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PRACA ORYGINALNA
ORIGINAL PAPER

Depth and rate of chest compression in CPR simulation during 10-minute continuous external cardiac compression

Ocena głębokości i częstotliwości kompresji klatki piersiowej podczas symulacji resuscytacji krążeniowo-oddechowej, w trakcie 10-minutowego ciągłego zewnętrznego masażu serca

Bogusław Bucki[1], Jacek Karpe[2], Robert Michnik[3], Arkadiusz Niczyporuk[1], Joanna Makarska[1], Dariusz Waniczek[4], Andrzej Bieniek[3], Hanna Misiołek[2]

[1]Katedra Medycyny Ratunkowej i Neurochirurgii Dziecięcej, Wydział Zdrowia Publicznego w Bytomiu, Śląski Uniwersytet Medyczny w Katowicach
[2]Katedra Anestezjologii, Intensywnej Terapii i Medycyny Ratunkowej, Wydział Lekarski z Oddziałem Lekarsko--Dentystycznym w Zabrzu, Śląski Uniwersytet Medyczny w Katowicach
[3]Katedra Biomechatroniki, Wydział Inżynierii Biomedycznej w Zabrzu, Politechnika Śląska w Gliwicach
[4]Katedra Chirurgii Ogólnej, Kolorektalnej i Urazów Wielonarządowych, Wydział Nauk o Zdrowiu w Katowicach, Śląski Uniwersytet Medyczny w Katowicach

ABSTRACT

INTRODUCTION: External cardiac massage has been a basic CPR maneuver for years. The aim of the study was to assess the quality of chest compression during a real-time continuous cardiac compression simulation on a cardiopulmonary resuscitation mannequin (considering medical rescuer experience and BMI).
MATERIAL AND METHODS: This was a prospective study involving 17 medical rescuers, and 21 Medical Rescue students and university lecturers. During the simulation the participants performed continuous external cardiac compression for 15 minutes or until the refusal to continue. The depth and rate were analyzed at 60-second periods, leading to average values of cardiopulmonary resuscitation effectiveness. The analysis covered complete research data gathered in real time (10 minute periods).
RESULTS: The average compression depth significantly decreased from the first (40.66 SE ± 0.80 mm) to the fourth minute of the study (38.21 SE ± 0.95 mm). The average compression rate was significantly different between the initial values (120.97 SE ± 2.83/min) and the sixth minute of the study (123.69 SE ± 2.55/min). The average compression depth amounted to n 36.03 SE ± 1.22 mm in non-professionals and 40.06 SE ± 1.37 mm in professionally active participants. In the participants with a BMI > 25, the only differentiating point in time was the beginning of the task when the average compression depth was 41.97 SE ± 1.12 mm. In the participants with a BMI < 25, there was a gradual decrease in the compression depth within the initial four minutes of the task.

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Address for correspondence: Dr n. med. Bogusław Bucki, Katedra Medycyny Ratunkowej i Neurochirurgii Dziecięcej, Wydział Zdrowia Publicznego w Bytomiu, Śląski Uniwersytet Medyczny w Katowicach, ul. Piekarska 18, 41-902 Bytom, tel. + 48 504 218 181, e-mail: bubog@interia.pl

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CONCLUSION: Rescuer body mass is an important factor influencing proper chest compression depth during continuous cardiac compression. Professional rescuers are capable of performing continuous cardiac compression longer than non-professionals, at the same time maintaining acceptable sternum deflection and compression rate.

KEY WORDS
chest compression, cardiopulmonary resuscitation, professional rescuers

