

Research

CPR performed in battlefield emergency care

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Abstract

Introduction

During military missions medical care is provided to military personnel as well as civilians. Although cardiopulmonary resuscitation (CPR) may not be a common task in a military field hospital, all personnel need to be trained to deal with cardiac arrest.

Methods

This study was a comparative simulation study. Participants (n=36) from the Swedish armed forces performed CPR for 2 minutes at one of three different locations: at ground level, a military bed, or a transportable military stretcher. Compression depth and rate after 2 minutes of CPR and at the time of the participants' own request to be relieved were measured. Descriptive and inferential analysis was conducted.

Results

There is a direct correlation between compression depth and working level, concluding that the higher working level, the lower the compression depth. There is in total an overall low percentage of participants within limits for correctly conducted CPR regarding both compression depth and rate. Time to fatigue is related to working level, where increased level results in early fatigue.

Conclusion

The quality of CPR is affected by the level at which it is performed. The quality of CPR was satisfactory when working at ground level, but suboptimal when working at hospital bed level or military stretcher level. When working at raised levels, participants appeared to misjudge their own compression depth and rate. This may indicate that changes are needed when CPR is practised in the military hospital setting. Future studies regarding the use footstools are required due to the height of military beds and transportable stretchers.

Keywords:

military medical personnel; CPR; simulation

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Introduction

This study focusses on the performance of cardiopulmonary resuscitation (CPR) on non-traumatic cardiac arrest in Swedish military field hospitals. A Swedish military field hospital is a collection of inflatable tents erected temporarily to function as an emergency department, operation theatres, intensive care units and wards. Field hospitals vary in size based on need.

Non-traumatic cardiac arrest is a rarely occurring event in Swedish field hospitals given the relative youth and general good health of Swedish military personnel. However, there are also older officers serving, and cases of cardiac arrest have occurred in this particular group during missions abroad. Furthermore, the Swedish armed forces (SwAF) focus primarily on United Nations international peacekeeping and humanitarian missions. Medical care may be provided to civilians, depending on circumstances, and such medical care may include assisting patients in all age groups.

In the United States, the American Heart Association (AHA) estimates that approximately 37 adults per hour (360,000 people annually) experience out-of-hospital cardiac arrest (1). Approximately 200,000 patients are hospitalised as a result (2). Of these, about 40% of adult patients and 30% of children survive (1). Cardiac arrests are not always associated with increasing age or morbidity. For example, one per 200,000 athletics with a mean age of 39 years, running a marathon, suffers a cardiac arrest every year. Thirty percent of those patients survive (1).

During military missions, CPR on military personnel and civilians will be performed according to guidelines for treatment of patients with a chance of survival (4). For example, it may be appropriate to withhold CPR in patients for whom death is the predictable outcome (4). Attempts to revive patients who have no realistic hope of survival can result in the consumption of large amounts of human resources, as well as medical products including blood, medications and equipment. Cardiopulmonary resuscitation should therefore not be done in a military setting at the expense of compromising the mission or denying lifesaving care to other casualties (4).

The quality of CPR is the key factor in responding to cardiac arrest (5). Well performed CPR comprises of good quality chest compressions maintaining adherence to rate, depth, full recoil and rescue breathing. Chest compressions are performed at a rate of 100–120 per minute at a depth of 5–6 cm. Compression-ventilation ratio is 30:2 (5,6).

The AHA states that perfusion during CPR is related to chest compressions, and for this reason, maintaining a constant rate of chest compressions while performing CPR should be prioritised (6). A low compression rate reduces the chance of survival, while too high a compression rate results in stretching of the sternum which has a negative influence on the blood

volume returning to the heart (6). When compressions are too shallow or too slow, the chance of survival decreases significantly (7).

Previous research shows that CPR is not always performed efficiently (8). The quality and competency of healthcare providers performing CPR in their daily work are low (8,9). Even after appropriate training, healthcare providers fail to perform CPR within established European Resuscitation Council (ERC) guidelines during cardiac arrest (5,8).

