The effects of flashlight guidance on performance for chest compression of cardiopulmonary resuscitation in a noisy environment

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The effects of flashlight guidance on performance for chest compression of cardiopulmonary resuscitation in a noisy environment

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ABSTRACT

The effects of flashlight guidance on performance for chest compression of cardiopulmonary resuscitation in a noisy environment

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Introduction

In real cardiopulmonary resuscitation (CPR) situations, noise can arise from instructional voices and from environmental sounds in places such as the battlefield, industrial, commercial shopping and high traffic areas. The World Health Organization (WHO) suggested guideline limits for community noise in specific environments. In the specific environments mentioned above, noise levels were measured to be >70 dB, which can induce annoyance and hearing impairment. A simple feedback device using flashlight stimulus was designed for overcoming

noise-induced stimulus saturation during CPR. This study was conducted to determine whether flashlight guidance influences CPR performance in a simulated noisy setting.

Materials and Methods

We recruited 30 senior medical students with no previous experience using flashlight-guided CPR participated in this prospective, simulation-based, cross-over study. In a simulated noisy situation, the experiment was conducted using a cardiac arrest model without ventilation. Noise was artificially generated as patrol car and fire engine sirens. Siren noise intensity was adjusted to 80 ± 5 dB, with 60 pitches/minute. The flashlight guidance emitted light pulses at the rate of 100 flashes/minute from a light-emitting diode (LED). Participants also received the instruction that suited a target rate of 100 compressions/minute. CPR was randomly performed in one of two sequences. Compression rate and depth and percentage of compression with correct hand position were recorded with a Resusci Anne® manikin with a PC skill-reporting system. Participants were asked to report rescuer's fatigue on a visual analog scale (VAS) of 0-10. A linear mixed model for 2×2 cross-over design and evaluating changes in chest compression rate across time were used.

Results

There were significant differences between the control and flashlight groups for mean compression rate (MCR), MCR/minute, and VAS. However, there were no

significant differences for corrected compression depth (%), mean compression depth (mm), corrected hand position (%), and correctly released compression (%). The flashlight group MCR closely maintained the target 100 compressions/minute. However the control group MCR was distributed over a much wider range. The flashlight group had a tendency to maintain constant MCR, whereas the control group had a tendency to decrease MCR after 60 seconds

Conclusion

Flashlight guidance is effective low-cost CPR feedback system for maintaining desired MCR. Flashlight-guided CPR is particularly advantageous in maintaining desired MCRs during compression-only CPR in noisy environments where metronome-pacing might not be clearly heard.

Key words : cardiopulmonary resuscitation, chest compression, flashlight, noise

The effects of flashlight guidance on performance for chest compression of cardiopulmonary resuscitation in a noisy environment

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The Graduate School, Yonsei University

(Directed by Professor Sung Phil Chung)

I. INTRODUCTION

The 2010 American Heart Association (AHA) and European Resuscitation Council (ERC) cardiopulmonary resuscitation (CPR) guidelines have been optimized for high-quality CPR. Chest compression quality is of the utmost importance for a patient's survival after cardiac arrest.[1,2]

Many studies have been reported that audiovisual feedback systems improve CPR quality. Metronome guidance is the simplest and lowest cost feedback system.[3] Audio-prompt rate guidance significantly improves the chest compression rate and the mean end-tidal carbon dioxide (CO_2) concentration during CPR.[4-6] Oh et al. revealed that metronome use may increase mean compression rate (MCR) to the desired rate. However, compression depth was decreased by requiring multitasking for CPR technique and audio perception of audio tones.[7]

Stimulus saturation limits signal recognition during complex situations such as resuscitation. This effect can lead to annoyance and performance reduction and increase human error.[8] In real CPR situations, noise can arise from instructional voices and from environmental sounds in places such as the battlefield, industrial, commercial shopping and high traffic areas. The World Health Organization (WHO) suggested guideline limits for community noise in specific environments. In the specific environments mentioned above, noise levels were measured to be >70 dB, which can induce annoyance and hearing impairment.[9] A simple feedback device using flashlight stimulus was designed for overcoming noise-induced stimulus saturation during CPR. This study was conducted to determine whether flashlight guidance influences CPR performance in a simulated noisy setting.