STRESZCZENIE

WSTĘP: Celem pracy była prospektywna ocena jakości kompresji klatki piersiowej podczas symulacji ciągłego masażu serca na manekinie w czasie rzeczywistym, wykonywanego przez czynnych zawodowo ratowników medycznych, z uwzględnieniem ich BMI.
MATERIAŁ I METODA: Badanie przeprowadzono w grupie 17 ratowników medycznych oraz 21 studentów kierunku ratownictwo medyczne i wykładowców uczelni. Podczas próby każdy badany wykonywał nieprzerywany masaż zewnętrzny serca na manekinie do osiągnięcia punktu końcowego, jakim był czas 15 minut lub odmowa dalszego wykonywania zadania.
WYNIKI: Średnia głębokość wykonywanych uciśnięć zmniejszała się istotnie od pierwszej (40,66, SE ± 0,80 mm) do czwartej minuty badania, osiągając wartość 38,21 SE ± 0,95 mm. Średnia częstość uciśnięć klatki piersiowej istotnie różniła się od szóstej minuty (123,69 SE ± 2,55/min) w stosunku do wartości wyjściowych (120,97 SE ± 2,83/min). W dziesiątej minucie średnie wartości głębokości uciśnięć oraz częstości masażu klatki piersiowej osiągnęły odpowiednio 36,62 SE ± 1,04 mm oraz 128,06 SE ± 2,43/min.
Istotnym czynnikiem wpływającym na głębokość kompresji klatki piersiowej była przynależność do grupy czynnych zawodowo ratowników medycznych. Średnia głębokość ucisku w całym badanym przedziale czasowym w grupie nieprofesjonalistów wynosiła 36,03 SE ± 1,22 mm, podczas gdy w grupie profesjonalistów – 40,06 SE ± 1,37 mm. Drugim istotnym czynnikiem różnicującymi zakres głębokości kompresji klatki piersiowej był czas oraz BMI ratownika. U osób z BMI > 25 jedynym różnicującym punktem czasowym był początek badania, w którym średnia głębokość ucisku wynosiła 41,97 SE ± 1,12 mm.
WNIOSKI: Masa ciała ratownika jest istotnym czynnikiem wpływającym na uzyskanie głębszej kompresji klatki piersiowej. Profesjonalni ratownicy są w stanie prowadzić skutecznie ciągłą kompresję klatki piersiowej w dłuższym czasie, osiągając zadowalające ugięcie oraz częstotliwość jej kompresji.

SŁOWA KLUCZOWE
kompresja klatki piersiowej, resuscytacja krążeniowo-oddechowa, profesjonalni ratownicy

INTRODUCTION

External cardiac massage has been a basic CPR maneuver for years. The American Heart Association (AHA) guidelines published in 2010 emphasize the critical significance of prompt basic life support (BLS) in individuals with cardiac arrest [1]. Chest compression should be undertaken immediately in order to restore oxygen distribution to critical tissues and, in this way, to minimize the risk of progressive oxygen deficiency and raise the chances of survival [2,3,4]. The importance of the quality of maneuvers has been underlined, especially the quality of chest compression (with or without ventilator pauses) with a focus on its depth [5,6]. At the same time, it has been noted that effective chest compression during CPR is an activity requiring specific physical fitness. It has also been pointed out that the increasing fatigue of the rescuer has an impact on the quality of chest compression and may be difficult to perform by physically unprepared individuals who do not always have the sufficient skills [7,8,9,10]. The 2010 AHA guidelines emphasize a compression rate of at least 100/min and a compression depth of at least 2 inches (5 cm) [1,6,11].

What is more, it has been noted that simplification of life support guidelines more effectively encourages people to have an active attitude and support other people in a life-threatening condition. An example of such a simplification is the continuous chest compression CPR (CCC-CPR) guideline as an alternative to a standard CPR procedure [3,12,13]. Prompt CPR is one of the most important elements in the “chain of survival”: it helps to save life, limits the post-CPR neurological deficit and is a predictor of survival in non-hospital cardiac arrest [2,3].

Cardiac compression (especially CCC-CPR) is a difficult maneuver currently requiring an increased compression depth, and thus greater effort from the rescuer. The focus of the study is to find the factors that might influence the quality of chest compression during CCC-CPR.

AIM OF THE STUDY

A prospective assessment of the quality of chest compression during a real-time CCC simulation on a CPR mannequin (considering medical rescuer experience and BMI).

