

Factors influencing high-quality chest compressions during cardiopulmonary resuscitation scenario, according to 2015 American Heart Association Guidelines

Halla Kaminska¹, Wojciech Wieczorek^{2,3}, Pawel Matusik⁴, Lukasz Czyzewski⁵,
Jerzy Robert Ladny⁶, Jacek Smereka⁷, Krzysztof J. Filipiak⁸, Lukasz Szarpak^{3,6}

¹Department of Children's Diabetology, School of Medicine in Katowice, Medical University of Silesia, Katowice, Poland

²Department of Anaesthesiology and Intensive Care, School of Medicine in Katowice, Medical University of Silesia, Katowice, Poland

³Department of Emergency Medicine, Medical University of Warsaw, Warsaw, Poland

⁴Department of Paediatrics and Paediatric Endocrinology, Medical University of Silesia, Katowice, Poland

⁵Department of Nephrology Nursing, Medical University of Warsaw, Warsaw, Poland

⁶Department of Emergency Medicine and Disaster, Medical University of Bialystok, Bialystok, Poland

⁷Department of Emergency Medical Service, Wrocław Medical University, Wrocław, Poland

⁸1st Chair and Department of Cardiology, Medical University of Warsaw, Warsaw, Poland

Abstract

Background and aim: Recent American Heart Association guidelines from 2010 and 2015 stressed the importance of high-quality chest compression and defined standards for compression rate, depth, recoil, and maximal acceptable time for interruptions. High-quality cardiopulmonary resuscitation (CPR) is the "cornerstone" of a system of care that can optimise outcomes beyond the return of spontaneous circulation.

Methods: One hundred medical students were enrolled to the study. Study participants, after attending a Basic Life Support Course according to American Heart Association 2015 guidelines, performed 2-min CPR on a Resusci Anne[®] QCPR Manikin. The following data were collected: age, sex, and health status. The study made use of a Tanita MC-980 MA for body composition analysis.

Results: Mean height of participants was 170.2 ± 8.3 cm, and mean weight was 65 ± 11.8 kg. Mean body mass index was 22.1 ± 2.7 , and mean fat-free mass (FFM) was 50.1 ± 10.5 kg. The mean fat mass (FAT%) was 22.9 ± 7.6 . Basal metabolic rate, FFM, trunk muscle mass, left arm muscle mass, and right arm muscle mass were positively correlated with compression depth (all p for trend < 0.05). Mean compression depth was 49.7 ± 8.4 (for female 48.7 ± 7.9 mm, for male 42.4 ± 9.5 mm; $p = 0.144$). Compression rate for males and females was the same, at 114 \times /min ($p = 0.769$).

Conclusions: In our study, basal metabolic rate, FFM, trunk muscle mass, and left and right arm muscle mass were positively correlated with compression depth. Moreover, an arm muscle mass rise of 1 kg caused a rise of compression depth parameter of 7.3 mm, while when chest compression was performed by females, a fall of compression depth of 3.3 mm was seen.

Key words: chest compression, quality, cardiopulmonary resuscitation, body composition

Kardiol Pol 2018; 76, 3: 642–647

Address for correspondence:

Mgr Wojciech Wieczorek, Department of Emergency Medicine, Medical University of Warsaw, ul. Lindleya 4, 02-005 Warszawa, Poland,
e-mail: wieczorekwojciech.pl@gmail.com

Received: 21.11.2017

Accepted: 20.12.2017

Available as AoP: 06.01.2018

Kardiologia Polska Copyright © Polskie Towarzystwo Kardiologiczne 2018

INTRODUCTION

It is estimated that sudden cardiac arrest (SCA) is still the leading cause of death both in Europe and in the United States. According to global statistics, every year due to SCA 50 to 100/100,000 citizens die from this cause around the world [1]. The World Health Organisation shows that ischaemic heart disease is the major cause of deaths in Poland, which led to the death of 89.2 thousand people in 2012. Out-of-hospital cardiac arrest frequently ends with patient death and still implicates poor neurological outcome. Survival in out-of-hospital cardiac arrest ranges from 4.3% to 10.7% [1–4].