II. MATERIALS AND METHODS

1. Participants

We recruited 30 senior medical students with no previous experience using flashlight-guided CPR participated in this prospective, simulation-based, cross-over study. This study was approved by the Institutional Review Board. This study was explained to participants, and written informed consent was obtained from all subjects. All participants had previous CPR training in which adult basic life support (BLS) was taught according to 2010 AHA guidelines,[1] using a training manikin. This training lasted 6 hours (2 hours of lecture and 4 hours of practical training), in accordance with 2010 AHA guidelines for CPR to be taught as part of a regular college course. The training was given at least 6 months before this study.

2. Study Protocol

All participants were given a 20-minute instruction concerning flashlight guidance CPR and an overview of this study. The memory rate of 100 ticks/minute was provided by metronome. In a simulated noisy situation, the experiment was conducted using a cardiac arrest model with hands only CPR. Noise was artificially generated as patrol car and fire engine sirens (Sirens-iPhone application; BrennanMoyMedia, New York, NY, USA). Siren noise intensity was adjusted to 80 ± 5 dB, with 60 pitches/minute by a sound dose meter (DT-805L, Gunpoong Electronics; Busan, Korea). We designed and manufactured the flashlight guidance device (Top-Lighting; Seoul, Korea). The flashlight guidance emitted light pulses at the rate of 100 flashes/minute from a light-emitting diode (LED). As participants performed CPR with flashlight guidance, they received instruction that suited the rate of the flashlight guidance. When participants performed CPR without flashlight guidance, they also received the instruction that suited a target rate of 100 compressions/minute. CPR was randomly performed in one of two sequences. In Sequence A, the participant conducted CPR with flashlight guidance. After a 30-minute rest period, the participant conducted CPR without flashlight guidance. In Sequence B, the participant conducted CPR without flashlight guidance. After a 30-minute rest period, the participant conducted CPR with flashlight guidance. Single-rescuer adult BLS was performed on the manikin for 2 minutes by all participants. Sequence selection for CPR performance was computer-randomized. Skill assessment was performed according to the 2010 AHA guidelines. A Resusci Anne® manikin with a personal-computer (PC) skill-reporting system (Laerdal, Stavanger, Norway) was used for assessing CPR performance.

3. Outcome Assessment

Compression rate and depth and percentage of compression with correct hand position were recorded with a Resusci Anne® manikin with a PC skill-reporting system. Participants were asked to report rescuer's fatigue on a visual analog scale (VAS) of 0-10 (0=extremely easy, 10=extremely difficult). Open questions were posed to all participants on strengths and weaknesses of performing chest compressions with or without flashlight guidance in a noisy situation. After answers for open questions were collected, all participants were re-questioned for consistency.

4. Statistics

Sample size was calculated according to our primary endpoints. Differences of five compressions per minute and 5 mm in mean compression depth between the two methods were selected as minimum clinically significant values. Using these values, we calculated that a sample size of 28 participants was sufficient to detect an effect value of 0.75 (mean difference/common SD) at a significance level of 0.05 (two-sided) with 80% power. A linear mixed model for 2×2 cross-over design was used. Three fixed effects were included: 1 between-subject effect which was the sequence effect (CPR without flashlight for the first half of the subject and then CPR with flashlight for the second half, CPR with flashlight for the first half of the subject and then CPR without flashlight for the second half) and 2 within-subject effects which were the group effect (CPR with flashlight, CPR without flashlight) and the period effect (first, second). Subject was considered as random effect. Since a half of the subject was assigned to one sequence and the rest was assigned to the other half, they were nested within sequence.