MATERIAL AND METHODS

This was a prospective study involving medical rescuers, first year university students of Medical Rescue, and doctors – university lecturers. The study was conducted within the KNW-1-164/N/3/0 project with approval of the Medical University of Silesia bioethics committee in Katowice. The participants of the study were divided into two groups: group I including 17 professionally active medical rescuers, and group II – including 21 medical university students and lecturers, who at the time of the study were no longer active rescuers. All the participants were theoretically and practically prepared as far as BLS was concerned. During the simulation, each of the participants performed continuous external cardiac compression (CCC-CPR) in accordance with the 2010 AHA guidelines. The simulation was performed until the endpoint of 15 minutes or until refusal to continue the task. During the study, the participants involved were in a room, in stable temperature conditions, with no current feedback on the time spent on the activity or the correctness of the performed maneuver. The mannequin was situated on the floor and each rescuer performed the resuscitation activities kneeling on the right side of the mannequin. The equipment used was the Ambu Cardiac Care Man that enables the function of continuous recording of control parametres, i.e. with a depth and rate of compression resistance of 9.0 N/cm^2. The compression depth and rate data were continuously recorded during the whole simulation. The measured data (depth and rate) were analyzed at 60-second intervals, leading to average values of cardiopulmonary resuscitation effectiveness. Analysis of the results was based on the data from all the study participants, gathered in real time during the 10 minutes of performing the task, including refusal to continue the procedure by one of the participants as the time of completion of all the trials.

The statistical analysis was based on the data analysis software system STATISTICA, v.10, a product of the StatSoft, Inc. (2011) creator. Firstly, the sample distribution was estimated by means of the Shapiro-Wilk test. In the comparison of time results in the particular participant groups, the multi-factor analysis of variance (MANOVA) was applied to data repeated with the post-hoc Bonferroni test. In the analysis of the correlations between the parameters, the Pearson product-moment correlation was implemented. All of the values recorded during the study were included in the correlation. The data is presented as the mean and standard error. $P < 0.05$ values were adopted as statistically significant.

RESULTS

In the study, there was only one instance of reaching the endpoint of the tenth minute of performing the task. The reason for finishing the task before the expected 15 minutes was wrist pain in the hand directly connected with the chest. Such pain was a dominant complaint reported by 35 (92.1%) participants of the study. Among other rescuer complaints, there were 32 of (84.2%) knee pain and 17 (44.7%) lumbosacralis area cases reported. Other participants of the study could continue with the task longer than the expected 15 minutes. None of the participants complained of excessive fatigue. The average participants' height in group I amounted to 179.4 (sd ± 4.7) cm, body mass in 85.1 (sd ± 12.4) kg, and BMI 26.4 (sd ± 3.4). In group II, the average height was 179.8 (sd ± 4.6) cm, body mass 80.1 (sd ± 11.0) kg, BMI 24.7 (sd ± 2.9). There was no significant difference between the values.

The following table presents the significance index values of the analyzed parameters in the multi-factor analysis of variance (Tab. I).

Table I. Significance of differences between analyzed CPR parameters ($p < 0.05$ values)
Tabela I. Istotność różnic dla badanych parametrów skuteczności masażu pośredniego serca (wartość $p < 0.05$)

Factors	Rate	Depth
Profession	0.145	0.035
BMI	0.834	0.273
Profession*BMI	0.186	0.974
Time	0.000	0.000
Time*Profession	0.269	0.903
Time*BMI	1.000	0.046
Time*Profession*BMI	0.997	0.142

For both parameters, rate and depth, time was a significant factor indicating differences among the participants. The average compression depth significantly decreased from the first (40.66 SE ± 0.80 mm) to the fourth minute of the study (38.21 SE ± 0.95 mm). The average compression rate was significantly different between the initial values (120.97 SE ± 2.83/min) and the sixth minute of the study (123.69 SE ± 2.55/min). In the tenth minute of the experiment, the average compression depth and rate values reached 36.62 SE ± 1.04 mm and 128.06 SE ± 2.43/min respectively (Fig. 1 and Fig. 2).

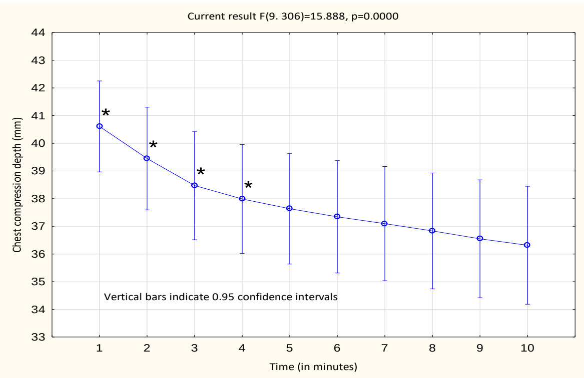

Fig. 1. Average values and standard deviation of chest compression depth recorded at particular minutes of study.
Ryc. 1. Wartości średnie i odchylenie standardowe głębokości kompresji klatki piersiowej uzyskane w kolejnych minutach badania.

