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Low-dose, high-frequency CPR training with feedback for firefighters

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Abstract

Purpose- To investigate the effects of the intervention of low-dose, high-frequency CPR training with feedback for firefighters for one month.

Design- The study had a quantitative approach. Data was collected through an intervention by means of simulation. The data collection consisted of a pre- and post-assessment of 38 firefighter's CPR performants.

Findings- There was a statistically significant improvement from pre- to post-assessment regarding participants' compression rates. Compression depth increased statistically significantly to average 2 mm too deep in the group. Recoil decreased in the group with an average of 1 mm for the better. There was a statistically significant improvement in participants' ventilation volume from pre- to post-assessment.

Originality/value –

Prehospital staff such as firefighters, police, and ambulance perform CPR under less than optimal circumstances. It is therefore of the utmost importance that these professionals are trained in the best possible way. The result of this study shows that low-dose, high-frequency CPR training with an average of 6 training sessions per month improves ventilation volume, compression depth, rate, and recoil. This study concludes that objective feedback during training enhances the firefighters' CPR skills which in turn also could be applied to police and ambulance CPR training.

Keywords: CPR, Firefighters, emergency medical technicians, low-dose high-frequency, objective feedback

Paper type Research paper

Introduction

In Sweden, firefighters are dispatched as emergency medical technicians (EMTs) on prehospital medical emergencies when the ambulance needs additional help with severely injured or critically ill patients. The fire brigade participates as firefighters/EMTs in all major accidents and they can also be dispatched when there are no ambulances available. The firefighters are trained to provide immediate resuscitation, which is essential for survival, and to perform cardiopulmonary resuscitation (CPR). All fire trucks are therefore equipped with defibrillators and basic medical equipment.

As EMTs, the firefighters encounter a variety of scenarios. Often incomparable to in-hospital emergency care due to the trauma or critical nature of the patients. Some example of patients the firefighters encounter and perform emergency care on are; traumatic or non-traumatic cardio-respiratory arrest, electrocutions with muscular paralysis, drowning victims with water-filled airways and lungs, accidental hypothermia with chest solidification or hyperthermia caused by fire (Truhlar et al., 2015).

The decision to initiate CPR is based on medical judgment. Resuscitation protocols define the obligation and responsibility of healthcare professionals (Bossaert et al., 2015). The decision to initiate CPR is motivated by the fact that a person with cardiac arrest shall be given the best possible chance of survival. The norm is to provide CRP in all but a few well-defined cases. This includes when the safety of the staff cannot be guaranteed. Also, when there are obvious clinical signs of irreversible death including decapitation, incineration, rigor mortis or dependent lividity (Bossaert et al., 2015; Mancini et al., 2015; Monsieurs et al., 2015).

The integration of firefighters as a part of the emergency medical service (EMS) contributes to an increased survival rate in out-of-hospital cardiac arrests in both urban and rural areas (De Maio et al., 2003). In isolated areas, other forms of EMS can be assisted by the fire brigade. An additional advantage of using the fire brigade in medical emergencies in Sweden is that they are well-trained in medical care. They have well operating leadership, teamwork, task management, and structured communication. These are examples of non-technical skills that according to Monsieurs et al., (2015) all improve patient outcomes. The fire brigade also has more personnel at the accident site, which is associated with better survival rates for the patients (Rossi et al., 2016). Fatigue is not a problem, nor is a shortage of hands.

Well performed CPR comprises good-quality chest compressions containing adherence to rate (100-120 compressions per minute), depth (between 5-6 cm), full recoil and fraction. It also includes ventilation of the patient with a compression to ventilations ratio of 30:2 using basic skills with a pocket mask or a bag mask (Monsieurs et al., 2015). In 1961, the article *Ventilation and circulation with a closed-chest cardiac massage in man* (Safar et al., 1961, pp. 574) cited:

The author's experience has confirmed the circulatory efficacy of closed-chest cardiac massage. However, it cannot be relied upon for pulmonary ventilation.

Therefore, rhythmic sternal pressure must be accompanied by intermittent positive-pressure ventilation; coordinating ventilation and pressure is desirable.