Also linear mixed model for evaluating changes in chest compression rate across time was used. Two fixed effects were included: 1 between-subjects effect which was group effect (CPR with flashlight, CPR without flashlight) and 1 within-subject effect which was time effect (30, 60, 90, 120 seconds). A possible difference in sequence across 30 - 120 seconds was analyzed by group × time interaction. The group × time interaction was tested at a significance level of 0.05. The multiple comparisons with the Bonferroni correction as the post-hoc analysis were used to compare point of rate change that was significantly different from the baseline. All statistical analyses were conducted using SAS 9.2 (SAS Institute INC, Cary, NC, USA).

III. RESULTS

1. Variables of CPR performance

All 30 participants successfully completed the study. The median participant age was 25 (interquartile range [IQR]: 25, 26) years, and 22 (73.3%) participants were male. Results from linear mixed model are displayed in Table 1, including outcome and group differences from baseline to 120 seconds. P-values of main effects for sequence, period, and group are given. The sequence did not affect the results for all performance variables, and there were no significant differences between the first and second periods. There were significant differences between the control and flashlight groups for MCR, MCR/minute, and VAS. However, there were no significant differences for correct compression depth (%), mean compression depth (mm), correct hand position (%), and correctly released compression (%).

Table 1. Results from a linear mixed-model for CPR performance. P-values of main effects for sequence, period, and group are given. The sequence did not affect the results for all performance variables, and there were no significant differences between the first and second periods. There were significant differences between the control and flashlight groups for mean compression rate (MCR), MCR/minute, and VAS. However, there were no significant differences for corrected compression depth (%), mean compression depth (mm), correct hand position (%), and correctly released compression (%).

	Control, Estimated mean (95% CI))	Flash, Estimated mean (95% CI)	Difference (control – flash), Estimated mean (95% CI)	P-values		
				Sequence	Period	Group
Mean compression depth (mm)	54.7 (52.9~56.5)	54.7 (52.9~56.5)	<-0.001 (-0.92~0.92)	0.43	0.77	>0.99
Correct compression depth (%) (compression depth > 50mm)	82.1 (71.9~92.3)	84.7 (74.5~94.97)	-2.63 (-8.05~2.78)	0.39	0.54	0.33
Mean compression rate	120.4 (117.0~123.7)	100.7 (97.4~104.1)	19.63 (14.98~24.28)	0.35	0.33	<0. 01
Mean compression rate/minute	120.7 (117.4~124.1)	100.8 (97.5~104.2)	19.90 (15.30~24.50)	0.35	0.31	<0.01
Correct hand position (%)	87.6 (80.7~94.5)	84.2 (77.3~91.1)	3.40 (-0.23~7.03)	0.50	0.41	0.06
Correctly released compression (%)	97.5 (93.8~101.2)	96.6 (92.9~100.3)	0.97 (-1.57~3.51)	0.52	0.30	0.44
rescuer fatigue (VAS*)	6.2 (5.6~6.9)	4.8 (4.2~5.4)	1.42 (0.52~2.31)	0.95	0.51	<0.01

VAS*, Visual analog scale of 0-10 (0=extremely easy, 10=extremely difficult).

2. Mean compression rate at a target rate of 100/minute

Results of MCR at the target rate (100 compressions/minute) were shown in Figure 1. The flashlight group MCR closely maintained the target 100 compressions/minute, estimated mean 100.8 compressions/minute (95% CI: 97.5 to 104.1). The 100 was included in 95% confidence interval (95% CI). However the control group MCR was distributed over a much wider range, estimated mean 120.7 (95% CI: 117.4 to 124.1). The 100 was not included in 95% CI (Figure 1).