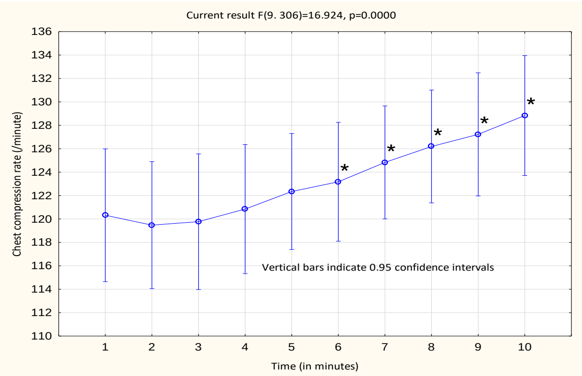

Fig. 2. Average values and standard deviation of chest compression rate recorded at particular minutes of study.
Ryc. 2. Wartości średnie i odchylenie standardowe częstości kompresji klatki piersiowej uzyskane w kolejnych minutach badania.

Another important factor influencing the quality and depth of chest compression was in favor of professionnally active medical rescuers. The average compression depth in the complete duration of the study amounted to 36.03 SE ± 1.22 mm in non-professionals and 40.06 SE ± 1.37 mm in professionally active participants (Fig. 3).

In all the cases of the study, independent of the division into two groups, the significant factors differentiating chest compression values were time and BMI. In the participants with a BMI > 25, the only differentiating point in time was the beginning of the task when the average compression depth was 41.97 SE ± 1.12 mm. In the later minutes of the task, there were no reported differences between the results. As far as participants with a BMI < 25 were concerned, there was a gradual decrease in the compression depth within the initial four minutes of the task. Starting from the fifth minute of the task, there was a significant chest compression decrease (37.16 SE ± 1.38) that led to the value of 35.02 SE ± 1.49 in the tenth minute (Fig. 4).

Fig. 3. Comparison of chest compression depth in group of 'non-professionals' with group of professionally active medical rescuers.
Ryc. 3. Porównanie głębokości kompresji klatki piersiowej w grupie „nieprofesjonalistów" (other) i czynnych zawodowo ratowników medycznych (professional).

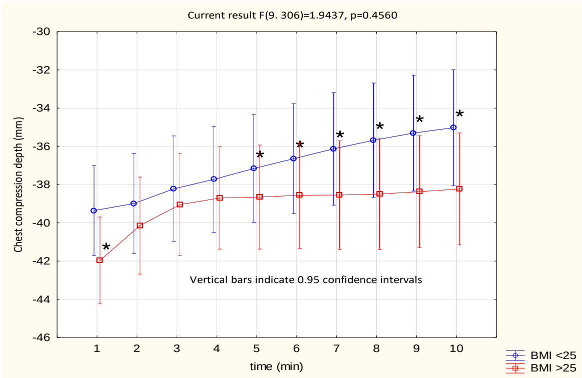

Fig. 4. Chest compression and BMI (Body Mass Index) of rescuer.
Ryc. 4. Głębokość kompresji klatki piersiowej z uwzględnieniem masy ciała ratownika.

DISCUSSION

The effectiveness of CPR depends on a proper chest compression depth and rate [2,6]. We have studied CCC performed by potential and experienced rescuers to verify if the best correlation of chest compression depth and rate with time is possible to be estimated. A rescuer performing CCC may find it difficult to subjectively assess the compression depth and rate during external cardiac compression [10], which could also be observed in this study. The average chest compression depth gradually decreased during the task and in the 2nd minute the depth was already insufficient (< 40 mm). This is connected with a potential risk of low-quality cardiac massage, especially when experimental research and the 2010 AHA guidelines are taken into account [9,14,15]. However, it has also been noted in studies by other authors that chest compression quality depends on the biometrical factor (body mass), fitness and professional preparation of the rescuers. In those studies, the above mentioned elements are important factors predicting a properly performed maneuver [9,16]. In this study, participants with a BMI > 25 were able to reach deeper compression during the whole task. Moreover, their depth compression values were quite stable from the 2nd minute of the observation till its end (average sternum deflection > 38 mm). The other participants of the study were not as effective as the participants with a BMI > 25. Another observation was that none of the participants managed to reach the expected sternum deflection < 50 mm. However, a continuous chest compression depth within time was noted in the participants with a BMI < 25. This leads to the risk of potential low effectiveness of the performed external cardiac massage [9,14]. The accepted > 40 mm chest compression depth according to 2005 AHA guidelines could be reached only by professional medical rescuers. This indicates that effective use of the potential energy of rescuer body mass is a significant predictor of cardiac massage effectiveness. The factors confirming this observation in this study are the acceptable chest deflection values attained by professional rescuers ($p = 0.035$) with a higher body mass ($p = 0.046$).