The quality of CPR provided during resuscitation may be affected by the height at which CPR is performed. In-hospital chest compressions during CPR are often performed with the patient placed on a bed, or as in the military setting, on a stretcher. The height of both a military bed (72 cm) and a transportable military stretcher (84 cm) can be considered high and affect the ability to perform high-quality CPR. The military bed has a firm, thin mattress; the transportable military stretcher is made of stretched nylon. Both are hard and do not yield during compressions. Maintaining sufficient compression depth has proven difficult due to fatigue (10). However, neither AHA nor ERC guidelines provide information regarding the rescuer's position in relation to the level of the patient (3,6).

The objective of this study was to evaluate the quality of CPR in predictable locations in the military environment, in order to tailor future training.

Methods

A simulation study conducted at a military field hospital. Data were collected by participants performing CPR for 2 minutes either:

- (1) at ground level
- (2) on a military bed (72 cm)
- (3) on a transportable military stretcher (84 cm).

The quality of CPR in terms of compression depth and rate were monitored over time, and the participants were asked to express when they experienced fatigue and wanted to be relieved from CPR.

Participants

Participants in this study consisted of 36 military medical personnel: 23 men and 13 women serving in the SwAF (SwAF medical personnel consist of medics, nurses and physicians employed either full-time or part-time as reserves). The participants included in this study were medics (n=16), registered nurses (n=12) and physicians (n=8). Medics undergo 14 months of theoretical and clinical education from within the armed forces. Registered nurses undergo a civilian 3-year Bachelor degree at university level, followed by a specialisation in the form of a 1-year Master degree in critical care (eg. pre-hospital care, anaesthesia or intensive care).

Table 1. Description of participants regarding education, age, height and CPR training divided into three groups

Subgroups	Participants n=36	Age (years)	Height (cm)	Time since last formal CPR training (months)
CPR on military bed n=12	Medics n=5 Nurses n=4 Physicians n=3	21–62 Mean 38 Median 37 SD=13	165–186 Mean 175 Median 174 SD=8	Mean 14 Median 6 SD=13
CPR on military stretcher n=12	Medics n=5 Nurses n=4 Physicians n=3	23–56 Mean 38 Median 38 SD=11	165–190 Mean 177 Median 178 SD=8	Mean 17 Median 12 SD=14
CPR on ground level n=12	Medics n=6 Nurses n=4 Physicians n=2	22–56 Mean 36 Median 34 SD=11	H 164–178 Mean 174 Median 173 SD=7	Mean 20 Median 12 SD=15

SD = standard deviation

Physicians undergo 5.5 years in a medical school, 2 years of internship and a 5-year specialisation practice (eg. surgery, anaesthesiology or emergency medicine). SwAF medical personnel are prepared for military medical care through specific military medical courses. All participants received oral information about this study and were asked if they were willing to participate. Inclusion criteria were military medical personal enrolled for emergency response in the SwAF (Table 1).

Data collection

Participants performed CPR on a Laerdal Resusci Anne Q CPR® according to ERC guidelines (5). The spring simulating the thoracic resistance required 45 kg chest compressions to achieve correct compressions depth. Data for CPR were collected through a SimMan 3G® (Laerdal, Stavanger) that was connected to a computer with PC Skill reporter software allowing real-time recording of CPR parameters. The participants performed CPR, with their dominant hand against sternum, either at ground level, on a military hospital bed or on a transportable military stretcher. The CPR parameters relating to mean compression depth and rate were recorded at 2 minutes and once again when the participant experienced fatigue and wanted to be relieved from CPR. Participants did not receive any feedback on the quality of their compression during the experiment. The parameters relating to ventilation were not assessed. The participants completed a questionnaire which gathered information on their profession, gender, age, height, educational level, experiences of CPR and time elapsed since previous formal CPR training.

Outcome measures

Compression depth and compression rate after 2 minutes of CPR performance and at the time of the participants' own request to be relieved were measured.

Data analysis

A descriptive and inferential analysis was conducted using

IBM Statistical Package for the Social Sciences (SPSS) 24.0. Descriptive analysis (central tendency and distribution) was used to describe the data, whereas inferential statistics (z-test, post-hoc Tukey) compared potential differences of the variables between groups. The level of significance used was set at $\alpha=0.05$.

Ethics approval

This study followed ethical principles relating to anonymity and integrity in accordance with the World Medical Association (11). Ethics approval was obtained from the Swedish Armed Forces Centre for Defence Medicine. Informed consent was obtained from each participant.