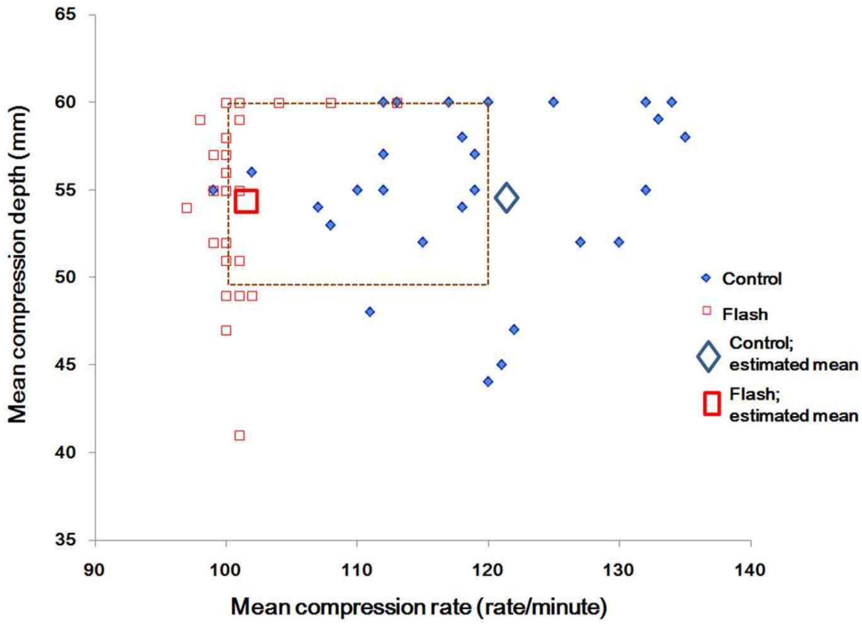

Figure 1. Results from mean compression rate (MCR) at desired rate (100 compressions/minute). The flashlight group MCR closely maintained the target (100 compressions/minute), estimated mean 100.8 compressions/minute (95%CI: 97.5 to 104.2). However, the control group MCR was distributed over a much wider range, estimated mean 120.7 (95% CI: 117.4 to 124.1)

3. Changes in chest compression across time

Effects obtained for time (p=0.01), by group (p<0.01), and interactions (p=0.01), suggested that changes from 0 to 120 seconds were in general different between the groups. Post-hoc analyses were conducted for the point of rate changes. No differences in MCRs were seen in time by group interactions from 30 to 60 seconds (p>0.99). However, effects were observed for time by group interactions from 30 to 90 seconds (p=0.04) and from 30 to 120 seconds (p=0.03). The results suggested that flashlight group had a tendency to maintain constant MCR, whereas the control group had a tendency to decrease MCR after 60 seconds (Figure 2).

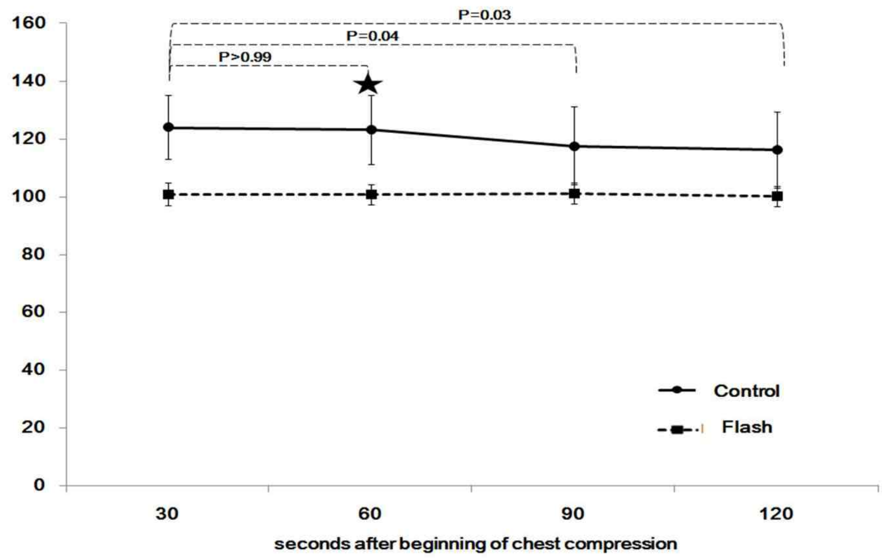

Figure 2. Changes in chest compression rate across time. The results suggested that flashlight group had a tendency to maintain constant mean compression rate (MCR), whereas the control group had a tendency to decrease MCR after 60 seconds (★).