The other parameter influencing the effectiveness of external cardiac massage during CPR is a chest compression rate higher than 100/min [2,6]. In this study, all of the rescuers maintained the expected compression rate that started with 121/min and systematically increased to finally reach 128/min in the last minute of the observation. The analysis of the chest compression rate fluctuation in this study indicates that the chest compression values observed here are in accordance with the prescribed values and, therefore, potentially lead to a more efficient cardiac massage [2,5,12,13]. It should be pointed out that the prior experience of the professional group (the rescuers started in preselections for the Polish Medical Rescue Championships), has an influence on the correctness of the performed CCC-CPR. Therefore, frequent resuscitation training for both professionals and non-professionals may improve general CPR skills. Another important point is the recruitment expectations in selecting potential medical rescuers. The authors of this study are aware of the fact that it would be difficult to preselect candidates for the profession of a medical rescuer. However, according to the findings of this article and other sources [7,8,9], it would be advisable to preferably accept well-built candidates of a certain body fitness. Inefficient chest compression depth is difficult to be objectively justified. Other sources indicate that fatigue might be the reason for rescuers refusal to continue resuscitation [9,14]. Nevertheless, none of the participants of this study indicated fatigue as a reason for interrupting the maneuver. All in all, as the source of the phenomenon is not known, considering the research results by other authors, resuscitation performed by non-professional rescuers should involve rescuer change. This change should be made not later than every 2 minutes, otherwise the resuscitation may be ineffective [13,14,17,18]. Another perspective has been taken as far as professional rescuers with a high body mass are taken into account; as already presented, professional rescuers are capable of effectively performing cardiac massage for a longer period of time. Having added the guideline of maximally limiting the number of pauses in cardiac massage [1,6], the authors of this article suggest amending the maneuver procedure in the case of professional rescuers. It has been assumed that it is possible to prolong the period of time between rescuer change even up to 10 minutes. This suggestion seems to be reasonable as none of the participants of this study mentioned fatigue, and in other sources, fatigue was the most frequently noted factor demanding rescuer change during external cardiac massage [10,17,19,20,21]. Other complaints (wrist pain, knee pain, lumbosacralis pain) indicated by the CCC-CPR rescuers were similar to those found in other sources but they came out relatively late during observation and were not a reason to stop resuscitation [22]. In this context, especially when the 2010 AHA guidelines are considered, the authors of the article claim that further studies on chest compression-improving predictive factors are needed.

CONCLUSIONS

1. Rescuer body mass is an important factor influencing proper chest compression depth during CCC-CPR.
2. Professional, experienced rescuers are capable of performing CCC-CPR longer than non-professionals, at the same time maintaining acceptable sternum deflection and compression rate.

Author's contribution

Study design – B. Bucki, R. Michnik
Data collection – A. Bieniek, A. Niczyporuk, D. Waniczek, J. Makarska, B. Bucki
Data interpretation – B. Bucki, J. Karpe, R. Michnik
Statistical analysis – J. Karpe
Manuscript preparation – B. Bucki, J. Karpe, R. Michnik, H. Misiołek
Literature research – J. Makarska, B. Bucki

REFERENCES

1. Berg R.A., Hemphill R., Abella B.S., Aufderheide T.P., Cave D.M., Hazinski M.F., Lerner E.B., Rea T.D., Sayre M.R., Swor R.A. Part 5: adult basic life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation 2010; 122(18 Suppl. 3): 685–705.

2. Rajab T.K., Pozner C.N., Conrad C., Cohn L.H., Schmitto J.D. Technique for chest compressions in adult CPR. World J. Emerg. Surg. 2011; 6: 41.

3. Lee K. Cardiopulmonary resuscitation: new concept. Tuberc. Respir. Dis. (Seoul) 2012; 72(5): 401–408.

4. Stiell I.G., Brown S.P., Christenson J., Cheskes S., Nichol G., Powell J., Bigham B., Morrison L.J., Larsen J., Hess E., Vaillancourt C., Davis D.P., Callaway C.W. What is the role of chest compression depth during out-of--hospital cardiac arrest resuscitation? Crit. Care. Med. 2012; 40(4): 1192––1198.

