Journal of the Korea Academia-Industrial cooperation Society
Vol. 18, No. 6 pp. 381-388, 2017

https://doi.org/10.5762/KAIS.2017.18.6.381
ISSN 1975-4701 / eISSN 2288-4688

The changes of symptom, EKG and hemodynamic in healty firefighters after delivering multiple cycles of cardiopulmonary resuscitation

Hyo-Ju Lee[1], Ho-Jung Kim[2*], Eun-Kyung Jung[3]

[1]Dept. Emergency Medical Technology, Gyeongbuk Provincial College
[2]Dept. Emergency Medicine, Bucheon Hospital of Soonchunhyang University
[3]Dept. Emergency Medical Services, Honam University

반복적인 심폐소생술 시행 후 건강한 소방대원에서 나타나는 증상, 심전도 및 혈역학적 변화

이효주[1], 김호중[2*], 정은경[3]
[1]경북도립대학교 응급구조과
[2]순천향대학교 부천병원 응급의학과
[3]호남대학교 응급구조학과

Abstract The CPR guidelines emphasize the delivery of effective chest compressions but do not address the effects of chest compressions on CPR providers. This study determined the effects of chest compressions on healthy adult firefighters' symptoms, hemodynamics, and electrocardiography after performing multiple cycles of CPR. Healthy adult firefighters were trained in CPR and performed CPR on mannequins. The provider vital signs, electrocardiography, and fatigue scores were determined immediately before CPR, after 5cycles of CPR, and after 10 cycles of CPR. In addition, the presence of clinical symptoms among the providers was determined after CPR; 39 firefighters participated in the study. Their mean age was 35.54±10.26 years. Many providers developed fatigue, shortness of breath, and dizziness. Significant changes in heart rate (??=0.000), respiratory rate (??=0.010), end-tidal CO2(??=0.000), O2 saturation(??=0.000), and pulse pressure (??=0.000) were observed after both 5 and 10 cycles of CPR. One participant developed sinus dysrhythmia and premature ventricular contractions after 10 cycles of CPR. The delivery of chest compression results in fatigue and hemodynamic alterations in many young healthy adults after performing 5 or 10 cycles of CPR. The CPR guidelines and education should take into consideration the effects of chest compressions on CPR providers.

요 약 심폐소생술 가이드라인에서는 효과적인 가슴압박을 강조하지만, 구조자들이 가슴압박을 시행하는 것과 관련한 피로에 대해서는 적절히 다루지 않는다. 본 연구에서는 건강한 소방대원들을 대상으로 마네킨에 심폐소생술을 여러 사이클을 수행한 후에 보일 수 있는 증상, 혈역학적 상태, 그리고 심전도 등을 측정하였다. 연구 대상자의 활력징후, 심전도, 주관적 피로도 점수를 심폐소생술 시작 전, 심폐소생술 5주기 후, 10주기 시행 후에 측정하였으며, 심폐소생술 후 나타나는 증상에 대해 설문하였다. 39명의 연구 대상자들의 평균 연령은 35.54±10.26세이었으며, 심폐소생술 후 피로와 숨가쁨, 어지러움 등을 호소했다. 심폐소생술 시작 전, 5주기 후, 10주기 후 심박수, 호흡수, 호기말이산화탄소, 산소포화도, 맥압에서 유의한 차이를 보였으며, 1명의 참가자에서 심폐소생술 10주기 후 부정맥이 나타났다. 본 연구 결과 지속적인 심폐소생술은 건강한 성인들에서 피로와 혈역학적 변화 등을 초래할 수 있다고 판단되며, 심폐소생술 가이드라인 및 교육에서는 장시간 심폐소생술을 하는 경우 구조자들에게 미칠 수 있는 영향에 대한 적극적인 안내가 필요하다.