Recent American Heart Association (AHA) guidelines from 2010 and 2015 stressed the importance of high-quality chest compression and define standards for compression rate, depth, recoil, and maximal acceptable time for interruptions. High-quality cardiopulmonary resuscitation (CPR) is the “cornerstone of a system of care that can optimise outcomes beyond return of spontaneous circulation” [5–9].

Despite evidence that survival benefit can be achieved with optimal CPR delivery, CPR quality both in-hospital and out-of-hospital remains poor. The authors herein note that there is poor retention of CPR skills after standard training [10, 11].

In a systematic review Mancini et al. [12] suggest that CPR skill decay occurs rapidly after three months. Factors influencing this poor skill retention are suboptimal training procedures during the course, lack of standardisation, and infrequently performed training [13]. In the AHA recommendations from both 2013 and 2015 the research board agrees that the educational system of medical staff should be constantly improved [14]. Furthermore, implementation of standardised and widely available educational training for resuscitation teams and lay persons may increase SCA survival rates [14, 15].

The aim of the study was to identify factors influencing high-quality chest compression during Basic Life Support (BLS) procedures according to the 2015 AHA guidelines.

METHODS

This prospective, observational, single-centre study was conducted between April and June 2016 and approved by the Medical University of Silesia Bioethical Commission (KNW/0022/KB/13/17).

Participants

One hundred medical students were enrolled to the study.

Sixth year medical students included in the study were recruited on a voluntary basis. All participants were previously trained in BLS procedures according to the 2015 AHA guidelines.

Exclusion criteria were chronic diseases that may disable physical activity.

Body composition measurement

The following data were collected: age, sex, and health status. The study made use of a Tanita MC-980 MA body composition analyser (Tanita Corp., Tokyo, Japan), a technique based on BIA measurement with the use of a single frequency current of 50 kHz (single frequency BIA (SF-BIA)) and an eight-contact electrode system. Anthropometric measurements included: standing height measured by wall-mounted Harpenden Stadiometer to the nearest 0.1 cm and weight by electronic scale with readings accurate to 0.1 kg. Body mass index (BMI) was calculated using the standard formula (kilograms per metre squared). Body composition parameters: fat mass (FAT), fat-free mass (FFM), predicted muscle mass, and total body water, were assessed as percentage of body composition.

Study design

Before the study all the participants participated in CPR training according to the 2015 AHA BLS algorithm. Anthropometric data from 72 subjects were recorded. Investigators developed a single two-minute-simulation scenario (AHA BLS), which was performed on a Resusci Anne[®] QCPR Manikin (Laerdal Medical, Stavanger, Norway). For registration of CPR variables Laerdal Wireless SkillReporter[™] Software was used. To assess the high-quality chest compression (CC) the following data were analysed: CC depth (in mm), CC rate (in CC per minute), percentage of correct CC, and different types of errors (insufficient and excessive depth, insufficient chest recoil).

Statistical analysis

Results concerning quantitative variables were presented as average values and standard deviation (SD). In the comparative analysis of compression depth and compression rate, as well as the body composition characteristic, simple linear regression analysis (Pearson) was applied to detect and describe the strength and direction of correlations. In the multivariable linear regression, ANOVA was applied with compression depth as a dependable variable. Qualitative variables (age, sex) were presented as quantity (n) and percentage values of the whole group (%). In the comparative characteristics of sex groups, Student t-test was used. Statistica 13.1 software (StatSoft Inc., Tulsa, OK) was used in the statistical analysis. $P < 0.05$ was adopted as the significance level.