4. Open questionnaire

In open questioning, 28 of 30 participants (93.3%) responded that flashlight guidance made it easier to adjust CPR to the desired target rate. The majority of participants (24 of 30; 80.0%) reported that it was difficult to mentally count compression numbers to maintain the target MCR because they were influenced by the noisy siren. Twelve of the participants (40.0%) responded that flashlight-guidance during CPR distracted them from verifying correct hand position. More than half of the participants (16 of 30; 53.3%) responded that noise of a slow siren at 60 pitches/minute caused an excessive MCR increase.

IV. DISCUSSION

Our study demonstrated that flashlight-guidance influences desired MCR during CPR and reduces rescuer fatigue similar to the effects of metronome. The 2010 AHA guidelines recommend an MCR of at least 100 compressions/minute and of an adequate depth of at least 5 cm. According to 2005 AHA/ERC guidelines, many researchers considered that compression rate did not be reached at a rate of about 100/minute. Recent 2010 AHA/ERC guidelines emphasized more fully the concept of "Push hard, push fast" than previous guidelines. Compared to the flashlight-guided group, the control group MCR was significantly increased beyond the desired rate in noisy situations. Field et al. revealed that a chest compression rate above 120 compressions/min reduces compression quality. Field et al and 2010 ERC guidelines recommended that a MCR of 100-120 compressions/minute for 2 min is feasible for maintaining adequate chest compression quality.[2,9] There were no significant differences between two groups for compression depth and appropriate compression depth (%). Results for compression depth can be viewed as education effects resulting from the "push hard" CPR training emphasized by the 2010 AHA/ERC guidelines.[1,2]

For improving CPR quality, maintenance of appropriate compression rate and depth is a primary consideration. Although further study is needed, CPR performance may be interrupted by noises like sirens, instructions, voices, and other environmental sounds. Emergency patients requiring CPR can be encountered anytime and anywhere. Emergency situations frequently occur in noisy places such as battlefields, festivals, industrial and commercial districts, shopping centers, and high traffic areas. In particular, CPR feedback systems used in prehospital setting should be simple and low cost. Until recently, audio-tone guidance has been considered as a standard feedback system for public CPR. However, audio-guidance may not be effective in noisy situations. Light signals are a potential alternative or supplementation for audio-guided CPR. Light travels much faster than sound and has additional obvious benefits when CPR must be performed in a dark place. The flashlight can facilitate rapid recognition of CPR guidance at farther distances. Abella et al. reported that resuscitation complexity increases the possibility of human error, leading to decreased performance.[11] The stimulus saturation effect limits signal recognition during complex situation like resuscitation. This effect can lead to annoyance and reduced CPR performance.[8,12] Light can be a new and effective alternative pacing stimulus because CPR itself creates extraneous auditory stimuli. Although our study revealed flashlight guidance distracted 40% of participants from hand position correction, new light stimuli development and CPR training regimens should be able to overcome this effect.

Additional training courses are strongly encouraged to achieve adequate CPR performance. A variety of flashlight-devices for CPR could be produced and distributed to the general public to encourage nationwide use of flashlight-guided CPR, thus improving resuscitation effectiveness. These flashlights could be attached to key rings, necklaces, or cellular phones. If flashlight-rate can be standardized with the desired MCR, in emergency situation, calibrated directional indicators in cars and lightbars in emergency vehicles could be considered as flashlight-guidance CPR devices (Figure 3).