Prior research has shown that the quality and the level of competency of healthcare providers performing CPR in their daily work is low (Abella, 2013; Smart et al., 2015). Even after appropriate training, healthcare providers fail to perform CPR within established American Heart Association (AHA) (Kleinman et al., 2015) guidelines during cardiac arrest (Smart et al., 2015). Important measures to improve the survival of patients are efficient training and evaluation of skills (Monsieurs et al., 2015). AHA, therefore, recommends monitoring of CPR quality (Meaney et al., 2013). CPR scenario training together with objective feedback devices have shown to improve CPR skills acquisition. Among other things, it improves the compression quality, which in turn leads to improved patient outcome and survival (Smart et al., 2015). Feedback devices are therefore preferred during CPR training for all healthcare professionals (Smart et al., 2015; Bobrow et al., 2013; Greif et al., 2015). The aim of this study was to investigate the effects of the intervention of low-dose, high-frequency CPR training with feedback for firefighters for one month.

Method

This study had a quantitative approach. Data was collected through an intervention by means of simulation. The data collection consisted of a pre- and post-assessment of the participants CPR performants.

Participants

Participants in this study consisted of 38 firefighters, 37 male and 1 female. The age of the participants ranged from 23 to 64 years (mean 43). Time since latest CPR training ranged from 6 months to 2 years (mean 6 months). Time since latest CPR performed on patient: 53 % (n = 20) within the last 12 months, 32 % (n = 12) within the last 5 years, 15 % (n = 6) never performed CPR on a patient. All firefighters received information about the study and were then asked to participate voluntarily. Inclusion criteria were firefighters employed for emergency response.

Data collection

The study was carried out in three steps. *Step one* was to assess the participants' objective CPR performance. Participants performed CPR for two minutes on a Laerdal Resusci Anne Q CPR[®]. Each of the two firefighters either performed chest compressions or ventilations according to European Resuscitation Council (ERC) Guidelines for Adult Basic Life Support (BLS) (Monsieurs et al., 2015). The firefighters then shifted task and repeated the CPR performance. Data were collected on the overall score, ventilation volume, compression depth, rate and recoil.

In *step two*, the firefighters practiced low-dose, high-frequency CPR for one month. The low-dose, high-frequency training consisted of two minutes training with feedback during every shift (range 2-15 practices). The springs simulating the thoracic resistance were changed randomly without the participants' knowledge. The alternating springs required 30 kg, 45 kg or 60 kg chest compressions respectively to achieve the correct compression depth.

The month of training was completed with *step three*. Step three was to assess the objective CPR performance of the participants once more. No feedback about CPR quality was given during step one, nor step three assessments. All results were recorded in a SimPad Skill reporter[®].

Data analysis

The descriptive and inferential analysis was conducted using IBM Statistical Package for the Social Sciences (SPSS) 24.0. Descriptive analysis was used to describe the data, whereas inferential statistics compared potential differences between the variables before and after the interventions and between individuals. The level of significance used was set at $\alpha=0.05$.

Ethical consideration

The study followed the ethical principals in accordance with the World Medical Association (2013) about anonymity, integrity and maintaining of public confidence. Ethical approval was not needed according to Swedish law (SFS, 2008:192). Informed consent was obtained from each participant.

Results

The aim of this study was to investigate the effects of the intervention of low-dose, high-frequency CPR training with feedback for firefighters for one month. The result shows how the participants' skills improve during the month of practice regarding; compression rate, depth, recoil and ventilation volume.

Compression rate

The participants had a statistically significant change in compression rate for the post-measurement, for the better ($p = .003$). The most common mistake in the post-measurement was that the participants made the compressions too fast. There were a few participants ($n = 5$) that made slow compressions (Fig. 1, Table 1).