Results

The aim of this study was to evaluate the quality of CPR in three predictable locations in a military environment, in order to tailor future training for specific situations. The results are presented as compression depth in relation to working level, compression rate in relation to working level, total quality of CPR performances in relation to working level and quality of CPR in relation to working level and experience of fatigue.

Compression depth in relation to working level at 2 minutes

There was a direct correlation between compression depth and working level demonstrating that the higher the working level, the lower was the compression depth (Figure 1).

There was a statistically significant difference between CPR at ground level compared to both military bed ($p=0.010$) and the military stretcher ($p=0.002$) (Table 2). In total, few participants performed correct compression depths within the desired 50–60 mm range.

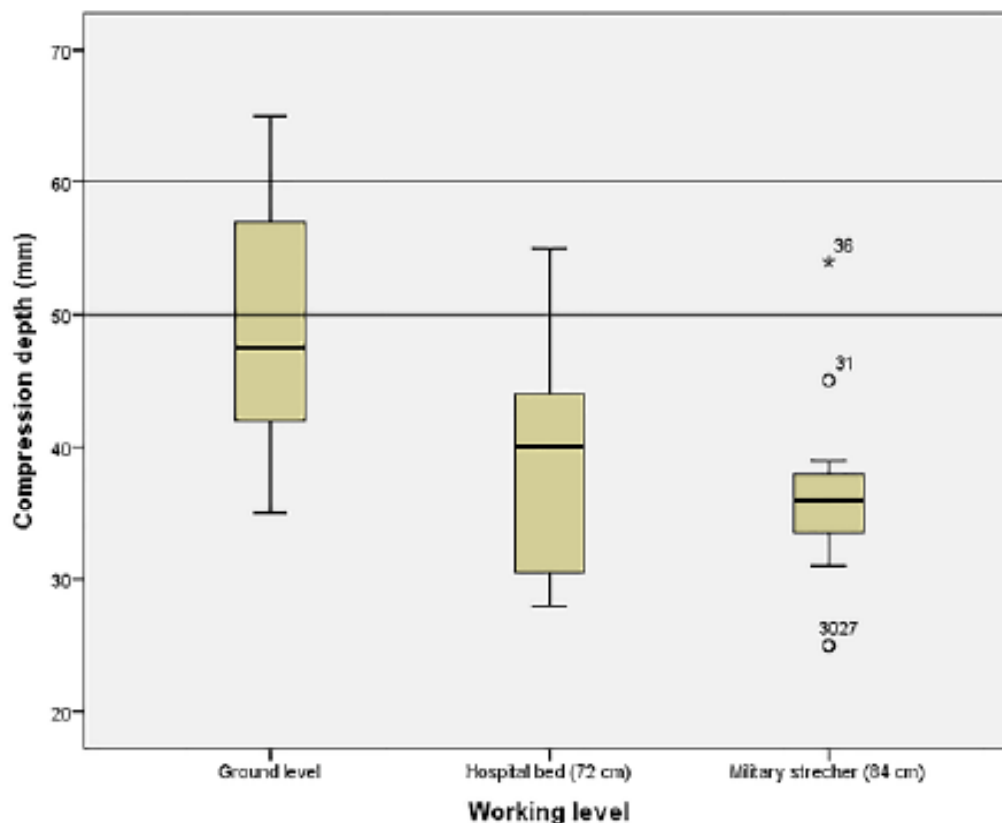


Figure 1. The correlation between compression depth and working level (compression depths between 50–60 mm marked by range lines)

Table 2. Compression depth in mm at 2 minutes

Working level	Compression depth (mm)	Sig.	SD	95% confidence interval for mean		Min	Max
	Mean			Lower bound	Upper bound		
Ground level	49.1 *1, 2		8.6	43.6	54.6	35	65
Military bed	38.6 *1	.010	8.1	33.4	43.8	28	55
Military stretcher	36.3 *2	.002	7.9	31.3	41.3	25	54

*= statistically significant difference at 5% level analysed with z-test (post-hoc Tukey). The number (1-2) indicates pairwise comparison. SD = standard deviation

Compression rate in relation to working level at 2 minutes

At ground level, 75% of the participants performed CPR within the desired interval of 100–120 compressions per minute. The remaining participants performed compression at less than 100 compressions per minute. On the military bed, 20% of participants performed CPR within the desired interval of 100–120 compressions per minute. The remaining participants

performed less than 100 compressions per minute. There was a tendency for differences in compression rate between ground level and military bed level (0.073). On the military stretcher, 60% of the participants performed the correct compression rate, while the remaining participants had a compression rate lower than 100 per minute (Figure 2, Table 3).