5. Jäntti H., Silfvast T., Turpeinen A., Kiviniemi V., Uusaro A. Influence of chest compression rate guidance on the quality of cardiopulmonary resuscitation performed on manikins. Resuscitation 2009; 80(4): 453–457.

6. Bradley S.M. Update in cardiopulmonary resuscitation. Minerva Cardioangiol. 2011; 59(3): 239–253.

7. Hansen D., Vranckx P., Broekmans T., Eijnde B.O., Beckers W., Vandekerckhove P., Broos P., Dendale P. Physical fitness affects the quality of single operator cardiocerebral resuscitation in healthcare professionals. Eur. J. Emerg. Med. 2012; 19(1): 28–34.

8. Ock S.M., Kim Y.M., Chung Jh., Kim S.H. Influence of physical fitness on the performance of 5-minute continuous chest compression. Eur. J. Emerg. Med. 2011; 18(5): 251–256.

9. Russo S.G., Neumann P., Reinhardt S., Timmermann A., Niklas A., Quintel M., Eich C.B. Impact of physical fitness and biometric data on the quality of external chest compression: a randomised, crossover trial. BMC Emerg. Med. 2011; 4; 11: 20.

10. McDonald C.H., Heggie J., Jones C.M., Thorne C.J., Hulme J. Rescuer fatigue under the 2010 ERC guidelines, and its effect on cardiopulmonary resuscitation (CPR) performance. Emerg. Med. J. 2013; 30(8): 623–627.

11. Ong E.H. Improving the quality of CPR in the community. Singapore Med. J. 2011; 52(8): 586–591.

12. Heidenreich J.W., Bonner A., Sanders A.B. Rescuer fatigue in the elderly: standard vs. hands-only CPR. J. Emerg. Med. 2012; 42(1): 88–92.

13. Heidenreich J.W., Berg R.A., Higdon T.A., Ewy G.A., Kern K.B, Sanders A.B. Rescuer fatigue: standard versus continuous chest-compression cardiopulmonary resuscitation. Acad. Emerg. Med. 2006; 13(10): 1020–1026.

14. Ochoa F.J., Ramalle-Gómara E., Lisa V., Saralegui I. The effect of rescuer fatigue on the quality of chest compressions. Resuscitation 1998; 37(3): 149–152.

15. Abella B.S., Sandbo N., Vassilatos P., Alvarado J.P., O'Hearn N., Wigder H.N., Hoffman P., Tynus K., Vanden Hoek T.L., Becker L.B. Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. Circulation 2005; 111(4): 428–434.

16. Ashton A., McCluskey A., Gwinnutt C.L., Keenan A.M. Effect of rescuer fatigue on performance of continuous external chest compressions over 3 min. Resuscitation 2002; 55(2):151–155.

17. Foo N.P., Chang J.H., Lin H.J., Guo H.R. Rescuer fatigue and cardiopulmonary resuscitation positions: A randomized controlled crossover trial. Resuscitation 2010; 81(5): 579–584.

18. Field R.A., Soar J., Davies R.P., Akhtar N., Perkins G.D. The impact of chest compression rates on quality of chest compressions – a manikin study. Resuscitation 2012; 83(3): 360–364.

19. Trowbridge C., Parekh J.N., Ricard M.D., Potts J., Patrickson W.C., Cason C.L. A randomized cross-over study of the quality of cardiopulmonary resuscitation among females performing 30:2 and hands-only cardiopulmonary resuscitation. BMC Nurs 2009; 8: 6.

20. Chi C.H., Tsou J.Y., Su F.C. Effects of compression-to-ventilation ratio on compression force and rescuer fatigue during cardiopulmonary resuscitation. Am. J. Emerg. Med. 2010; 28(9): 1016–1023.

21. Manders S., Geijsel F.E. Alternating providers during continuous chest compressions for cardiac arrest: every minute or every two minutes? Resuscitation 2009; 80(9): 1015–1018.

22. Kovic I., Lulic D., Lulic I. CPR PRO® device reduces rescuer fatigue during continuous chest compression cardiopulmonary resuscitation: a randomized crossover trial using a manikin model. J. Emerg. Med. 2013; 45(4): 570–577.