Keywords : Cardiopulmonary Resuscitation, Chest Compression, Fatigability, Pulse Pressure, Vital Signs

*Corresponding Author : Ho Jung Kim(Bucheon Hospital of Soonchunhyang University)
Tel: +82-32-621-5119 email: lovelydr@schmc.ac.kr
Received March 7, 2017 Revised (1st April 4, 2017, 2nd May 8, 2017)
Accepted June 9, 2017 Published June 30, 2017

1. Introduction

Immediate delivery of cardiopulmonary resuscitation (CPR) by bystanders significantly reduces mortality in patients with sudden cardiac arrest [1-6], since severe brain damage occurs as early as 4-6min after cardiac arrest[7-8]. As a result, CPR training has targeted the general population without any medical background [9-11], depending on a few studies that evaluating the optimal methods for achieving this goal[12.13].

Several studies have demonstrated an association between provider exhaustion and poor quality of CPR and there is evidence that switching roles during the delivery of CPR can reduce fatigue [14-18]. CPR providers can easily become exhausted, especially when only one rescuer is available [19] or when rescuers are female or relatively thin [20]. Moreover, in 2011, The Korean Association of CPR published a study demonstrating fatigue in middle-aged women providers resulting in a low quality of chest compressions [21] despite following appropriate CPR recommendations. However, few if any studies have paid particular attention to fatigability and the medical safety of CPR providers while delivering CPR.

According to a survey conducted by The Seoul National University in Korea, most cardiac arrest occur at home and are witnessed by a family member, and it that it took on average 8.6min for paramedic to arrive [22]. Unlike in public places, where many people can get involved in the rescue, 8.6 min is too long a time for a single person to perform chest compressions, which requires considerable physical strength [23]. In addition, recent studies on the new CPR guidelines have found that emphasis on chest compressions has resulted in low quality performance due to fatigability among CPR providers [16, 24-26]. Therefore, the current study was designed to evaluate the impact of performing multiple cycles of CPR on provider symptoms, fatigue, and hemodynamics.

2. Methods

2.1 Study design

We performed a prospective, observational study to determine the effects of performing chest compressions on CPR providers. In order to measure the degree of rescuer's fatigue, physical as well as mental are considered. while those factors include, but not limited to, ammonia, cortisol catecholamine, visual pain scale, pulse, oxygen consumption, and electromyography, there is no standard for objective, fatigue measurement[27-29]. In this study, biochemical changes which can be observed in rescuers, such as visual pain scale, pulse, blood pressure, pulse pressure, end-tidal CO_2 partial pressure, oxygen saturation, and electrocardiogram were analyzed.

2.2 Study subjects

The study enrolled healthy adult firefighters with or without prior CPR training and/or experience. Participants were fully informed about the purpose and method of this study and decided to participate voluntarily.

2.3 Study intervention [Figure 1]

Participants were asked to fill out a pre-test survey and then they viewed a 2 min CPR education video clip produced by The Korean Association of CPR. Participants were connected to a device that monitored vital signs and 3-lead electrocardiogram (Lifepack® 15 Monitor/Defibrillator, Physio-Control, USA). The subjective level of fatigue was measured on a verbal numeric scale from 0 (no fatigue) to 10 (most fatigue imaginable). Measurements were taken at rest immediately prior to CPR (T_1), after 5 cycles of CPR (T_2), and after 10cycles of CPR (T_3). After performing 5 cycles of CPR on a mannequin, the subjects were instructed to take a break, long enough for them to return to their resting state, prior to beginning another 10 cycles of CPR. A board-certified emergency medicine physician was present throughout the experiment in case of any medical emergency among the participants.