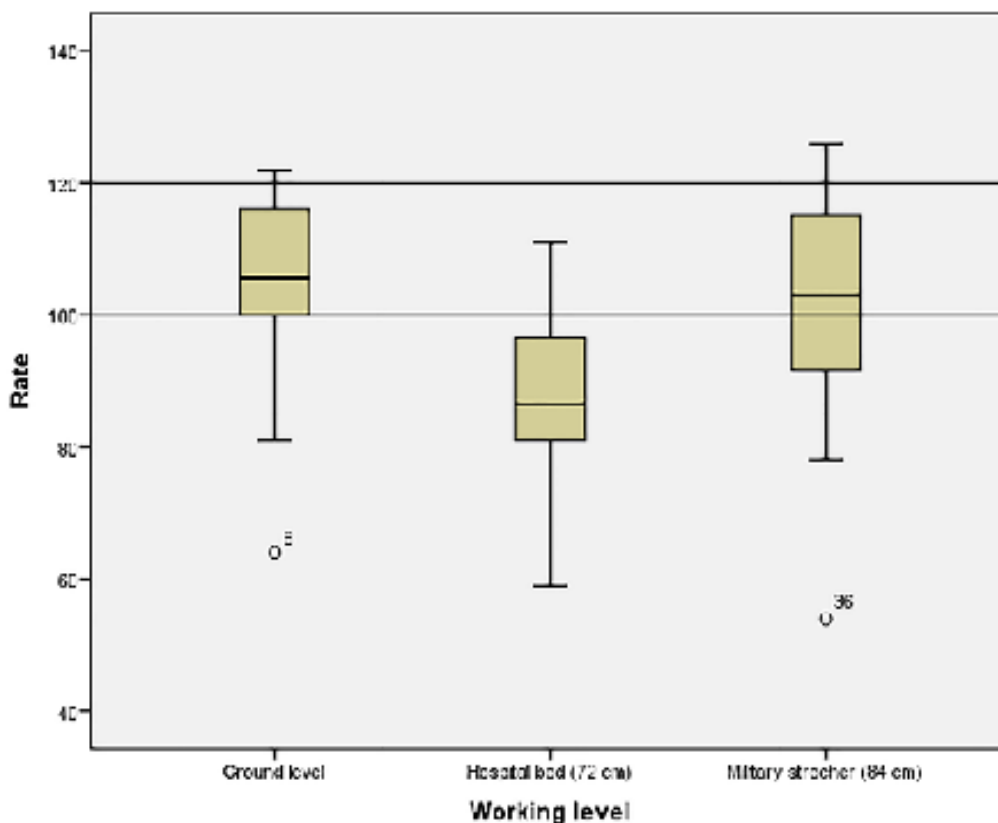


Figure 2. The correlation between compression rate and working level (compression rates between 100–120 marked by range lines)

Table 3. Compression rate at 2 minutes divided into groups

	Compression rate		95% confidence interval for mean			
Working level	Mean	SD	Lower bound	Upper bound	Min	Max
Ground level	104	16.6	93	114	64	122
Military bed	87	15.6	77	97	59	111
Military stretcher	101	20.4	88	114	54	126

SD = standard deviation

The total quality of CPR performances in relation to working level

As seen in Figure 3, there is a low percentage of participants within the range for correctly conducted CPR. When CPR is

performed on military hospital bed level (Figure 3b) and military stretcher level (Figure 3c), the participants misjudge both the rate and the depth during CPR.