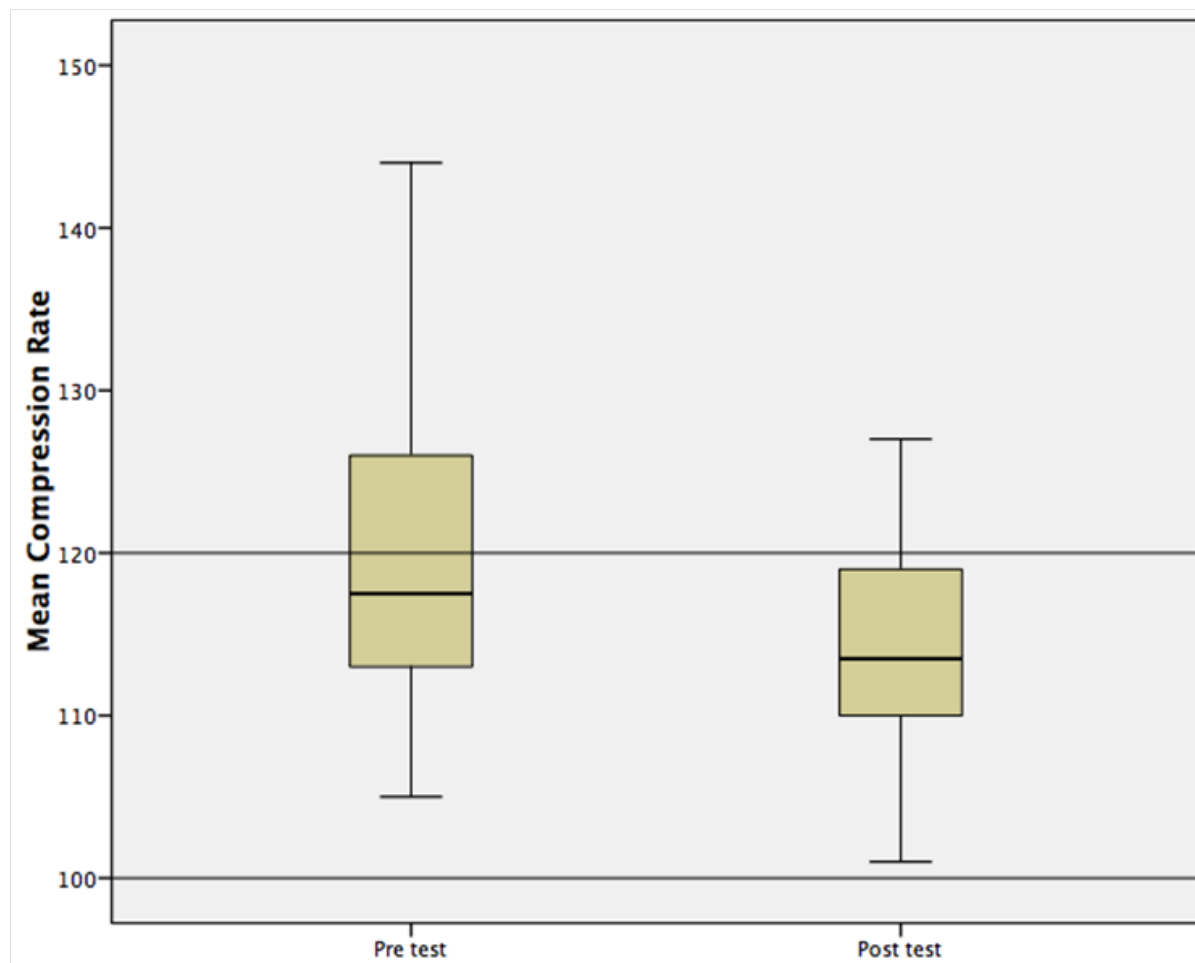


Fig. 1. Individual mean compression rates (Pre/Post-test, $n = 38$).

Table 1. Statistical measurements on individual mean values (Pre/Post-test, n = 38).

	Mean	SD	95% confidence interval		Median	Minimum	Maximum
			Lower	Upper			
Mean compression rates							
Pre-Test	119.29	9.03	116.63	122.26	117.5	105	144
Post-Test	113.87	6.40	111.76	115.97	113.5	101	127
Mean compression depth in mm							
Pre-Test	5168.42	677.24	4945.82	5391.02	5185.5	3681	6243
Post-Test	6119.18	229.22	6043.84	6194.53	6142.0	5154	6666
Mean compression recoil in mm							
Pre-Test	415.16	221.05	342.5	487.82	407.5	52	925
Post-Test	341.95	220.01	269.63	414.26	316.0	19	1025

Compression depth

Participants had a statistically significant increase in compression depth ($p < .001$) at the post-measurement. In general, participants performed compressions with correct depth at the pre-measurement and with a tendency for slightly too deep compressions at the post-measurement (2 mm too deep) (Fig. 2, Table 1).