RESULTS

Study population

Seventy-two from 100 students finally participated in the study (21 men and 51 women). All the participants obtained full protocol of the 2015 AHA BLS guidelines and were trained before the study by experienced AHA instructors. The mean age of participants was 23.4 years (minimum 19.5; maximum

Table 1. Body composition characteristics of the study population

Parameters	Mean \pm SD	Minimum	Maximum
Body mass index [kg/m ²]	22.1 \pm 2.7	16.9	28.6
Basal metabolic rate [kJ]	6375.3 \pm 1202.5	4699.0	9623.0
Fat mass [%]	22.9 \pm 7.6	2.4	40.7
Fat-free mass [kg]	50.1 \pm 10.5	36.2	77.7
Total body water [kg]	36.6 \pm 7.7	26.5	56.9
Visceral fat rating	2.0 \pm 1.6	1.0	9.0

Data are shown as mean \pm standard deviation (SD).

Table 2. Chest compression and ventilation parameters

Parameters	Mean \pm SD	Minimum	Maximum
Total number of chest compressions [n]	224.4 \pm 30.8	117.0	295.0
Compression depth [mm]	49.7 \pm 8.4	31.0	63.0
Compressions fully released [%]	48.4 \pm 36.5	0.0	100.0
Compressions deep enough [%]	31.3 \pm 27.6	0.0	96.0
Compression rate [\times /min]	113.7 \pm 14.2	68.0	148.0
Total ventilations [n]	15.6 \pm 7.1	3.0	34.0
Mean ventilation volume [mL]	716.0 \pm 173.6	215.0	999.0
To small ventilation volume [%]	8.3 \pm 20.1	0.0	100.0
To large ventilation volume [%]	60.0 \pm 41.4	0.0	100.0
Correct ventilations [%]	31.7 \pm 35.6	0.0	100.0

Data are shown as mean \pm standard deviation (SD).

33.4 years; median 22.95 \pm 2.40). Students with any physical disabilities were excluded from the trial.

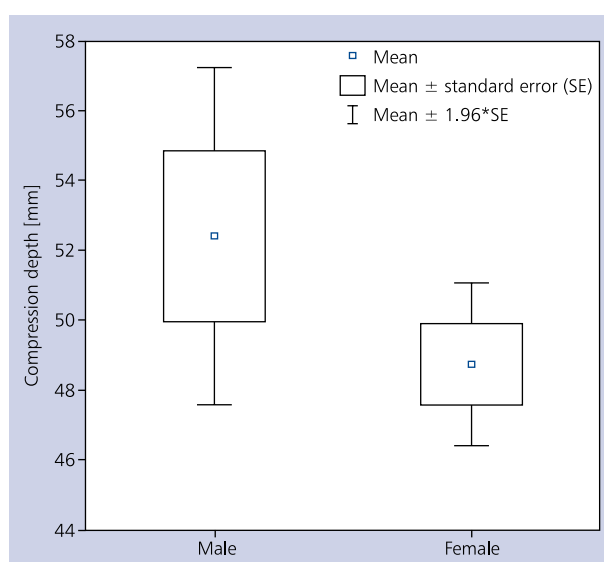
Anthropometric measurements of the participants

Mean height was 170.2 \pm 8.3 cm (minimum 154 cm; maximum 192 cm) and mean weight was 65 \pm 11.8 kg (minimum 42.6 kg; maximum 96.7 kg). Mean BMI was 22.1 \pm 2.7 kg/m² and mean FFM was 50.1 \pm 10.5 kg. The mean FAT% (fat mass), which describes the percentage of fat tissue, was 22.9 \pm 7.6. Body composition characteristics of the study population are presented in Table 1.

Chest compression quality

Chest compression and ventilation parameters are presented in Table 2. Mean compression depth was 49.7 \pm 8.4 mm (for females 48.7 \pm 7.9, for males 42.4 \pm 9.5 mm; $p = 0.144$) (Fig. 1). The compression rates for males and females were the same, i.e. 114 \times /min ($p = 0.769$).