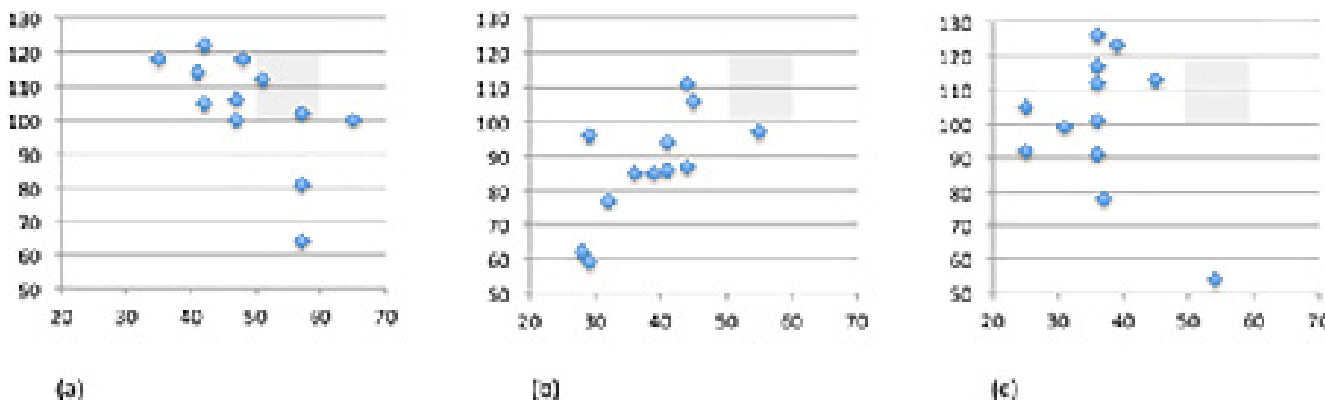


Figure 3. Compression rate on the X-axis and compression depth on the Y-axis in relation to: (a) ground level, (b) hospital bed and (c) military stretcher (correct CPR range is within the grey box)

