Applied Ergonomics xxx (2016) 1–8

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Investigation of low back and shoulder demand during cardiopulmonary resuscitation

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ARTICLE INFO

Article history:
Received 25 August 2015
Received in revised form
21 April 2016
Accepted 25 April 2016
Available online xxx

Keywords:
CPR
Electromyography
Spine
Biomechanics
Experience

ABSTRACT

Limited research has examined the effect of different compression-ventilation ratios on the ergonomic demand of performing cardiopulmonary resuscitation (CPR) over time. This study aimed to compare the biomechanical demand of performing continuous chest compression CPR (CCC-CPR) and standard CPR (30:2 compression to breath ratio). Fifteen CPR certified individuals performed both standard CPR and CCC-CPR, randomly assigned, for three 2-min periods. Trunk and upper limb muscle activation, lumbar spine posture and compression force applied to a testing mannequin chest were measured throughout each CPR trial. No differences in muscle activation of spine posture were observed, however chest compression force decreased over the two minutes ($p < 0.0001$). Further, this drop in force was larger and initiated immediately during the CCC-CPR trials. This immediate drop in force during the CCC-CPR trials may be an anticipatory adjustment in order to be able to sustain continuous compressions for the full 2 min duration.

1. Introduction

The efficacy of cardiopulmonary resuscitation (CPR), with respect to compression-ventilation ratio, has been previously investigated (Chandra et al., 1994; Kern et al., 2002; Valenzuela et al., 2005; Cavus et al., 2008; Trowbridge et al., 2009; Hüpfl et al., 2010; Iyanaga et al., 2012). Such investigations stem from the notion that an increase in survival rate after cardiac arrest may exist if CPR is performed using continuous chest compressions (CCC-CPR) rather than the current American Heart Association (AHA) standard CPR, which uses a compression-ventilation ratio of 30:2 (Kern et al., 2002; Hüpfl et al., 2010; Bobrow et al., 2010; Rea et al., 2010; Svensson et al., 2010; Zuercher et al., 2010).

The main difference between standard and CCC-CPR is that there is no break in chest compressions for the administration of rescue breaths during CCC-CPR. As a result, performing CCC-CPR has been reported to be very exhausting when compared to performing standard CPR (Ashton et al., 2002). In a recent study, performing CCC-CPR compared to standard CPR resulted in significantly reduced chest compression force, depth, rate, and percentage of effective chest compressions (measured as at least 100 compressions/min with a minimum depth of 1.5 inches) in a group of CPR-certified females (Trowbridge et al., 2009). Specifically, CCC-CPR resulted in significantly less chest compression force (461 N) compared to standard CPR (472 N) during the first 5 min of CPR which dropped to 427 N during standard CPR and 391 N during CCC-CPR after 10 min. Interestingly, muscle activation levels and kinematics of trunk and upper limbs in these females were not affected by CPR type.

This significant drop in chest compression force observed during CPR is critical in terms of the survival of the victim. According to the current revised AHA guidelines for CPR administration, one needs to depress the chest by at least 2 inches at a rate of at least 100 chest compressions per minute in order to be considered effective at creating blood flow in the victim. In a sample of 40 doctors and nurses performing CCC-CPR, participants were able to perform at least 100 total chest compressions per minute, but they were only able to perform 82 effective chest compressions in the first minute (Ashton et al., 2002). This number dropped rapidly with each successive minute of CCC-CPR administration down to only 27 effective compressions in the sixth minute of CPR. Similarly, another study tested a sample of medical students performing CPR (Heidenreich et al., 2006). Interestedly, it was found that during CCC-CPR, participants were able to perform more effective

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http://dx.doi.org/10.1016/j.apergo.2016.04.013
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compressions during CCC-CPR (47/minute in the first minute) compared to standard CPR (32/minute in the first minute). However, the authors calculated the total number of effective compressions in a minute, and since during standard CPR there are breaks in compressions for the administration of rescue breaths, the number of compressions will inherently be lower than during CCC-CPR. Despite these breaks in compression, after only 3 min of CPR administration, the number of effective compressions during CCC-CPR (approximately 28/minute) was not found to be significantly different from standard-CPR (approximately 24/minute), emphasizing the exhaustive nature of CCC-CPR.

The previously described studies examined CPR administration by trained medical professionals. In many medical emergencies, however, bystanders will often initiate CPR administration before emergency responders arrive and current AHA guidelines recommend CCC-CPR rather than standard CPR for non-trained or inexperienced individuals. However, it has been shown that while 60% of trained individuals are able to apply sufficient force to result in effective chest compressions, only 37% of untrained individuals are able to apply sufficient force (Geddes et al., 2007).