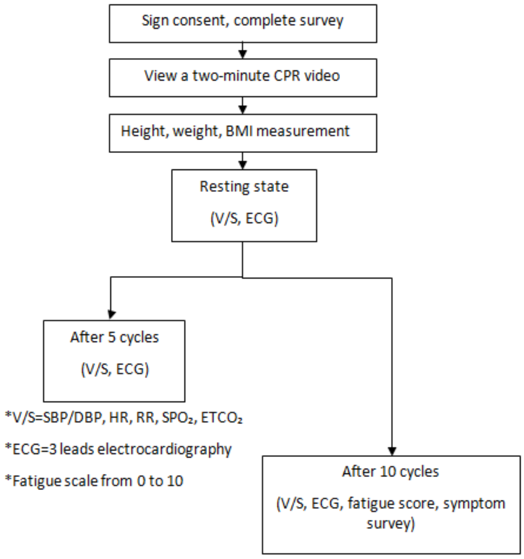


Fig. 1. Flow chart for research

2.4 Data analysis

Binary data were summarized as numbers and percentage frequency of occurrence. Continuous data were summarized as means and standard deviations (SD) or medians and interquartile ranges (IQR). The paired t-test and ANOVA were used to compare hemodynamic changes by number of CPR cycles and BMI. The X^2 test was used to compare the occurrence of any ECG changes by number of CPR cycles and BMI. Pearson's correlation was used to analyze the correlation between alternation of pulse pressure and $ETCO_2$. A *p*-value less than 0.05 was considered statistically significant. SPSS for Windows version 21.0 was used for all statistical analyses.

3. Results

3.1 General subject characteristics [Table 1]

The total number of subjects participating in the study was 39. All of the subjects were currently employed firefighters. Of all participants, 38 subjects had taken a CPR course at least once in the past. The mean age of the participants was 35.54±10.26 years and 84.6% of the subjects were male. The mean height and weight of the study subjects were 171.21±6.74 cm and 69.18±8.34 kg respectively. Based on BMI calculations, 18 of the subjects were overweight (25.0 - 29.9 kg/m^2) and 7 were obese (30.0-39.9kg/m^2).One subject had a previous medical history of hypertension.

Table 1. Characteristics of the study subjects (N=39)

	First responder
Age (years)	35.54±10.26
Sex	
Males, No. (%)	33 (84.6%)
Females, No. (%)	6 (15.4%)
Height (cm)	171.21± 6.74
Weight (kg)	69.18± 8.34
BMI* (kg/m^2)	23.57± 2.23
Normal, No. (%)	14 (35.9%)
Overweight, No. (%)	18 (46.2%)
Obese, No. (%)	7 (18.0%)
CPR† Training	
Prior CPR† training experience, No. (%)	38 (97.4%)
Less than 6 months since last training, No. (%)	17 (43.6%)

*BMI: Body Mass Index, † CPR: Cardio pulmonary resuscitation

3.2 Clinical symptoms and fatigue after 10 cycles of CPR [Table 2]

Of all subjects, 13 participants (33.3%) experienced shortness of breath, 12 participants (30.8%) complained of hand pain, and 4 participants (10.3%) reported dizziness. The mean fatigue score was 6.84±1.81.

Table 2. Clinical manifestations and fatigue scores (N=39)

	N (%)	Mean±SD
Clinical manifestation		
Shortness of breath?	13 (33.3)	
Dizziness	4 (10.3)	
Back hand problems	12 (30.8)	
Other	2 (5.1)	
None	8 (20.5)	
Mean fatigue score		6.84± 1.81

3.3 Hemodynamic and electrocardiographic change [Table 3, Table 4, Figure 2]

There were no statistically significant changes in blood pressure after both 5 cycles (T_2) and 10 cycles

Table 3. Hemodynamic changes by compression by compression-ventilation cycle (N=39)

	Resting state (T_1)	After 5 cycles (T_2)	After 10 cycles (T_3)	*p*
Systolic BP‡	135.51±11.29	140.87±13.05	136.87±14.73	.163
Diastolic BP‡	90.23±10.40	88.92±10.91	88.67±11.02	.340
Peak heart rate	74.08±11.40*	103.79±12.80*	106.46±16.04*	<.001
Peak respiration rate	18.64± 4.73*	21.03± 4.08	21.92± 5.55*	.010
$ETCO_2$ §	41.05± 4.41*	45.92± 3.86*	44.33± 4.40*	<.001
SpO_2 ‖	98.28± 1.39*	97.23± 1.22*	96.87± 1.64*	<.001
Pulse pressure (mean)	45.28± 6.93*†	51.95±10.26*	53.21± 9.61†	<.001
Pulse pressure (median)	46 (29-66)	53 (21-73)	54 (38-76)	
ECG¶				
Dysrhythmia, No.(%)	0 (0.0%)	0 (0.0%)	1 (2.6%)	1.000
Normal, No.(%)	39 (100.0%)	39 (100.0%)	38 (97.4%)	

