Firstly, the purpose of conducting CC as a key component of providing assistance was discussed. Next, the study participants were asked to perform CC as if they actually wanted to provide the aid. It was assumed that the measurement would be completed after 2 minutes regardless of whether a child had the strength to compress or not, but the child was free to stop compressions when they decided to do so. After the measurements were completed, the children were instructed on how high-quality CC should be conducted. Each child practiced three times: twice for 30 seconds and once for as long as they could continue — but no longer than 2 minutes. After the class was completed, the measurement was repeated. A teacher was always present in the classroom while the study was being conducted.

Variables

The following parameters were defined as primary outcomes: CCF (1), session time (2), mean depth (3), rate (4) of compressions, percent of compressions at the correct depth (5), and recoil (6) and the correct rate of compression (7).

Measurements and equipment

The ResusciAnne QCPR (Laerdal Medical AS, Stavanger, Norway) human simulator was used in the study.

During the test, the following parameters were monitored with Session Viewer Software 6.2.6400 (SimVentures 2019): CCF (1), session time (2), mean depth (3), rate (4) of compressions, percent of compressions at the correct depth (5), and recoil (6) and the correct rate (7).

Statistical analysis

Statistical analysis was performed in STATISTICA Application, version 13 using the author's database. Descriptive statistics of measurable variables (age, mean depth, and rate of compressions, percent of CC with proper relaxation, percent of compressions with adequate depth and rate in, meantime of session) were performed during the analysis. Due to the non-normal distribution among the variables, nonparametric tests were used. Data were presented as mean±standard deviation (SD) in the case of a normal distribution and median [interquartile range] in the case of a non-normal distribution. To check the significance of differences the Mann-Whitney U test and Wilcoxon pairwise rank test were used as appropriate. To check the correlation between age and CC quality parameters, Spearman's rank correlation test was used. A value of $p < 0.05$ was considered statistically significant.

Results

Study group

A total of 447 trials were conducted. 45 measurements were ineligible because these children had prior first aid training. Finally, 402 trials were qualified for further analysis. There were 200 girls (49.75%) and

202 boys (50.24%) in the study group. The median age was 9 years (7–12). The median body weight was 33 kg (19–74). The mean height was 142.00 ± 11.74 cm.

Pre-training outcomes

The median depth of compressions in the study group was 22 mm (10–69). The median percentage of compressions performed to the correct depth was 1 (0–100). The median compression rate was 110 (33–188) compressions per minute. The median percentage of compressions performed at the correct rate was 9% (0–100%) and correctly recoiled 100% (2–100). The median time the child was able to conduct compressions was 90 (10–120) sec. The subjects achieved a median CCF of 96% (7–100). Spearman's rank-order correlation analysis showed a statistically significant positive correlation for all investigated parameters except chest decompression, which was conducted less accurately with age. The detailed distribution according to age along with correlation coefficients was presented in Figures 1–5. It was also found that before training the quality of boys' performance was higher than that of girls' (Tab. 1).

Post-training outcomes

The training resulted in a statistically significant increase in all evaluated quality parameters. Detailed values were summarized in Table. 2.

Participants after training were able to perform compressions longer and achieved a higher CCF. Although the rate remained within the normal range, the percentage of compressions delivered at the correct rate increased. This indicates that the compressions were conducted more consistently. There was also an increase in depth indices. Despite the significant improvement, apart from the rate and CCF, the standards recommended in the ERC Guidelines were not achieved. Moreover, the number of compressions performed with correct relaxation decreased. Although this difference was not large, it proved to be statistically significant. As before the training, there was a statistically significant positive correlation of all analyzed parameters to age except chest decompression (Tab. 3). The difference between boys' and girls' performance also decreased as a result of training (Tab. 1).

Table 1. Comparison of test results by gender

Variable	Female	Male	P-value*
BT CCF (%)	95 (7–100)	97 (11–100)	0.0098
AT CCF (%)	99 (2–100)	98 (1–100)	0.7080
P-value#	≤ 0.001	≤ 0.001	
BT session time (sec)	72 (10–120)	120 (12–120)	0.0016
AT session time (sec)	106 (12–120)	120 (15–120)	0.0578
P-value#	≤ 0.001	≤ 0.001	
BT Mean Depth (mm)	21 (10–67)	24 (11–69)	0.0043
AT Mean Depth (mm)	25 (11–65)	29 (11–74)	0.0436
P-value#	≤ 0.001	≤ 0.001	
BT Deep enough compressions (%)	1 (0–99)	1 (0–100)	0.4371
AT Deep enough compressions (%)	1 (0–100)	1 (0–100)	0.0974
P-value#	≤ 0.001	≤ 0.001	
BT Compressions with adequate rate (%)	12 (0–99)	7 (0–100)	0.6048
AT Compressions with adequate rate (%)	53 (0–100)	45 (0–100)	0.0427
P-value#	≤ 0.001	≤ 0.001	
BT Mean rate of compressions (1/min)	104 (33–188)	119 (42–180)	≤ 0.001
AT Mean rate of compressions (1/min)	114 (61–146)	117 (0–143)	0.0826
P-value#	≤ 0.001	0.1720	
BT Compressions fully recoiled (%)	100 (2–100)	100 (2–100)	0.5368
AT Compressions fully recoiled (%)	100 (13–100)	99 (0–100)	0.0519
p-value#	0.5089	≤ 0.001	