It is without question that the fate of someone who has gone into cardiac rest relies on not only how quickly CPR commences but also in the quality of the administered CPR (Steen and Kramer-Johansen, 2008). If a rescuer is unable to maintain enough force to the chest at a fast enough rate due to the fatiguing nature of CPR, the effectiveness of the CPR drops substantially. Therefore, the purpose of this study was to examine the biomechanical demand of CCC-CPR and standard CPR performed by emergency responders and civilians.

2. Materials and methods

2.1. Participants

Fifteen CPR-certified participants were recruited for this study. Three firefighters, six paramedics, and one police officer comprised the emergency responder population, and two lifeguards and three students comprised the civilian population (Table 1). Participants were excluded if they had suffered from low back pain or shoulder pain in the previous 12 months that required them to see a doctor and/or take time off work. This study was reviewed and approved by the University Research Ethics Board.

2.2. Instrumentation

2.2.1. Electromyography (EMG)

Pairs of Ag–AgCl electrodes (Ambu, Ballerup, Denmark) were adhered to the skin bilaterally over the lumbar erector spinae, thoracic erector spinae, rectus abdominus and external oblique muscles of the trunk (McGill et al., 1996). Upper extremity muscle activity was collected by placing electrodes over the pectoralis major muscle and lateral head of the triceps brachii muscle (SENIAM – Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles). EMG data were bandpass-filtered from 10 to 1000 Hz, amplified (Bortec Biomedical, Calgary, Alberta) and sampled at 2048 Hz.

2.2.2. Kinematics

To capture motion data, two electromagnetic sensors (Liberty, Polhemus, Colchester, Vermont) were placed on the spine at the L5/S1 and T12/L1 joints. This placement isolated the lumbar spine to measure flexion-extension. Kinematic data were sampled at 128 Hz, dual low-pass filtered at 6 Hz and normalized to the full range of flexion-extension motion.

2.2.3. Force application

Force applied to the chest of a testing CPR mannequin (Fig. 1) during CPR application was collected using a uniaxial load cell (8524-6002, Burster, Gernsbach, Germany) placed on the sternum of the mannequin. Load cell range was 0–2 kN, and data were sampled at a rate of 2048 Hz.

2.3. Protocol

2.3.1. Baseline data collection and signal processing

Following EMG electrode placement, muscle-specific maximum voluntary isometric contractions (MVC) were performed in order to normalize EMG data. All MVCs were performed statically against resistance provided by the researcher. Briefly, a Biering-Sorensen back extension test was performed to obtain the back musculature MVC; a modified sit-up (trunk set at 45 ° from horizontal) was used to obtain the abdominal musculature MVC; an elbow extension (elbow at 90 °, shoulder at neutral) was used to obtain the tricep brachii MVCs; a modified fly position (shoulders and elbows at 90 °) was used to obtain the pectoralis major MVCs.

Following MVCs, participants were instrumented with the two spine motion sensors, after which they were instructed to perform a full flexion-extension range of motion trial. Last, an upright standing trial was collected for 5 s to determine the neutral lumbar spine posture.

2.3.2. Assessment of fatigue, exertion and discomfort

To examine the effect of CPR on back extensor muscular fatigue, participants were instructed to perform a static back extension task. When instructed, the participant extended their torso to horizontal (parallel with the ground), and held their body weight against gravity. Each back extension task lasted 5 s while EMG data were collected, and served as a means of measuring trunk extensor muscle fatigue. The static fatigue test was performed at four separate points during the data collection protocol and was used to assess muscle fatigue before and after performance of the CPR trials. After the completion of each back extension test, participants were also instructed to fill out ratings of perceived exertion (RPE) and discomfort (RPD) scales.

2.3.3. CPR trials

Two CPR conditions (randomized order) were examined: 1) CPR with a compression-ventilation ratio of 30:2 (standard), and 2) continuous compression CPR (CCC-CPR). During the standard CPR trials, compressions were applied to the mannequin chest at a rate

Table 1
Participant demographic data; mean (±1SD).

	n	Height (cm)	Weight (kg)	Age (yrs)	Professional (#)			Civilian (#)	
					Firefighter	Paramedic	Police	Lifeguards	CPR-cert.
Male	8	182.88 (4.89)	87.01 (14.82)	37.38 (15.19)	3	2	1	1	1
Female	7	165.16 (6.54)	65.38 (8.25)	31.29 (9.68)	0	4	0	1	2
Total	15	174.61 (10.69)	76.91 (16.23)	34.53 (12.90)	3	6	1	2	3

Please cite this article in press as: Dainty, R.S., Gregory, D.E., Investigation of low back and shoulder demand during cardiopulmonary resuscitation, Applied Ergonomics (2016), http://dx.doi.org/10.1016/j.apergo.2016.04.013