学位論文

Chest Compression Depth and Rate

— Effect on Instructor Visual Assessment of Chest Compression Quality —

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ORIGINAL ARTICLE
Ischemic Heart Disease

Chest Compression Depth and Rate
— Effect on Instructor Visual Assessment of Chest Compression Quality —

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Background: The aim of the present study was to determine whether instructors could accurately assess chest compression quality visually, considering the association between chest compression depth and rate.

Methods and Results: In this prospective, observational study, the quality of chest compressions performed by a simulated actor in a video was visually assessed by certified instructors. The film consisted of 14 case scenarios, each including a combination of depth (2 patterns: adequate, 5–6 cm; and inadequate, <5 cm) and rate (7 categories: compressions 90–150 times/min in increments of 10 times/min). The participants evaluated whether the compression depth was adequate, deep, or inadequate; and whether the compression rate was appropriate, fast, or slow. Of 198 instructors, 56% of participants misidentified adequate depth as deep at a chest compression rate of 120/min (the tendency toward this response increased as chest compression rate increased), and 64.1% of participants incorrectly determined 130/min to be appropriate. On generalized linear mixed-effects model analysis, perceived chest compression depth and rate were significant factors for a correct response (P<0.01, both). A significant interaction between chest compression depth and rate was observed (P<0.01).

Conclusions: In the visual assessment of chest compression quality, recognition of chest compression depth was closely associated with compression rate. Misidentification of adequate chest compression depth as deep increased as the compression rate increased.

Key Words: Basic science; Cardiopulmonary resuscitation; Chest compression resuscitation

Sudden cardiac arrest is one of the leading causes of death in Japan, and the resuscitation rate has been found to increase by more than 2-fold if a bystander performs cardiopulmonary resuscitation (CPR). In particular, chest compression quality is a major contributing factor to resuscitation rates.[1–5]

The details of chest compression quality, including chest compression depth, rate, and fraction, were established in the 2015 American Heart Association (AHA) guidelines. Regarding chest compression depth, although the 2010 AHA guidelines recommend the depth to be a minimum of 2 inches (5 cm) for the average adult, the 2015 AHA guidelines with class I recommendation state that rescuers should avoid excessive depths (>2.4 inches or >6 cm).[6] Regarding chest compression rate, although the 2010 AHA guidelines recommend a rate of >100 compressions/min,[7] the 2015 AHA guidelines introduced an upper limit, defining an adequate compression rate as 100–120 times/min;[6] furthermore, as the rate increases to >120 times/min, the depth should decrease in a dose-dependent manner.[8] Indeed, return of spontaneous circulation after ≥10 min of emergency medical services resuscitation, complying with 2015 AHA guidelines (chest compression depth, rate, and fraction), was associated with improved clinical outcomes.[9]

Resuscitation training is frequently facilitated by instructors without evaluating whether they can assess the accuracy of CPR quality in participants.[10–12] One study of 15 instructors reported that instructor assessment of chest compression rate had poor sensitivity and specificity.[11] The accuracy, however, of chest compression quality, and the association between chest compression depth and rate, and factors influencing appropriate instructor response during visual assessment, have not been completely examined with large populations.

The aim of the present study was therefore to determine whether instructors could accurately assess chest compression