Data are presented as median (IQR). AT — after training; BT — before training; CCF — chest compression fraction; *Mann-Whitney test; #Wilcoxon test

Table 2. Comparison of the results in pre-training and post-traning gropus

Variable	BT	AT	P-value
CCF (%)	95 (7–100)	99 (1–100)	≤ 0.001
Session time (sec)	90 (9–120)	120 (12–120)	≤ 0.001
Deep enough compressions (%)	1 (0–100)	1 (0–100)	≤ 0.001
Mean Depth (mm)	22 (10–69)	28 (11–74)	≤ 0.001
Compressions with adequate rate (%)	9 (0–100)	49 (0–100)	≤ 0.001
Mean rate of compressions (1/min)	110 (33–188)	115 (80–147)	≤ 0.001
Compressions fully recoiled (%)	100 (2–100)	99 (0–100)	0.0036

Data are presented as median (IQR); AT — after training; BT — before training; CCF — chest compression fraction

Discussion

This is an indisputable fact that the time in which CPR is performed (no flow time length) is crucial for the long-term survival of people suffering from OHCA. Early initiation of CPR by bystanders, even before Emergency Medical Service arrival, may increase the number of survivors and decrease the possibility of brain damage or death during the first year after sudden cardiac arrest [10–12]. It seems that there are two main difficulties concerning providing first aid by non-professionals — the lack of appropriate training and anxiety about performing CPR. The studies have shown that despite some improvement, unwillingness to perform CPR is ever-present in the relevant number of questioned people [13–15]. Most studies reveal that the only way to address this issue is by providing high-quality CPR training [16–18].

All over the world, medical specialists hustle to spread the knowledge of first aid among society. There is still very little research analyzing whether essential parts of lifesaving procedures, such as CC and rescue breaths, can be executed by anyone at any age. Schoolchildren were considered one of the target groups for CPR training, which leads to widening the awareness and capability to provide first aid in OHCA [19, 20]. This study focused on hands-only CPR abilities in children aged 7–12. According to the presented results, children who took part in CC training can perform more effective compressions, but their efficiency remains below the norms suggested in the ERC Guidelines in most of the tested parameters (except for the compression rate and CCF).

In the 2015 ERC Guidelines, the CC rate was established as 100–120 compressions per minute and depth as at least 5 cm but not more than 6 cm. In this study, the depth goal was not reached in a bigger part of the group — neither before nor after training whereas children could already perform compressions at a proper rate before training. After the course, not only the rate remained accurate, but also the percentage of compressions done at the correct rate rose. This study was conducted in 2020 when the 2015 guidelines were in force. The new resuscitation guidelines were published in 2021, but there are no changes to the CC quality criteria.

It is worth stressing that both parameters improve with age. Among younger children (7 years old), even after training, the mean depth of compressions was lower than 25 mm while in older children (12 years old) the mean depth was raised to almost 40 mm. Moreover, there is a need to give prominence to fully recoiled compressions. Although the results are notably high, they may arise from the fact that many children did not manage to reach appropriate depths of CC.

Although the standards recommended in the ERC Guidelines were not achieved, the requirement to teach young children first aid was met. Even a short training course can increase significantly the knowledge and ability to execute improved methods, which creates a higher possibility that the child will be an active participant in CPR and defibrillation procedures in the future. According to other studies, the abilities acquired during high-quality training persist for some time, which is even longer if training is repeated [21, 22].

That reveals another aspect of the CPR training. It is really important to think about the possibility of children being able to teach other groups of potential OHCA bystanders (parents, other family members, and friends) the most important techniques of CPR, such as CC or rescue breaths. This course of action may increase the number of people who can be more prepared and more willing to help sufferers of OHCA in the future, even if their knowledge is not comprehensive. Furthermore, as we believe, young people who took part in CPR training and have basic knowledge about first aid may be more likely to attend CPR courses in the future.