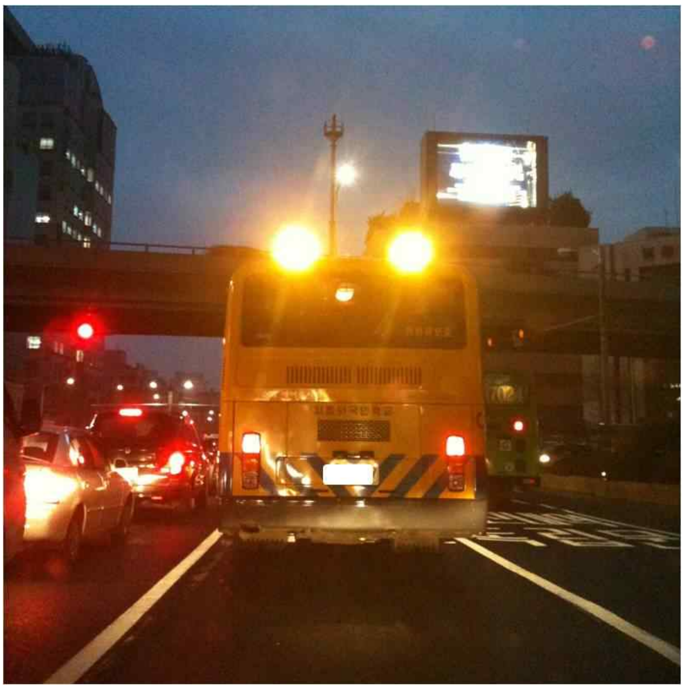

Figure 3. A school bus warning light could function as a flashlight-guidance CPR device.

Photosensitivity is an abnormal sensitivity to light stimuli, and in humans can be usually expressed as the frequency range between 10 and 30 Hz.[13] Most patients are sensitive to stimulation of 16 Hz. Almost half of the population (49%) is sensitive to 50 Hz, and only 15% is sensitive to 60 Hz, which are the frequencies of television in Europe and North America, respectively.[13] About 3% of the photosensitive population with some degenerative disorder is sensitive to intermittent photic stimulation at 1–3 flashes/second.[14] The flashlight rate for CPR guidance can be expressed as a range of frequencies usually between 1.7 flashes/second (1.7 Hz) and 2 flashes/second (2 Hz). Thus, the flashlight can be used safely for improving CPR performance.

Limitations

There were several limitations to our study. First, this study used manikins as models to simulate an emergency resuscitation situation. This simulation could not reproduce the nature of real emergent situations. Second, laypersons can be confused by additional visual CPR-guidance stimuli in noisy environments. Application of flashlight guidance could increase the complexity of CPR, thus delaying CPR initiation due to hesitation by inexperienced laypersons. However, based on this study, this problem can be overcome by training and nationwide campaigns. Third, the participants might have had atypical motivations and emotional responses for participation in this study. Participants in this study were not laypersons, but medical students trained according to the 2010 AHA guidelines. We observed no significant differences between performance variables among the two test groups except for maintaining desired MCR. It is likely that a lay rescuer would perform lower-quality CPR. Compression depth by inexperienced lay rescuers could be one distinction between two groups. Fourth, our study showed that subjective fatigue of participants using flashlight-guided CPR was less than fatigue in the control group in noisy environments. However, the results may not arise from effects of the flashlight itself, but by preventing excessive MCRs during CPR performance in a noisy environment.

At present, the impact of the flashlight-guided CPR on patient outcome has yet to be evaluated in actual noisy emergent situations. Our study demonstrated that both flashlight- and metronome-based CPR guides are simple and economical feedback systems, with a similar beneficial effect on CPR performance. Further studies are required to determine the effect of flashlight-guided CPR performance when adjusting a MCR of 110 and 120 compressions/minute according to the 2010 AHA/ERC guidelines and on the clinical results of flashlight-guided CPR performed by laypersons in prehospital settings.