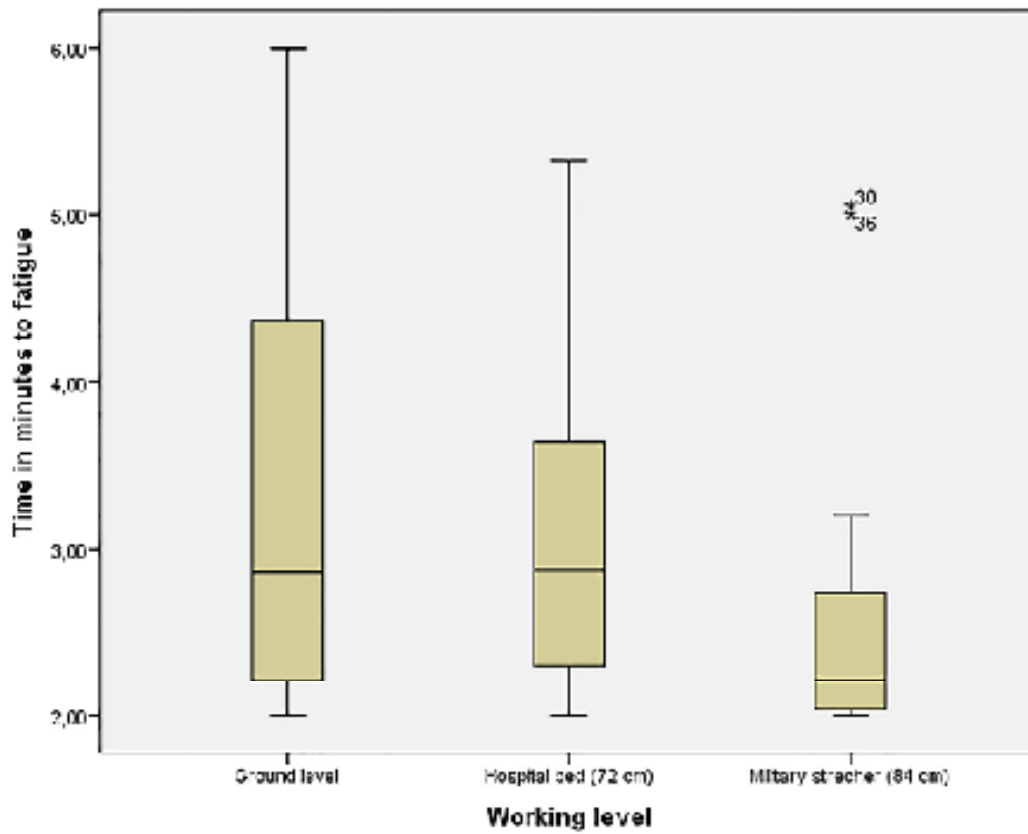


Figure 4. Time in minutes to self-expressed fatigue in relation to working level

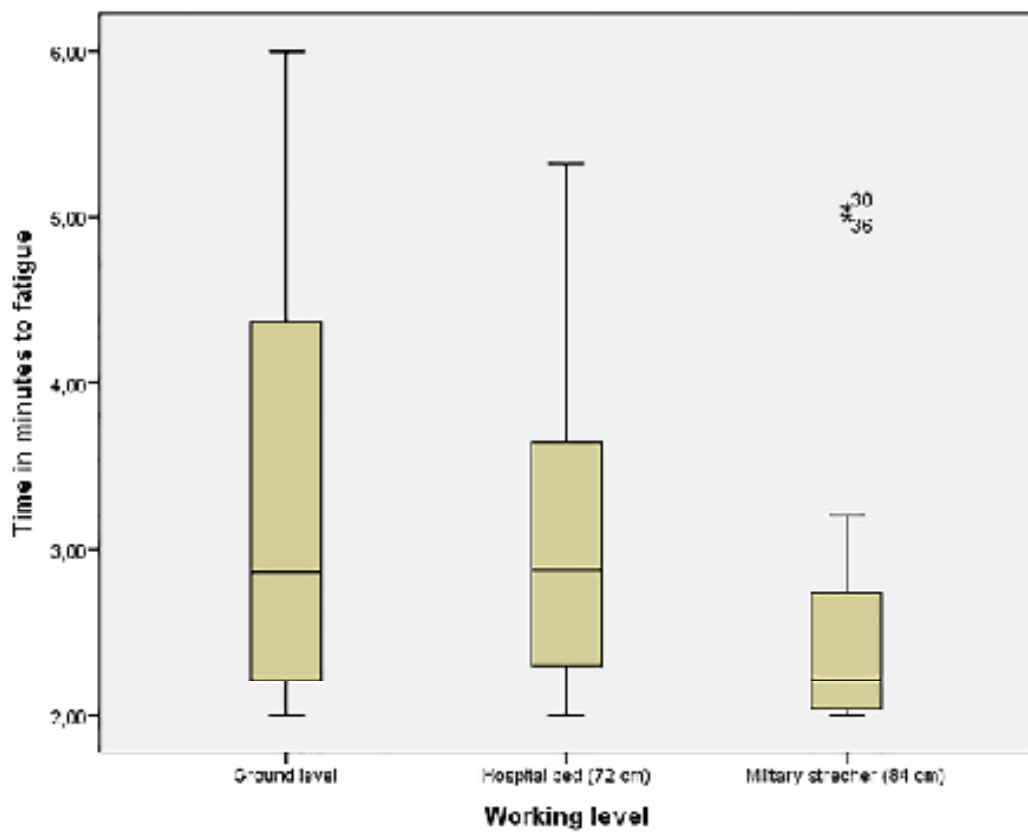


Figure 5. Compression depth in mm at time of self-expressed fatigue (compression depth between 50–60 mm marked by range lines)

Quality of CPR in relation to working level and time of self-expressed fatigue

After the obligatory 2 minutes of CPR, the participants conducting CPR on the military bed and on a military stretcher were close to expressing fatigue. Participants conducting CPR at ground level expressed fatigue later than the other two groups. Most of the participants conducting CPR on military stretchers expressed fatigue at the time when 50% of participants conducting CPR on the military bed and on the ground expressed fatigue. On the military stretcher, 75% of participants expressed fatigue after 2.13 minutes.

The exception was two participants where the time taken to express fatigue can be explained by other factors. Participant number 30 had a compression depth of 25 mm at 2 minutes and 21 mm at the time of fatigue. Participant number 36 had a compression frequency of 54 at 2 minutes and 46 at the time of fatigue. Regardless of the group, the participants stayed within 5 mm of impairment of the compression depth between 2 minutes and time of fatigue (Figure 4).

Regarding compression rate at the time of self-expressed fatigue, the ground level had a mean rate of 100 compressions per minute, the hospital bed (72 cm) a mean rate of 86 compressions per minutes and the military stretcher (84 cm) a mean rate of 100 compressions per minute. The compression depth at the time of self-expressed fatigue for the ground level was mean 47 mm (min 34, max 59); for the hospital bed, mean 37 mm (min 23, max 55); and for the military stretcher, mean 35 mm (min 21, max 55) (Figure 5).