The subject of children performing hands-only CPR is not frequently discussed in scientific research, especially among scientists in Poland. Prior to this

Table 3. Comparison of the results and correlation in pre-training and post-traning groups by age

Variable	Age of the participants						Spearman's rank correlation	P-value
	7 y.o.	**8 y.o.**	**9 y.o.**	**10 y.o.**	**11 y.o.**	**12 y.o.**		
BT Mean Depth (mm)	16 (14–25)	19 (15–24)	23 (19–28)	26.5 (18–34)	23 (18–28)	32 (24–41)	r = 0.3483	< 0.001
AT Mean Depth (mm)	23 (16–30)	22 (16–32)	30 (23–39)	29 (24–37)	28 (23–35)	42.5 (32–52)	r = 0.3763	< 0.001
BT Deep enough compressions (%)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–7)	r = 0.1849	< 0.001
AT Deep enough compressions (%)	0 (0–0)	0 (0–0)	0 (0–1)	0 (0–3)	0 (0–0)	4.5 (0–580	r = 0.2697	< 0.001
BT Compressions with adequate rate (%)	7 (0–35)	8 (0–29)	9 (0–37)	7.5 (0–45)	9 (0–60)	13.5 (1–57)	r = 0.1577	0.0015
AT Compressions with adequate rate (%)	55 (31–91)	44 (25–69)	65 (29–89)	44 (26–78)	66 (28–92)	54.5 (28–86)	r = 0.0743	0.1369
BT Mean rate of compressions (1/min)	87 (66–113)	96 (68–128)	115 (90–132)	119 (98–133)	114 (107–135)	119 (102–131)	r = 0.2746	< 0.001
AT Mean rate of compressions (1/min)	112 (109–122)	112 (106–121)	113 (110–122)	121 (112–126)	116 (110–125)	117 (110–122)	r = 0.2082	< 0.001
BT Compressions fully recoiled (%)	99 (98–100)	100 (97–100)	100 (99–100)	100 (96–100)	99 (89–100)	98 (80–100)	r = –0.2609	< 0.001
AT Compressions fully recoiled (%)	100 (88–100)	100 (95–100)	100 (99–100)	99 (90–100)	99 (82–100)	95.5 (61–100)	r = –0.2049	< 0.001

Data are presented as median (IQR). AT — after training; BT — before training; y.o. — years old

study, only a few children's groups were tested on their abilities to perform sufficient CC after a first aid course. Even though there seems to be an agreement worldwide that CPR courses should be implemented in primary schools, there is still an open issue about the right age at which first CPR training should be conducted. The key point is gaining the capability to achieve appropriate CC parameters by trained children.

Other studies agree with our results. Banfai et al. suggest that the best age is 10 years old [23]. Similarly, Beard et al. indicate 11 years old [24] and Hill et al. 10–11 years old [25]. Jones et al. propose a slightly more advanced age and point to 13–14 years old [26]. Even though there is some variance, most researchers agree on similar age. Moreover, it is important to stress that children as young as 7 years old can learn CC technique and BLS theoretical skills and are more willing to participate in CPR courses than children who attend their first course after the beginning of puberty [27–29]. Therefore, they should be considered in first aid training as well. Furthermore, as Stroobants et al. state, one child who participated in BLS training shares their knowledge with an average of 1–7 other people — this rate is significantly higher in younger children [30]. In the recent 2021 ERC Resuscitation Guidelines, the authors recommend teaching children according to the "Check-call-compress" algorithm. Moreover, training ten more people within next two weeks should be assigned as their homework. Because real-life CPR conducted by non-professionals is always associated with lots of emotions and pressure, there is still an uncertainty if our results could be confirmed in non-simulated conditions.

Limitations

The most important limitation of the study was narrow population demographics. The trial was conducted only among children from the City of Poznan. The number of children participating in the training was not large either. Those aspects could lower the quality of our results.

Both, the training and the final test after the training were executed in simulated conditions therefore participants potentially were not put under pressure.

Because the study ended right after the final test, we are not able to scrutinize how long the children's acquired knowledge and skills will be held on the same level, either.

It is important to highlight as well that the training was performed and finalized within the group of six children. They were able to watch not only the qualified instructors but also their peers' actions, which might have influenced the results.

Conclusions

Children aged 7–12 cannot perform quality CC. However, brief training is effective and improves the quality of compressions delivered. Our training was planned to be short, yet it was conscientiously prepared. We focused on the individual evaluation of every participating child, which was shown in this study. Owing to this fact, we were able to reveal that even short training can significantly raise CRP skills among this group.

It is important to highlight that performing a quick course can increase chances of participants attending similar courses in the future, which might raise the number of children that will take part in similar training.

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