In simple linear regression analysis, basal metabolic rate, FFM, trunk muscle mass, left arm muscle mass, and right arm muscle mass were positively correlated with compression depth (all p for trend < 0.05) (Table 3, Fig. 2). The other parameters did not correlate with compression depth and compression rate.

**Figure 1.** Compression depth values according to sex

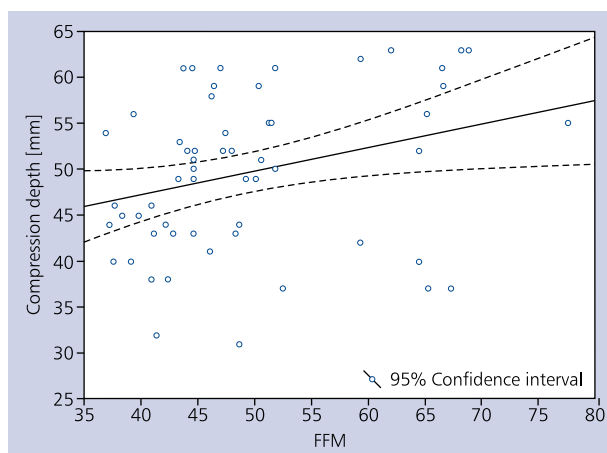
In multivariable linear regression analysis with compression depth as a dependent variable, the retained independent predictors were arm muscle mass and CC performed by a fe-

Table 3. Results of simple regression analyses between compression depth, compression rate and body composition data

Parameters	Compression depth		Compression rate	
	R	P	R	P
Body mass index	-0.089	0.518	0.004	0.978
Age	-0.028	0.833	-0.162	0.238
Basal metabolic rate	0.287	0.034	-0.001	1.00
Fat mass %	-0.107	0.437	0.112	0.416
Fat free mass	0.297	0.023	-0.011	0.940
Trunk muscle mass	0.296	0.023	-0.022	0.866
Left arm muscle mass	0.314	0.015	-0.002	0.983
Right arm muscle mass	0.321	0.013	0.004	0.979

Table 4. Multivariable linear regression model of compression depth

Covariate	Effect	Standard error	95% confidence interval	P	R ²
Model				0.018	0.364
Arm muscle mass	7.286	2.933	1.410 to 13.163	0.016	
Female	-3.257	2.370	-8.006 to 1.491	0.042	

**Figure 2.** Simple linear regression analysis (Pearson) between compression depth and fat-free mass (FFM)

male. The remaining factors were eliminated. An arm muscle mass rise of 1 kg caused a rise of compression depth parameter of 7.29 mm, while when CC was performed by a female a fall of compression depth of 3.26 mm was seen (Table 4).

DISCUSSION

Both European and American guidelines for resuscitation recommend and stress the importance of high-quality CPR during resuscitation. It is estimated that high-quality CC improves the survival rates after SCA [16–18].

Chest compression depth is an important component of CPR and should be measured routinely [19, 20], the most effective depth is currently unknown. In our study, we obtained mean CC depth on 49.7 ± 8.4 mm. Stiell et al. [21] measured characteristics of CCs via an accelerometer interface between the rescuer and the patient's chest using commercially available defibrillators. They included 1029 adult patients with cardiac arrest. They indicated that the median compression rate was 106 per minute, median compression fraction was 0.65, and median compression depth was 37.3 mm with 52.8% of cases having depth < 38 mm and 91.6% having depth < 50 mm. Moreover Stiell et al. [22] found an inverse association between depth and compression rate. Other study of out-of-hospital cardiac arrest patients, performed by Stiell et al. [22], demonstrated that increased CPR compression depth is strongly associated with better survival. They found that maximum survival was in the depth interval of 40.3 to 55.3 mm (peak 45.6 mm), suggesting that the 2015 AHA cardiopulmonary resuscitation guideline target may be too high [22].

Another important indicator that has a large impact on quality of CC and thereby on the potential success of resuscitation is the CC rate [8, 10, 23].