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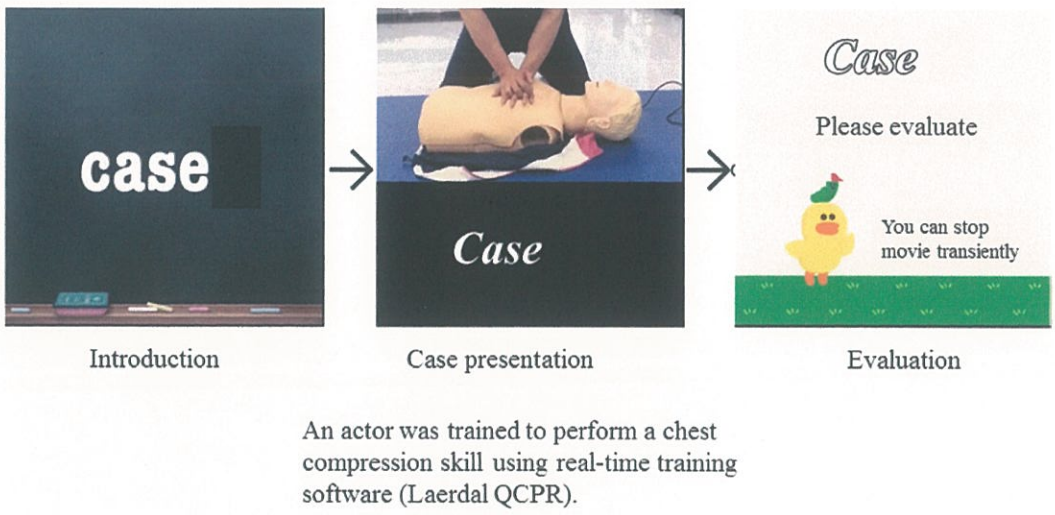

Figure 1. Web films (YouTube). Participants watched a YouTube film, in which a simulated actor was trained to continuously perform chest compressions using real-time training software (Laerdal QCPR).

quality visually, considering the association between chest compression depth and rate.

Methods

Study Design

A single-blind, prospective, observational study was conducted to evaluate the accuracy of instructor assessment of chest compression quality during simulated resuscitation. Data were collected from May 2016 to November 2017. This study was approved by the Research Ethics Board of the Kagawa University Hospital (approval number: H29-099), and informed consent was obtained from all the instructors who chose to participate.

Participants

All the participants were certified instructors of the Immediate Cardiac Life Support (ICLS) course by the Japanese Association for Acute Medicine (JAAM), or of the Basic Life Support (BLS) course by the AHA, with instructor experience in the 2015 AHA guidelines course, and were recruited for this study using the mailing list for instructors working on Shikoku Island, Japan. Participants with no teaching experience as an instructor were excluded. The ICLS course, designed as a multi-professional 1-day (8-h) resuscitation course, was developed and launched by JAAM for resident training in April 2002. It teaches the essential skills and team dynamics required to manage a patient in cardiac arrest for 10 min before the arrival of a cardiovascular specialist. The course consists of skill stations and scenario stations. The skill stations provide BLS using an automated external defibrillator and provide basic airway as well as in-hospital management, along with electrocardiographic monitoring using a manual external defibrillator,[13] whereas the scenario stations provide advanced life support for various cardiac arrest patterns.

Simulated Resuscitation

A simulated actor was trained for continuous performance of chest compressions using real-time training software (Laerdal QCPR). Two patterns (adequate, 5–6 cm; and inadequate, <5 cm) of chest compression depth were established. The depth was measured using the Laerdal QCPR feedback function to maintain accuracy. This device can detect depths up to 6.4 cm, but we did not set the situation significantly over 6.0 cm (e.g., 6.5 cm) because such a setting was difficult with regard to errors. A simulated actor maintained 4.0 cm in the setting of <5.0 cm, which was shown as clearly inadequate. In the setting of 5–6 cm, a simulated actor maintained 5.5 cm, which was shown as clearly adequate. Chest compression rates were classified into 7 categories from 90 to 150 times/min in increments of 10 times/min. Chest compression skills were examined in 14 cases, with 2 depth patterns and 7 rate categories. Each case was video recorded to obtain an 8-s film, and 14 case presentation films were compiled in random order (**Figure 1**). The order of presentation films was determined using simple randomization methods, i.e., we prepared 14 balls, labeled as 1–14, and then picked up the balls individually. The order of the presentation films is listed in **Supplementary Table**.