*, † post-hoc test
‡ BP: Blood pressure, § $ETCO_2$: End-tidal carbon dioxide,
‖ SpO_2 : Saturation by pulse oximetry, ¶ ECG: Electrocardiogram

of CPR (T_3). However, there were significant changes in heart rate (p=0.001), respiratory rate (p=0.010), end-tidal CO_2 ($ETCO_2$) (p<0.001), O_2 saturation(SpO_2) (p=0.000), and pulse pressure (p<0.001). There were also significant changes in pulse pressure between T_1 and T_2. Between T_1 and T_3, significant changes were observed in both respiratory rate and pulse pressure. Between T_1, T_2, and T_3, there were significant changes in heart rate, SPO_2, and $ETCO_2$. The largest change was observed in heart rate between T_1 and T_3 (increased by 32.4/min). Median (IQR) pulse pressure was 46.0 (29-66) mmHg at T_1, 53.0 (21-73) mmHg at T_2, and 54.0 (38-76) mmHg at T_3. Pulse pressure increased by 7.9 mmHg on average, and SpO_2 decreased by 1.4% on average. There was a positive correlation between pulse pressure and $ETCO_2$ after 10cycles of CPR (r=0.327, p=0.042). One participant developed sinus dysrhythmia and premature ventricular contractions (PVCS) after 10 cycles of CPR.

Significant differences were observed in SpO_2 (p=0.009) and respiratory rate (p=0.044) among the three BMI classes [Table 3]. In particular, SpO_2 dropped more between T1 and T3 in the normal BMI group (-2.36±1.95) compared to the over weight group (0.57±2.76) or the obese group (-1.44±1.54).

Table 4. Hemodynamic changes by BMI (N=39)

	Normal (N=14)	Overweight (N=18)	Obese (N=7)	*p*
Systolic BP*	2.29±10.86	4.89±10.52	7.14± 8.21	.575
Diastolic BP*	-4.00± 7.83	-3.11± 6.74	-3.86± 3.80	.927
Peak heart rate	35.93±11.89	32.33±16.42	25.43± 9.58	.278
Peak respiration rate	6.21± 6.67	1.89± 4.43	1.00± 4.08	.044
$ETCO_2$ †	2.21± 4.64	4.44± 3.68	2.43± 3.91	.271
SpO_2 ‡	-2.36± 1.94	-1.44± 1.54	0.57± 2.76	.009
Pulse pressure	6.29±10.76	8.00± 8.54	11.00± 9.00	.539
ECG§				
Dysrhythmia, No. (%)	0 (0.0%)	1 (5.6%)	0 (0.0%)	.550
Normal, No. (%)	14 (100.0%)	17 (94.4%)	7 (100.0%)	

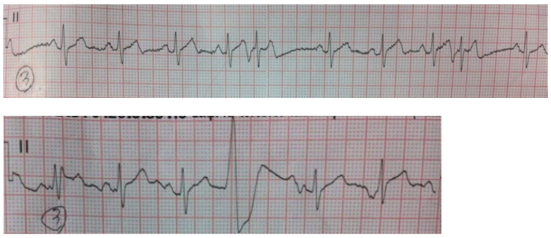


Fig. 2. Dysrhythmias detected in a subject after performing 10 cycles of CPR

4. Discussion

Recent CPR guidelines issued by the American Heart Association (AHA) emphasize immediate delivery of chest compressions by bystanders so called “Hands-only CPR” (CPR without ventilation) [30]. In addition, in 2010, the AHA changed its recommendations on the depth and rate of compression from 38-51 mm to 50-60 mm and from 100/min to 100-120/min respectively [31]. However, emphasis on chest compressions demands physical strength and may cause provider fatigue [32]. Therefore, the current study was specifically designed to 5assess the medical safety of the CPR provider, by studying the effects of chest compression on provider fatigue and symptoms, alternation of hemodynamics and ECG after performing multiple rounds of CPR.