Recent European Resuscitation Council (ERC) and AHA guidelines recommend a CC rate between 100 and 120 per minute (cpm) [23, 24]. According to the literature, the strong consensus about the target CC depth and CC rate has not yet been reached [25, 26]. Kilgannon et al. [25] showed that CC rate between 121 and 140 cpm had the greatest probability of return of spontaneous circulation (ROSC) (odds ratio 4.48;

95% confidence interval 1.42–14.14). In case of the CC rate recommended in ERC guidelines, ROSC was observed in 29%.

Moreover, Wallace et al. [20] presented a meta-analysis which stressed that CC rates closer to 85–100 cpm are significantly associated with improved survival from cardiac arrest. In our study the participants performed CCs according to international resuscitation guidelines ($113.7 \pm 14.2/\text{min}$). Factors which may influence both CC depth and rate implicate the process and quality of resuscitation, especially when the scenario is prolonged. Abelairas-Gomez et al. [27] concluded that factors like physical activity of the rescuer, strength, and muscle mass may influence the course of resuscitation. According to his data we extended the examined factors and checked whether the body composition measured on the Tanita analyser can have an impact on resuscitation quality. To the best of our knowledge, it is the first study that correlates body composition and its impact on high-quality CC.

In our study, linear regression analysis of basal metabolic rate showed that FFM, as well as trunk, and left and right arm muscle mass, positively correlated with compression depth. The results are compatible with data presented by López-González et al. [28], in a study where the authors reported that rescuers should be advised to exercise arm strength to improve the quality of CPR. Russo et al. [29] also indicated that the quality of the external chest compression and fatigue can both be predicted by BMI and physical fitness.

Limitations of the study

Our study had several limitations. Firstly, the study was conducted using a manikin scenario, not a real resuscitation situation. However, it seems to be impossible to perform this kind of research study in a real SCA situation — to date there has been no chance to record quality CC as in the study protocol. Secondly, the study group (previous-year medical students) may indicate some limitations. On the other hand, choosing the study participants was intentional. Previous-year medical students soon become self-reliant physicians and are highly likely to perform resuscitation procedures. A better understanding of the high-quality CC determinants is significant for educational improvements in the future.

CONCLUSIONS

In our study, basal metabolic rate, fat free mass, trunk muscle mass, and left and right arm muscle mass were positively correlated with compression depth. Moreover, an arm muscle mass rise of 1 kg causes a rise of compression depth parameter of 7.29 mm, while when CC was performed by a female a fall of compression depth of 3.26 mm is seen.