Data Collection

The participants evaluated the quality of chest compressions (depth and rate) performed by the simulated actor in each YouTube video. During assessment of each case, any use of auxiliary equipment to aid in evaluation, including stopwatches and metronomes, was prohibited, and the

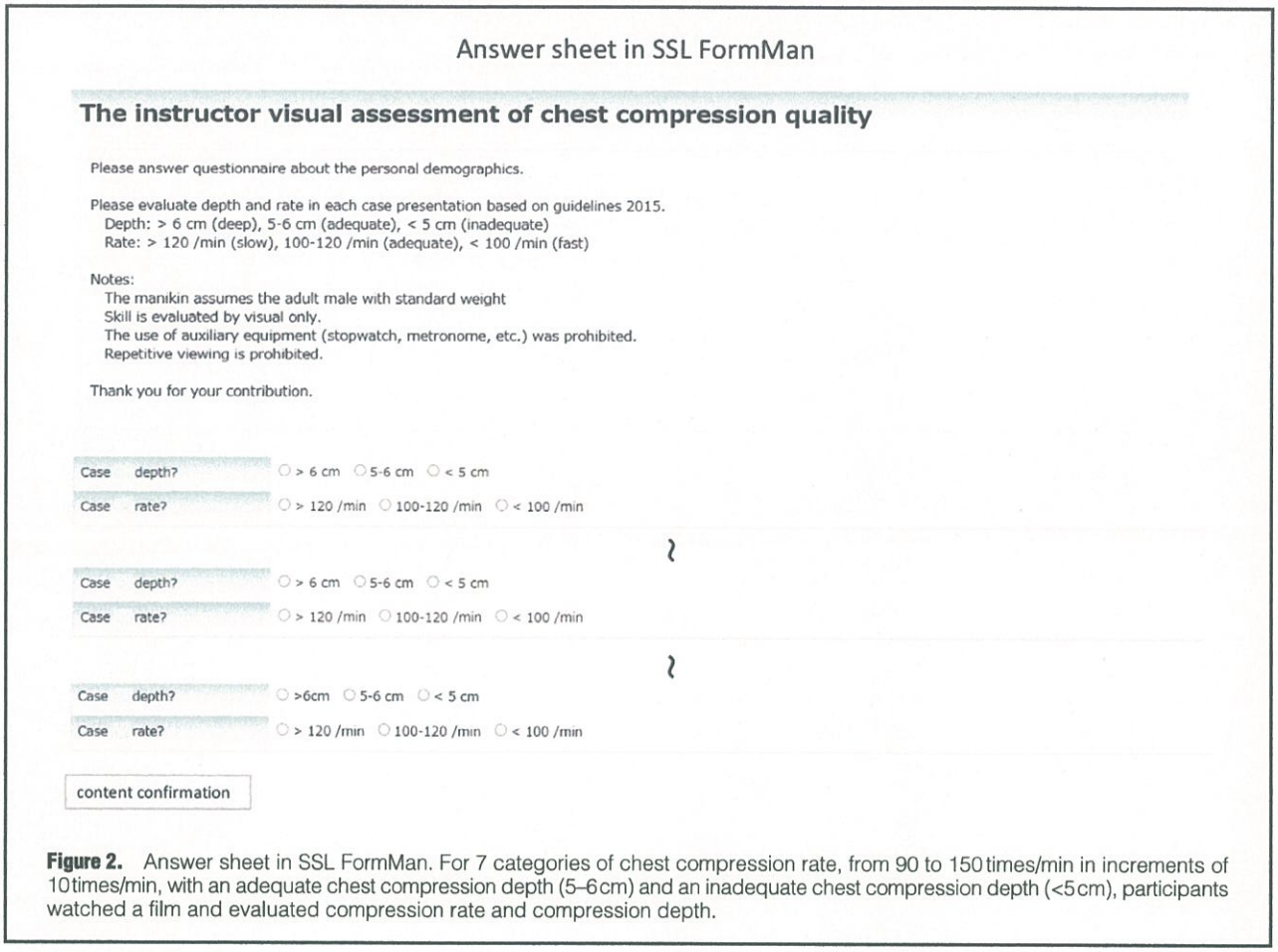

Figure 2. Answer sheet in SSL FormMan. For 7 categories of chest compression rate, from 90 to 150 times/min in increments of 10 times/min, with an adequate chest compression depth (5–6 cm) and an inadequate chest compression depth (<5 cm), participants watched a film and evaluated compression rate and compression depth.