We found statistically significant changes in heart rate, respiratory rate, $ETCO_2$, SpO_2 ,and pulse pressure after 5 or 10 cycles of CPR. Recent studies have also demonstrated significant changes in vital signs after performing CPR, such as heart rate, $ETCO_2$, and SpO_2 [19] or blood pressure and heart rate [21]. However, in contrast to previous studies, the current study found significant increases in pulse pressure after multiple cycles of CPR. This potentially is a clinically important finding since multiple studies have found that an elevated pulse pressure is associated with cardiovascular disease and increased mortality [33-36].

Increases in respiratory rate and $ETCO_2$ combined with decreases in SpO_2 are also of clinical relevance based on the fact that 33.3% of the participants reported difficulty in breathing after 10 cycles of CPR. Thier bach and colleagues asked subjects to perform CPR only by ventilation and claimed that artificial ventilation can adversely affect the CPR providers' health due to hyperventilation [37]. However, Kim et al demonstrated an increase in $ETCO_2$ after CPR including both chest compressions and ventilation [16], which is similar to our observations. This physiological phenomenon, which is potentially dangerous for the CPR provider, can be explained by excessive muscle use during chest compression, which causes a reduction in oxygen diffusion capacity and inadequate perfusion.

Recent studies recommended switching roles in CPR every two minutes in order to prevent one rescuer from performing chest compressions for more than 5 cycles [15,18]. The current study supports this recommendation by finding that there were significant changes in vital signs after 5 cycles of CPR.

In the current study one male participant (height: 163 cm, weight: 69kg, age: 50), with a prior history of hypertension, developed sinus dysrhythmia and premature ventricular contractions (PVCs) after 10 cycles of CPR [Figure 2]. This participant also complained of difficulty breathing. In addition, his pulse pressure was slightly above normal prior to CPR and rose to 61 mmHg after 5 cycles of CPR. As noted earlier, increased pulse pressure has been shown to be associated with cardiovascular disease and increased mortality [33-36], and in 1982 Memon and colleagues reported a case of fatal myocardial infarction following CPR training raising medical safety concerns in CPR providers [38]. The case reported here once again raises the potential danger of performing CPR.

Although recent studies found no association between physical characteristics of CPR providers and fatigability during CPR [16, 24-26], the current study found that the BMI of the CPR provider can adversely affect respiratory rate and SpO_2.This finding is clinically significant since 33.3% of participants reported difficulty in breathing after 10 cycles of CPR.

The following limitations should be considered when interpreting the results of the current study. First, the study was conducted using a mannequin and was not a live clinical scenario. Consequently, participants did not experience as much urgency, stress, or fatigue as they would in an actual emergency condition. Second, subjects were healthy firefighters who may not be representative of the general bystander population. Third, the device used to monitor vital signs was not able to detect continuous hemodynamic changes throughout CPR performance. Future studies should include a wider variety of study subjects and record vital signs and ECG continuously while performing CPR.

5. Conclusions

Significant fatigue, symptoms, and changes in hemodynamic parameters were noted among healthy adult firefighters after delivery of 5 and 10 cycles of hands only CPR on a mannequin. CPR guidelines and education should take into consideration fatigue and changes in hemodynamic parameters that may occur among CPR providers.

References

[1] Statement by the Ad Hoc Committee on Cardiopulmonary Resuscitation of the Division of Medical Sciences, National Academy of Sciences-National Research Council. Cardiopulmonary resuscitation. JAM, vol. 198, pp. 372-379, 1966.
DOI: http://doi.org/10.1001/jama.1966.03110170084023

[2] RO Cummins, MS Eisenberg. Prehospital cardiopulmonary resuscitation: is it effective? *JAMA*, vol. 253, no. 16, pp. 2408-2412, 1985.
DOI: http://doi.org/10.1001/jama.1985.03350400092028

[3] International Liaison Committee on Resuscitation. Guidelines 2005 for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*, vol. 112, no. Ⅳ, pp. 19-34, 2005.
DOI: http://doi.org/10.1161/CIRCULATIONAHA.105.170658