Conflict of interest: none declared

References

1. Fishman GI, Chugh SS, Dimarco JP, et al. Sudden cardiac death prediction and prevention: report from a National Heart, Lung, and Blood Institute and Heart Rhythm Society Workshop. *Circulation*. 2010; 122(22): 2335–2348, doi: [10.1161/CIRCULATIONAHA.110.976092](https://doi.org/10.1161/CIRCULATIONAHA.110.976092), indexed in Pubmed: [21147730](https://pubmed.ncbi.nlm.nih.gov/21147730/).
2. Atwood C, Eisenberg MS, Herlitz J, et al. Incidence of EMS-treated out-of-hospital cardiac arrest in Europe. *Resuscitation*. 2005; 67(1): 75–80, doi: [10.1016/j.resuscitation.2005.03.021](https://doi.org/10.1016/j.resuscitation.2005.03.021), indexed in Pubmed: [16199289](https://pubmed.ncbi.nlm.nih.gov/16199289/).
3. Marenco J, Wang P, Link M, et al. Improving Survival From Sudden Cardiac Arrest. *JAMA*. 2001; 285(9): 1193, doi: [10.1001/jama.285.9.1193](https://doi.org/10.1001/jama.285.9.1193), indexed in Pubmed: [11231750](https://pubmed.ncbi.nlm.nih.gov/11231750/).
4. Hasegawa M. [Statistics concerning patients of out-of-hospital cardiac arrests in Japan]. *Nihon Rinsho*. 2011; 69(4): 717–721, indexed in Pubmed: [21591429](https://pubmed.ncbi.nlm.nih.gov/21591429/).
5. Travers AH, Rea TD, Bobrow BJ, et al. Part 4: CPR overview: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2010; 122(18 Suppl 3): S676–S684, doi: [10.1161/CIRCULATIONAHA.110.970913](https://doi.org/10.1161/CIRCULATIONAHA.110.970913), indexed in Pubmed: [20956220](https://pubmed.ncbi.nlm.nih.gov/20956220/).
6. Monsieurs KG, Nolan JP, Bossaert LL, et al. ERC Guidelines 2015 Writing Group. European Resuscitation Council Guidelines for Resuscitation 2015: Section 1. Executive summary. *Resuscitation*. 2015; 95: 1–80, doi: [10.1016/j.resuscitation.2015.07.038](https://doi.org/10.1016/j.resuscitation.2015.07.038), indexed in Pubmed: [26477410](https://pubmed.ncbi.nlm.nih.gov/26477410/).
7. Wiecek W, Smereka J, Szarpak L, et al. Which position for resuscitation should we take? A randomized crossover manikin study. *Am J Emerg Med*. 2017 [Epub ahead of print], doi: [10.1016/j.ajem.2017.09.043](https://doi.org/10.1016/j.ajem.2017.09.043), indexed in Pubmed: [29100786](https://pubmed.ncbi.nlm.nih.gov/29100786/).
8. Smereka J, Kasiński M, Smereka A, et al. The quality of a newly developed infant chest compression method applied by paramedics: a randomised crossover manikin trial. *Kardiol Pol*. 2017; 75(6): 589–595, doi: [10.5603/KP.a2017.0015](https://doi.org/10.5603/KP.a2017.0015), indexed in Pubmed: [28150278](https://pubmed.ncbi.nlm.nih.gov/28150278/).
9. Szarpak Ł, Truszczyński Z, Smereka J, et al. Does the use of a chest compression system in children improve the effectiveness of chest compressions? A randomised crossover simulation pilot study. *Kardiol Pol*. 2016; 74(12): 1499–1504, doi: [10.5603/KP.a2016.0107](https://doi.org/10.5603/KP.a2016.0107), indexed in Pubmed: [27391911](https://pubmed.ncbi.nlm.nih.gov/27391911/).
10. Abella BS, Alvarado JP, Myklebust H, et al. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. *JAMA*. 2005; 293(3): 305–310, doi: [10.1001/jama.293.3.305](https://doi.org/10.1001/jama.293.3.305), indexed in Pubmed: [15657323](https://pubmed.ncbi.nlm.nih.gov/15657323/).
11. Ødegaard S, Olasveengen T, Steen PA, et al. The effect of transport on quality of cardiopulmonary resuscitation in out-of-hospital cardiac arrest. *Resuscitation*. 2009; 80(8): 843–848, doi: [10.1016/j.resuscitation.2009.03.032](https://doi.org/10.1016/j.resuscitation.2009.03.032), indexed in Pubmed: [19477573](https://pubmed.ncbi.nlm.nih.gov/19477573/).
12. Mancini ME, Soar J, Bhanji F, et al. Education, Implementation, and Teams Chapter Collaborators. Part 12: Education, implementation, and teams: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation*. 2010; 122(16 Suppl 2): S539–S581, doi: [10.1161/CIRCULATIONAHA.110.971143](https://doi.org/10.1161/CIRCULATIONAHA.110.971143), indexed in Pubmed: [20956260](https://pubmed.ncbi.nlm.nih.gov/20956260/).
13. Parnell MM, Larsen PD. Poor quality teaching in lay person CPR courses. *Resuscitation*. 2007; 73(2): 271–278, doi: [10.1016/j.resuscitation.2006.09.008](https://doi.org/10.1016/j.resuscitation.2006.09.008), indexed in Pubmed: [17250946](https://pubmed.ncbi.nlm.nih.gov/17250946/).
14. Neumar RW, Shuster M, Callaway CW, et al. Part 1: Executive Summary: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015; 132(18 Suppl 2): S315–S367, doi: [10.1161/CIR.0000000000000252](https://doi.org/10.1161/CIR.0000000000000252), indexed in Pubmed: [26472989](https://pubmed.ncbi.nlm.nih.gov/26472989/).
15. Meaney PA, Bobrow BJ, Mancini ME, et al. CPR Quality Summit Investigators, the American Heart Association Emergency Cardiovascular Care Committee, and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Cardiopulmonary resuscitation quality: [corrected] improving cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association. *Circulation*. 2013;