assessment was visual only. Sound was turned off. Total video run time was approximately 8 min, including case presentation and evaluation time for completing the answer sheet (**Figure 2**). The participants watched each film and evaluated whether the compression depth was adequate (5–6 cm), deep (>6 cm), or inadequate (<5 cm), and whether the compression rate was appropriate (100–120 times/min), fast (>120 times/min), or slow (<100 times/min).

Endpoints

The primary outcome was the accuracy of compression depth and of compression rate on visual assessment.

The secondary outcome was the identification of the factors associated with correct responses in instructor assessment.

Statistical Analysis

Baseline characteristics are presented as mean±SD for continuous variables and as n (%) for categorical variables. A generalized linear mixed-effects model (GLMM) was used to identify the factors associated with correct responses, including the association between the perceived chest compression depth and rate. Analyses were performed using R (The R Foundation for Statistical Computing, Vienna, Austria). Two-tailed $P<0.05$ was considered to be statistically significant.

Table 1. Instructor Demographics

	n=198
Gender: male	80 (40.4)
Age (years)	37.3±9.3
20–29	44 (22.2)
30–39	79 (39.9)
40–49	49 (24.7)
50–59	26 (13.1)
Occupation	
Physician	21 (10.6)
Nurse	145 (73.2)
Emergency medical technician	21 (10.6)
Other	11 (5.6)
Frequency of instruction experience	
1–2 times	42 (21.2)
3–7 times	51 (25.8)
≥8 times	105 (53.0)
Instructor license	
Japanese ICLS Assistant only	66 (33.3)
Japanese ICLS only	95 (48.0)
AHA BLS only	14 (7.1)
Japanese ICLS and AHA BLS	23 (11.6)

Data given as n (%) or mean±SD. AHA, American Heart Association; BLS, Basic Life Support; ICLS, Immediate Cardiac Life Support.

Results

Baseline Subject Characteristics

In total, 198 participants (men, 40.4%; mean age, 37.3 years) with teaching experience as an instructor (Japanese ICLS and/or AHA BLS) participated in this study (**Table 1**).

Chest Compression Depth and Rate on Visual Assessment

Adequate Compression Depth The association between chest compression depth and rate on visual assessment in the adequate chest compression depth scenario (5–6 cm) is shown in **Figure 3**. Of all participants, 56% misidentified adequate compression depth as too deep at a compression rate of 120/min, and the tendency toward this response increased as chest compression rate increased.

Inadequate Compression Depth The association between chest compression depth and rate in the visual assessment in the scenario of an inadequate chest compression depth (<5 cm) is shown in **Supplementary Figure 1**.

Chest Compression Rate: Correct Responses

Adequate Compression Depth The percentage of correct

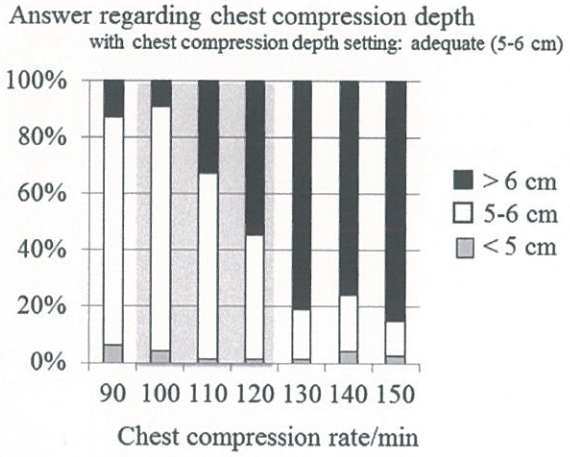

Figure 3. Classification of chest compression depth vs. chest compression rate in the setting of adequate chest compression depth (5–6 cm). Gray shading, range of the adequate compression rate that were recommended by the 2015 AHA guidelines.