Discussion

Previous research has shown how the link between theoretical education and practical training needs to be strengthened to improve military medical education in Nordic countries (12). Through simulations, the necessary knowledge and skills can be taught to deal with new, sometimes dangerous and complex situations (13).

Compression depth in relation to working level at 2 minutes

The results showed a statistically significant difference between the compression depth at 2 minutes when CPR was performed at ground level, as compared to the compression depth of CPR performed on a military bed or military stretcher. Compression depth on ground level was a mean of 49.1 mm, which can be considered shallow. Research shows that every millimetre of compression enhances the patient's chances of survival (14). The compression depth on the military bed (38.6 mm) and stretcher (36.3 mm) was not performed according to the ERC guidelines (5). The level of both the military bed and the military stretcher is too high to perform CPR with compression depth of sufficient quality that the patient's life can be saved.

Compression rate in relation to working level at 2 minutes

The compression rate at 2 minutes strongly correlated to

the CPR working level. At ground level, 75% of participants performed the correct compression rate at 2 minutes, compared to 20% on a military bed and 60% on a military stretcher. Participants conducting CPR on the military stretcher appeared to notice that they could not reach high enough on the patient, which in turn made them more likely to compensate for their inadequate compression rate. For the participants conducting CPR on a military bed, it is less obvious that they could not obtain height over the patient which seems to make them less likely to compensate, resulting in a lower overall compression rate.

Earlier studies describe how CPR performed with the patient in a bed lowered to the rescuer's knee-level provides both correct compression depth as well as correct compression rate (15). The depth and rate of compression are also shown to be adequate when the rescuers kneel on the patient's bed or when rescuers are standing on a footstool next to the bed (15,16). This may indicate that changes are needed when CPR is performed in the military hospital setting. To have footstools easily accessible in emergency rooms, operating rooms and wards may be a simple and inexpensive solution.

Quality of CPR in relation to working level and experience of fatigue

In our study, participants could perform CPR of continuous quality at ground level for longer periods of time, as compared to the other two levels. At military bed or military stretcher level, participants needed to perform deeper compressions which requires greater effort, and the physical exertion caused more rapid rescuer fatigue (17). Participants who performed CPR on a military stretcher experienced early fatigue (2.13 minutes). It is interesting that all participants, regardless of group, kept compression depth in a range within 5 mm from two minutes until they expressed fatigue. This can be interpreted that the participants are able to judge when they are so exhausted that they need to be relieved.

Shin et al (18) suggest that the quality of the compressions declines the longer the compressions conducted. This complies with Hong et al (16) and Kampmeier et al (17), which in their studies show how the participants who performed CPR on a stretcher expressed fatigue at an early stage. Shin et al (18) show how the number of adequate breast compressions decreased to below 70% after 2 minutes. This is comparable to Jo et al (19), who show that when rescuers switched within 2 minutes, they maintained a higher number of correct compressions and a more constant correct quality compared to rescuers that switched after 2 minutes. For both compression depth and rate we have previously discussed how rescuers who take a kneeling position when performing CPR on the patient's bed improve the quality of the compressions and are less prone to experience fatigue. A rescuer positioned on a patient's bed or on a footstool expressed fatigue after 5 minutes of CPR in a study by Foo et al. (20), compared to 3 minutes in this present study.

Limitations

One limitation of this study is that not all participants performed CPR at all levels, but instead different participants performed CPR at different levels. This may have affected the result. Another limitation of this study was that the time since the last CPR training for the participants was mean 17 months, median 10 months. Previous research shows that CPR skills and the quality of CPR decreases 3 months after CPR training. Repeated training is therefore needed within a year to keep the acquired CPR quality optimal.

Conclusion

The quality of CPR is affected by the height at which CPR is performed. The quality of CPR performance was satisfactory when working at ground level, but suboptimal when working on hospital bed level (72 cm) or military stretcher level (84 cm). These levels seem to make participants misjudge their own compression depth and compression rate. This may indicate that changes are needed when CPR is practised in the military hospital setting. This study concludes that further studies are needed to explore the use of a footstool during CPR. In a military setting, this could be a simple and cheap solution that enhance CPR practice.

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Conflict of interest

The authors declare they have no competing interests. Each author of this paper has completed the ICMJE conflict of interest statement.

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