- 128(4): 417–435, doi: [10.1161/CIR.0b013e31829d8654](https://doi.org/10.1161/CIR.0b013e31829d8654), indexed in Pubmed: [23801105](https://pubmed.ncbi.nlm.nih.gov/23801105/).
16. Bhanji F, Donoghue AJ, Wolff MS, et al. Part 14: Education: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015; 132(18 Suppl 2): S561–S573, doi: [10.1161/CIR.0000000000000268](https://doi.org/10.1161/CIR.0000000000000268), indexed in Pubmed: [26473002](https://pubmed.ncbi.nlm.nih.gov/26473002/).
 17. Truszewski Z, Szarpak L, Kurowski A, et al. Mechanical chest compression with the LifeLine ARM device during simulated CPR. *Am J Emerg Med*. 2016; 34(5): 917, doi: [10.1016/j.ajem.2016.02.025](https://doi.org/10.1016/j.ajem.2016.02.025), indexed in Pubmed: [26924321](https://pubmed.ncbi.nlm.nih.gov/26924321/).
 18. Truszewski Z, Szarpak L, Kurowski A, et al. Randomized trial of the chest compressions effectiveness comparing 3 feedback CPR devices and standard basic life support by nurses. *Am J Emerg Med*. 2016; 34(3): 381–385, doi: [10.1016/j.ajem.2015.11.003](https://doi.org/10.1016/j.ajem.2015.11.003), indexed in Pubmed: [26612703](https://pubmed.ncbi.nlm.nih.gov/26612703/).
 19. Talikowska M, Tohira H, Finn J. Cardiopulmonary resuscitation quality and patient survival outcome in cardiac arrest: A systematic review and meta-analysis. *Resuscitation*. 2015; 96: 66–77, doi: [10.1016/j.resuscitation.2015.07.036](https://doi.org/10.1016/j.resuscitation.2015.07.036), indexed in Pubmed: [26247143](https://pubmed.ncbi.nlm.nih.gov/26247143/).
 20. Wallace SK, Abella BS, Becker LB. Quantifying the effect of cardiopulmonary resuscitation quality on cardiac arrest outcome: a systematic review and meta-analysis. *Circ Cardiovasc Qual Outcomes*. 2013; 6(2): 148–156, doi: [10.1161/CIRCOUTCOMES.111.000041](https://doi.org/10.1161/CIRCOUTCOMES.111.000041), indexed in Pubmed: [23481533](https://pubmed.ncbi.nlm.nih.gov/23481533/).
 21. Stiell IG, Brown SP, Christenson J, et al. Resuscitation Outcomes Consortium (ROC) Investigators. What is the role of chest compression depth during out-of-hospital cardiac arrest resuscitation?. *Crit Care Med*. 2012; 40(4): 1192–1198, doi: [10.1097/CCM.0b013e31823bc8bb](https://doi.org/10.1097/CCM.0b013e31823bc8bb), indexed in Pubmed: [22202708](https://pubmed.ncbi.nlm.nih.gov/22202708/).
 22. Stiell IG, Brown SP, Nichol G, et al. Resuscitation Outcomes Consortium Investigators. What is the optimal chest compression depth during out-of-hospital cardiac arrest resuscitation of adult patients? *Circulation*. 2014; 130(22): 1962–1970, doi: [10.1161/CIRCULATIONAHA.114.008671](https://doi.org/10.1161/CIRCULATIONAHA.114.008671), indexed in Pubmed: [25252721](https://pubmed.ncbi.nlm.nih.gov/25252721/).