V. CONCLUSION

Flashlight guidance is effective low-cost CPR feedback systems for maintaining appropriate compression rate. Flashlight-guided CPR may be particularly advantageous during hands-only CPR in noisy environments where audio-tone is not clearly heard.

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ABSTRACT (IN KOREAN)

소음 환경에서 빛을 이용한 심폐소생술이 흉부압박의 수행도에 미치는 효과

<지도교수 정 성 필 >

연세대학교 대학원 의학과

유 제 성

서론

실제 심폐소생술이 발생하는 상황에서 소음은 심폐소생술을 지시하는 소리로도 유발될 뿐만 아니라 전쟁터, 쇼핑몰, 공장, 도로 등 같은 환경적인 요소에 의해서도 소음이 발생할 수 있다. 세계보건기구는 특별한 상황에서 소음 정도에 대해 가이드라인은 제시 하고 있는데 위에 언급한 특별한 상황은 약 70 dB 이상으로 측정되며 이는 집중력을 떨어뜨릴 뿐 아니라 청력의 손상도 유발 할 수 있다. 심폐소생술을 하는 동안에 소음에 의한 수많은 자극으로 집중이 방해되는 것을 극복하기 위해 빛을 사용한 간단한 피드백 시스템을 고안하였으며 이 연구는 소음이 유발되는 시뮬레이션 상황에서 빛을 이용한 피드백 시스템이 심폐소생술의 수행도에

미치는 효과를 알아보고자 한다.

방법

의과대학 4학년 학생 30명을 대상으로 소음을 유발한 시뮬레이션 상황에서 호흡 보조 없는 심폐소생술 시행 모델을 사용하여 전향적 교차 연구로 진행 되었다. 소음은 경찰차와 소방차의 싸이렌 소리를 이용하여 인공적으로 만들었으며 이 싸이렌 소리는 분당 60번의 소리의 최고 높이를 가지고 있으며 소리 강도는 80 ± 5 dB로 유지 하였다. 빛은 자체 제작한 LED로부터 분당 100회로 발광하였다. 연구의 참가자들은 소음환경에서 빛을 이용하여 심폐소생술을 하는 군과 빛 도움 없이 수행하는 경우로 나누어 무작위로 반복하여 목표로 제시된 분당 100회에 맞추어 심폐소생술을 수행 하였으며 정확한 흉부압박 수, 평균 흉부압박 횟수, 깊이, 정확한 손의 위치 등을 마네킹을 통해 평가하였다. 또한 수행자의 피로도는 visual analog scale (VAS)로써 평가 하였다. 시간 경과에 따른 흉부 압박 속도의 변화와 두 군의 수행도의 차이를 확인하기 위해 linear mixed 모델을 이용하였다.

결과

소음 환경에서 대조군 그룹과 빛을 이용한 심폐소생술 수행 군 간에 평균압박속도, 분당 평균압박속도, 수행자의 피로도에 있어 의미 있는

차이가 있었지만 흉부압박 깊이, 압박이완, 손의 정확한 위치, 그리고 평균압박 깊이는 두 군간에 차이가 없었다. 빛의 도움을 받은 군은 평균압박속도가 목표 속도인 100회/분을 일정하게 유지하였지만 대조군의 평균압박속도는 일정하지 않았다. 또한 빛의 도움을 받은 그룹은 일정하게 2분간 속도를 유지하였지만 대조군은 60초 이후부터 평균압박속도가 감소하였다.

결론

빛을 이용한 심폐소생술은 목표로 하는 평균압박 속도을 유지 하기 위해서 효과적이고 경제적인 심폐소생술 피드백 시스템이다. 특히 빛을 사용하는 심폐소생술은 메트로놈의 소리를 정확히 듣기 어려운 시끄러운 환경에서 흉부압박만 시행하는 심폐소생술에 있어 목표로 하는 평균 흉부 압박 속도를 유지 하는데 도움을 준다.

핵심되는 말 : 심폐소생술, 흉부압박, 빛, 소음