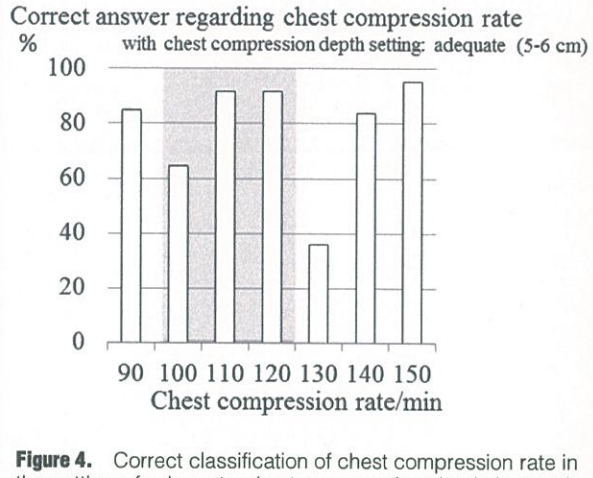

Figure 4. Correct classification of chest compression rate in the setting of adequate chest compression depth (5–6 cm). The participants watched a film and evaluated whether the compression rate was appropriate (100–120 times/min), fast (>120 times/min), or slow (<100 times/min). For example, in the scenario of a chest compression rate of 130 times/min, if the participants responded "fast", it was judged as correct. In the scenario of a chest compression rate of 110 times/min, if participants responded "appropriate", it was judged as correct. Gray shading, see Figure 3.

Table 2. Demographic Factors Associated With a Correct Answer†

Source of variation	d.f.	P-value	OR (95% CI)
Gender	1	0.82	0.98 (0.79–1.21)
Age	3	0.11	0.93 (0.85–1.02)
Occupation	3		
Physician			Ref.
Nurse		0.51	0.90 (0.66–1.23)
Emergency medical service personnel		0.81	0.96 (0.67–1.36)
Other		0.66	0.91 (0.59–1.41)
Instructor experience	2	0.36	1.07 (0.92–1.25)
Instructor license	3		
Japanese ICLS Assistant only			Ref.
Japanese ICLS only		0.51	1.09 (0.85–1.39)
AHA BLS only		0.28	1.23 (0.85–1.80)
Japanese ICLS and AHA BLS		0.41	1.16 (0.81–1.67)
Depth	1	0.00	120.74 (57.98–251.44)
Rate	6	0.00	1.01 (1.01–1.02)
Depth×Rate	6	0.00	0.97 (0.97–0.98)

†Generalized linear mixed-effects model analysis. n=5,544 (participants, 198; questions, 2 (depth or rate); depth setting, 2 patterns; rate setting, 7 categories). Depth×Rate, Depth+Rate+Interaction of depth and rate. Abbreviations as in Table 1.

classifications of chest compression rate at adequate compression depth (5–6 cm) is shown in **Figure 4**.

Of all participants, 64.1% incorrectly identified the compression rate of 130 times/min as appropriate.

Inadequate Compression Depth The percentage of correct classifications of chest compression rate at an inadequate compression depth (<5 cm) is shown in **Supplementary Figure 2**.

A total of 54% of the participants incorrectly classified the compression rate of 130/min as appropriate.

Factors Associated With Correct Visual Assessment

On GLMM analysis, chest compression depth and rate were significantly associated with correct response on visual assessment (both $P<0.01$; **Table 2**). Furthermore, a significant interaction between chest compression depth and rate was observed ($P<0.01$).

Discussion

In the instructors' visual assessment of chest compression quality, >50% of instructors misidentified adequate compression depth as deep at a compression rate of 120/min; furthermore, the tendency for this assessment increased as the compression rate increased. Regarding the assessment of chest compression rate, >60% of the participants incorrectly classified the compression rate of 130 times/min as appropriate. A significant association between perceived chest compression depth and rate was observed for correct responses.