[4] IG Stiell, GA Wells, B Field, DW Spaite, LP Nesbitt, VJ De Maio G Nichol, D Cousineau, J Bkackburn, D Munkley, L Luinstra-Toohey, T Campeau, E Dagnone, M Lyver. Advanced cardiac life support in out-of-hospital cardiac arrest. N *Engl J Med,* vol. 351, pp. 647-656, 2004.
DOI: http://doi.org/10.1056/NEJMoa040325

[5] M Eckstein, S Stratton, L Chan. Cardiac arrest resuscitation evaluation in Los Angeles: CARE-LA. *Ann Emerg Med,* vol. 45, pp. 504-509, 2005.
DOI: http://doi.org/10.1016/j.annemergmed.2004.11.024

[6] JW Heidenreich, RA Berg, TA Higdon, GA Ewy, K B Kern, AB Sanders. Rescuer fatigue: standard versus continuous chest-compression cardiopulmonary resuscitation, Acad Emerg Med, vol. 13, no. 10, pp. 1020-1026, 2006.
DOI: http://doi.org/10.1197/j.aem.2006.06.049

[7] E Platz, Scheatzle, PE Pepe, SR Dearwater. Attitudes towards CPR training and-performance in family members of patient with heart disease. *Resuscitation,* vol. 47, no. 3, pp. 273-280, 2000.
DOI: http://doi.org/10.1016/S0300-9572(00)00245-8

[8] JM Koh, TM Kim. CPR training effect for civilian. *Korean J Emerg Med Ser,* vol. 16, no. 1, pp. 19-29, 2012.

[9] BC Lee, MJ Lee, SJ Shin, HW Ryoo, JK Kim, JB Park, KS Seo, The current status of cardiopulmonary resuscitation training for school. *J Korean Soc Emerg Med,* vol. 23, no. 4, pp. 470-478, 2012.

[10] ML Anderson, M Cox, SM AI-Khatib, G Nichol, K L Thomas, PS Chan, P Saha-Chaudhuri, EL Fosbol, B Eigel, B Clendenen, ED Peterson. Rate of cardiopulmonary resuscitation training in the United States. *JAMA Intern Med,* vol. 174, no. 2, pp. 194-201, 2014.
DOI: http://doi.org/10.1001/jamainternmed.2013.11320

[11] OY Kwon, HJ Cho, HJ Cho, HS Choi, HP Hong, Y. G. Ko, S. C. Kim, D. P. Kim, Y. J. Kang. The educational benefits at each steps by expository cardiopulmonary resuscitation teaching and immediate remediation for non-healthcare providers in hospital. *J Korean Soc Emerg Med,* vol. 19, no. 3, pp. 273-281, 2008.

[12] HJ Kim, DS Lim, JO Lee, MK Lee, KY Kim, KS Lee, WJ Chang, SP Chung. Selection of target age for School education of cardiopulmonary resuscitation using Video self-instruction program. *J Korean Soc Emerg Med,* vol. 18, no. 3, pp. 196-201, 2007.

[13] CW Lee, JY Ahn, GC Cho, WW Lee, YD Son, HC Ahn, ME Ahn, JY Seo. E-learning can be helpful for mastering basic life support skills on public. *J Korean Soc Emerg Med,* vol. 21, no. 4, pp. 423-428, 2010.

[14] RA Berg, CR Hemphill, BS Abella, TP Aufderheide, DM Cave, MF Hazinski, EB lerner, TD Rea, MR Sayre, RA Swor. 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation,* vol. 122, no. Sppul 3, pp. S685-705, 2010.
DOI: http://doi.org/10.1161/CIRCULATIONAHA.110.970939

[15] KH Yi, SO Park, KR Lee, SC Kim, HS Jeong, DY Hong, KJ Baek.. Comparison of the alternating rescuer method between every minute and two minutes during continuous chest compression in cardiopulmonary resuscitation according to the 2010 guidelines. *J Korea Soc Emerg Med,* vol. 23, no. 4, pp. 455-459, 2012.