 23. Perkins GD, Handley AJ, Koster RW, et al. Adult basic life support and automated external defibrillation section Collaborators. European Resuscitation Council Guidelines for Resuscitation 2015: Section 2. Adult basic life support and automated external defibrillation. *Resuscitation*. 2015; 95: 81–99, doi: [10.1016/j.resuscitation.2015.07.015](https://doi.org/10.1016/j.resuscitation.2015.07.015), indexed in Pubmed: [26477420](https://pubmed.ncbi.nlm.nih.gov/26477420/).
 24. Kleinman ME, Brennan EE, Goldberger ZD, et al. Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015; 132(18 Suppl 2): S414–S435, doi: [10.1161/CIR.0000000000000259](https://doi.org/10.1161/CIR.0000000000000259), indexed in Pubmed: [26472993](https://pubmed.ncbi.nlm.nih.gov/26472993/).
 25. Kilgannon JH, Kirchhoff M, Pierce L, et al. Association between chest compression rates and clinical outcomes following in-hospital cardiac arrest at an academic tertiary hospital. *Resuscitation*. 2017; 110: 154–161, doi: [10.1016/j.resuscitation.2016.09.015](https://doi.org/10.1016/j.resuscitation.2016.09.015), indexed in Pubmed: [27666168](https://pubmed.ncbi.nlm.nih.gov/27666168/).
 26. Idris AH, Guffey D, Aufderheide TP, et al. Resuscitation Outcomes Consortium (ROC) Investigators. Relationship between chest compression rates and outcomes from cardiac arrest. *Circulation*. 2012; 125(24): 3004–3012, doi: [10.1161/CIRCULATIONAHA.111.059535](https://doi.org/10.1161/CIRCULATIONAHA.111.059535), indexed in Pubmed: [22623717](https://pubmed.ncbi.nlm.nih.gov/22623717/).
 27. Abelairas-Gómez C, Barcala-Furelos R, Szarpak Ł, et al. The effect of strength training on quality of prolonged basic cardiopulmonary resuscitation. *Kardiol Pol*. 2017; 75(1): 21–27, doi: [10.5603/KP.a2016.0165](https://doi.org/10.5603/KP.a2016.0165), indexed in Pubmed: [27878801](https://pubmed.ncbi.nlm.nih.gov/27878801/).
 28. López-González A, Sánchez-López M, Garcia-Hermoso A, et al. Muscular fitness as a mediator of quality cardiopulmonary resuscitation. *Am J Emerg Med*. 2016; 34(9): 1845–1849, doi: [10.1016/j.ajem.2016.06.058](https://doi.org/10.1016/j.ajem.2016.06.058), indexed in Pubmed: [27344099](https://pubmed.ncbi.nlm.nih.gov/27344099/).
 29. Russo SG, Neumann P, Reinhardt S, et al. Impact of physical fitness and biometric data on the quality of external chest compression: a randomised, crossover trial. *BMC Emerg Med*. 2011; 11: 20, doi: [10.1186/1471-227X-11-20](https://doi.org/10.1186/1471-227X-11-20), indexed in Pubmed: [22053981](https://pubmed.ncbi.nlm.nih.gov/22053981/).

Cite this article as: Kaminska H, Wieczorek W, Matusik P, et al. Factors influencing high-quality chest compressions during cardiopulmonary resuscitation scenario, according to 2015 American Heart Association Guidelines. *Kardiol Pol*. 2018; 76(3): 642–647, doi: [10.5603/KP.a2018.0003](https://doi.org/10.5603/KP.a2018.0003).