Although several studies regarding chest compression quality assessment have been published,[11,14,15] chest compression depth and rate were independently evaluated in these studies. To the best of our knowledge, no studies have focused on the interaction between chest compression depth and rate, unlike in the present study. In the present study, a significant association between chest compression depth and rate was observed, and both were found to be significant factors associated with correct response.

Regarding chest compression depth, several studies have demonstrated that the perceived duration of a moving stimulus is longer than that of a stationary stimulus having the same actual duration.[16–19] Thus, the perceived duration of visual motion (i.e., visual motion intensity) increases with the speed of movement.[20] Applying this principle to the assessment of CPR, the instructors tended to perceive greater depth in compression degree as compression rate increased in the current study. Also, as previously reported, the important phenomenon of significant decrease in the depth of chest compressions as the rate of chest compression increased can be explained by the theory that the perceived visual motion intensity increases with the speed of movement.[8] Furthermore, on GLMM analysis, the association between chest compression depth and rate was a significant factor associated with correct instructor assessment. Other factors such as instructor age and experience had no influence on the response. Thus, it can be concluded that visual illusion is a major contributing factor in the incorrect assessment of chest compression quality. The incorrect responses with regard to the 130 times/min compression rate were mainly attributed to the nature of visual recognition, given that the recommended chest compression rate in the 2015 AHA guidelines is 100–120 times/min. Chest compression rates of 140 times/min and 150 times/min were clearly recognized by the instructors as incorrect because these rates were clearly faster than the normal (100–120 times/min).

To date, practical skills in chest compression quality are predominantly assessed visually by one or more CPR instructors.[15] Discrepancies between the standard visual evaluation and a mechanical feedback device regarding the assessment of practical chest compression skills have been reported,[15] and more objective methods of assessing chest compression quality such as a smartwatch[21,22] and CPR manikins with specific software[14,23] have provided better accuracy and feedback. Due to the high equipment costs and shortage of resources, however, there is no doubt that visual evaluation will continue to be used in BLS courses worldwide. Thus, based on the present results, in the BLS course, if the instructors misidentified appropriate chest compression depth as being deep, they would suggest to the trainees to lighten the degree of chest compression; this would lead to an inappropriate chest compression depth. Therefore, instructors should be aware of the visual illusion that perceived visual motion intensity increases with the speed of motion. Routine use of stopwatch and metronome in the BLS course would help in appropriate recognition of chest compression rate and lead to a more accurate perceived chest compression depth among instructors. We hope that smartwatch and CPR manikins with specific software will be commonly available in the near future in the BLS course.

Study Limitations

This study had several limitations. First, there is a possibility that other factors associated with incorrect response were not examined in the analysis. Second, the sample size was relatively small; thus, the conclusions may not be generalizable. Third, because the actual instruction is performed at various angles and proximities to examinees, it may be different from video-only evaluation. Sound may support the proper recognition of chest compression quality. Fourth, because the subjects consisted of a mix of ICLS and AHA-BLS instructors, the manner of instruction would not have been homogenous in the study. Fifth, although 14 case videos were randomly compiled, the order of cases might affect the participant answers. We do not think that the order would strongly affect the outcome, however, because the pace and depth of chest compression were completely randomized. Sixth, the answer sheet includes >6 cm along with 5–6 cm and <5 cm, whereas the video demonstrated only 5–6-cm and <5-cm chest compressions, which may have been misleading.

Conclusions

In the instructors' visual assessment of chest compression quality, recognition of the compression depth was closely associated with the compression rate. Instructors tended to misidentify the adequate chest compression depth as deep, particularly as chest compression rate increased. Thus, the instructors should be aware of the visual illusion that the perceived strength of visual motion intensity increases with the speed of motion.

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Japanese Association for Acute Medicine, and of the Basic Life Support course by the American Heart Association.

Disclosures

The authors declare no conflicts of interest.

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Supplementary Files

Please find supplementary file(s);
http://dx.doi.org/10.1253/circj.CJ-18-0952