[16] YB Kim, SM Choi, YM Kim, WJ Lee, KN Park, MJ Lee, HJ Kim, SH Kim, SH Woo, JE Park. Effect or single-rescuer fatigue on the quality if cardiopulmonary resuscitation with 30:2 and 15:2 compression-to-ventilation ratios. *J Korea Soc Emerg Med,* vol. 17, no. 6, pp. 519-527, 2006.

[17] C Pozner, A Almozlino, S Poole, D McNamara, D Barash. Abstract P168: Early markers of rescuer's fatigue. *Circulation,* vol. 120, pp. S1478, 2009.
DOI: http://doi.org/10.1016/j.ajem.2010.01.008

[18] UJ Choi. Physiology changes on the rescuer and efficiency of CPR in the increased chest compression. *Korean J Emerg Med Ser*, vol. 12, no. 3, pp. 43-53, 2008.

[19] MS Jang, YJ Tak. The variation of elapsed time on fatigue and quality of single rescuer cardiopulmonary resuscitation. *Korean J Emerg Med Ser,* vol. 17, no. 1, pp. 9-19, 2013.

[20] DY Hong, SO Park, KR Lee, KJ Baek, DH Shin. A different rescuer changing strategy between 30:2 cardiopulmonary resuscitation and hands-only cardiopulmonary resuscitation that considers rescuer factor: A randomized cross-over simulation study with a time-dependent analysis. *Resuscitation,* vol. 83, pp.

353-359, 2012.
DOI: http://doi.org/10.1186/s13049-014-0059-x

[21] GN Kim, SS Choi, SW Choi. Comparison on the quality and fatigue of hands only CPR according to the presence or absence of verbal counting by some middle-aged women. *Journal of the Korea Academia-Industrial cooperation Society,* vol. 14, no. 3, pp. 1320-1329, 2013.
DOI: http://doi.org/10.5762/KAIS.2013.14.3.1320

[22] Surveillance and quality management of out-of-hospital cardiac arrest. Centers for disease control and prevention at Seoul National University.

[23] A Lucia, JF de las Heras, M Perez, JC Elvira, A Carvajal, AJ Alvarez. JL Chicharro. "The importance of physical fitness in the performance of adequate cardiopulmonary resuscitation." *Clinical Investigations in Critical Care,* vol. 115, pp. 158-164, 1999.

[24] C Sandroni, MG Bocci, F Damiani, R Proiette, D Speranza. Can the body size affect students' performance during CPR training. *Resuscitation,* vol. 34, pp. 191, 1997.
DOI: http://doi.org/10.1016/S0300-9572(97)84242-6

[25] D Yannopoulos, TP Aufderheide, A Gabrielli, DG Beiser, SH BS McKnite, FG Pirrallo, J Wigginton, L Becker, TV Hoek, W Tang, VM Nadkarni, JP Klein, AH Ahamed, KG Lurie. Clinical and hemodynamic comparison of 15:2 and 30:2 compression-to-ventilation ratios for cardiopulmonary resuscitation. *Crit Care Med,* vol. 34, pp. 1444-1449, 2006.
DOI: http://doi.org/10.1097/01.CCM.0000216705.83305.99

[26] FJ Ochoa, E Ramalle-Gomara, V Lisa, I Saralegui. The effect of rescuer fatigue on the quality of chest compressions. *Resuscitation,* vol. 37, pp. 149-152, 1998.
DOI: http://doi.org/10.1016/S0300-9572(98)00057-4

[27] MS Jang. The variation of elapsed time on fatigue and qualoty of single rescuer cardiopulmonary resuscitation. *Unpublished master's thesis. Graduate School of Korea National University of Transportation,* Chungju, Korea. 2012.

[28] DY Kim, DH Park, KH Kim. The comparison of fatigue by different exercise types under hot environment. *Exercise science,* vol. 17, no. 2, pp. 211-222.

[29] YJ Yu, YA Shin. The response of energy expenditure muscle activity and fatigue on wlking type. *Journal of Sport and Leisure Studies,* vol. 32, No. 2, pp. 767-777. 2008.

[30] GA Ewy. Cardiocerebral resuscitation: the new cardiopulmonary resuscitation. *Circulation,* vol. 111, pp. 2134-2142, 2005.
DOI: http://doi.org/10.1161/01.CIR.0000162503.57657.FA

[31] RA Berg, R Hemphill, BS Abella, TP Aufderheide, DM Cave, MF Hazinski, EB lerner, TD Rea, MR Sayre, RA Swor. Part 5: adult basic life support: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation,* 2010;122(2):S685-705.
DOI: http://doi.org/10.1161/CIRCULATIONAHA.110.970939

[32] A Lucia, JF de las Heras, M Perez, JC Elvira, A Carvajal, AJ Alvarez. JL Chicharro. "The importance of physical fitness in the performance of adequate cardiopulmonary resuscitation." *Clinical Investigations in Critical Care,* vol. 115, pp. 158-164, 1999.

[33] SS Franklin, SA Khan, ND Wong, MG Larson, D Levy. Is pulse pressure useful in predicting risk for coronary heart disease? The Framingham study. *Circulation,* vol. 100, pp. 354-360, 1999.
DOI: http://doi.org/10.1161/01.CIR.100.4.354

[34] GF Mitchell, LA Moye, E Braunwald, JL Rouleau, V Bernstein, EM Geltman, C Grey, MA Flaker. Sphygmomanometrically determined pulse pressure is a powerful independent predictor of recurrent events after myocardial infarction in patients with impaired left ventricular function. *Circulation,* vol. 96, pp. 4254-4260, 1997.
DOI: http://doi.org/10.1161/01.CIR.96.12.4254

[35] SW Cho. Correlation between the pulse pressure and IMT(intra-media wall thickness) of the carotid artery in hypertension patients. *Unpublished master's thesis. The graduate school of Chung-Ang University,* Seoul, Korea, 2005.

[36] M Domanski, J Norman, M Wolz, G Mitchell, M Pfeffer. Cardiovascular risk assessment usion pulse pressure in the first national health and nutrition examination survey (NHANES Ⅰ). *Hypertension,* vol. 38, pp. 793-797, 2001.
DOI: http://doi.org/10.1161/hy1001.092966

[37] AR Thierbach, BB Wolcke, F Krummenauer, M Kunde, C Janig, WF Dick. Artificial ventilation for basic life support leads to hyperventilation in first aid providers. *Resuscitation,* vol. 57, pp. 269-277, 2003.
DOI: http://doi.org/10.1016/S0300-9572(03)00042-X

[38] AM Memon, JE Salzer, EC Hillman Jr, CL Marshall. Fatal myocardial infarct following CPR training: the question of risk. *Ann Emerg Med,* vol. 11, pp. 322-323, 1982.
DOI: http://doi.org/10.1016/S0196-0644(82)80135-2

Hyo-Ju Lee [Regular member]

- Feb. 2012 : Soonchunhyang Univ., Dept. of Medical, MS
- Feb. 2017 : Soonchunhyang Univ., Dept. of Medical, PhD
- Sept. 2014 ～ current : Gyeongbuk Provincial College, Dept. of Emergency Medical Technology, Assistant Professor

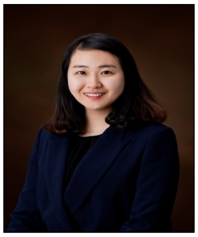
<Research Interests>
Prehospital care, Triage

Ho-Jung Kim [Regular member]

- Feb. 2004 : Yonsei Univ., Dept. of Medicine, MS
- Feb. 2012 : Yonsei Univ., Dept. of Medicine, PhD
- Mar. 2009 ~ current : Soonchunhyang Univ. Hospital, Dept. of Emergency Medicine, Associate Professor

<Research Interests>
Emergency medicine(Resuscitation, Cardiovascular disease), Sports medicine, Geriatircs

Eun-Kyung Jung [Regular member]



- Feb. 2013 : Chonnam National Univ., Dept. of Public Health, MS
- Apr. 2015 ~ current : Honam Univ., Dept. of Emegency Medical Services, Assistant Professor

<Research Interests>
Prehospital care, Public health