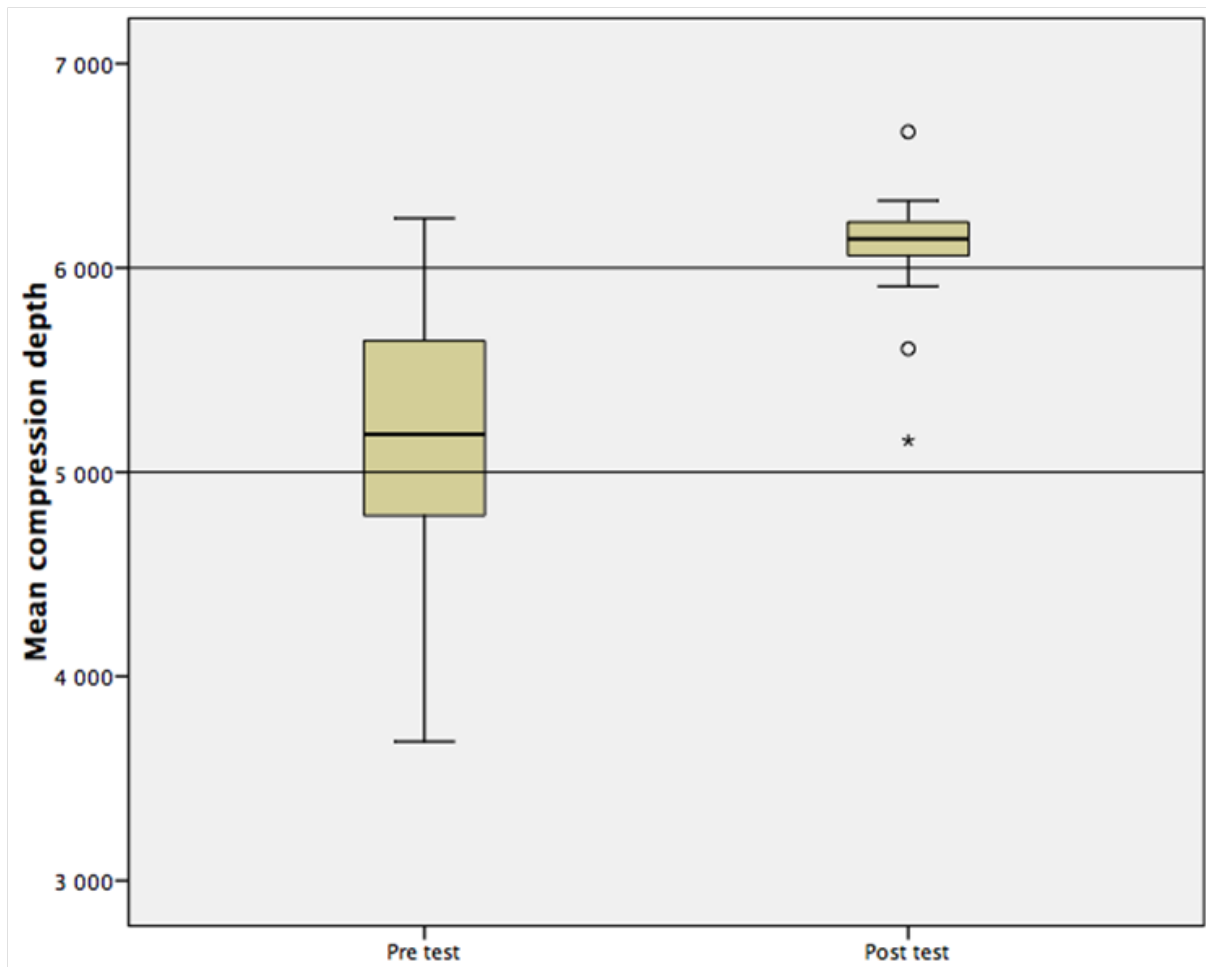


Fig. 2 Individual mean compression depth in mm (Pre/Post-test, n = 38).

Average recoil

Participants got a marginally reduced recoil at post-measurement for the better ($p = .116$). At the pre-measurement, the mean recoil depth was approximately 4 mm, while the post-measurement recoil depth had decreased to about 3 mm (Fig. 3, Table 1).

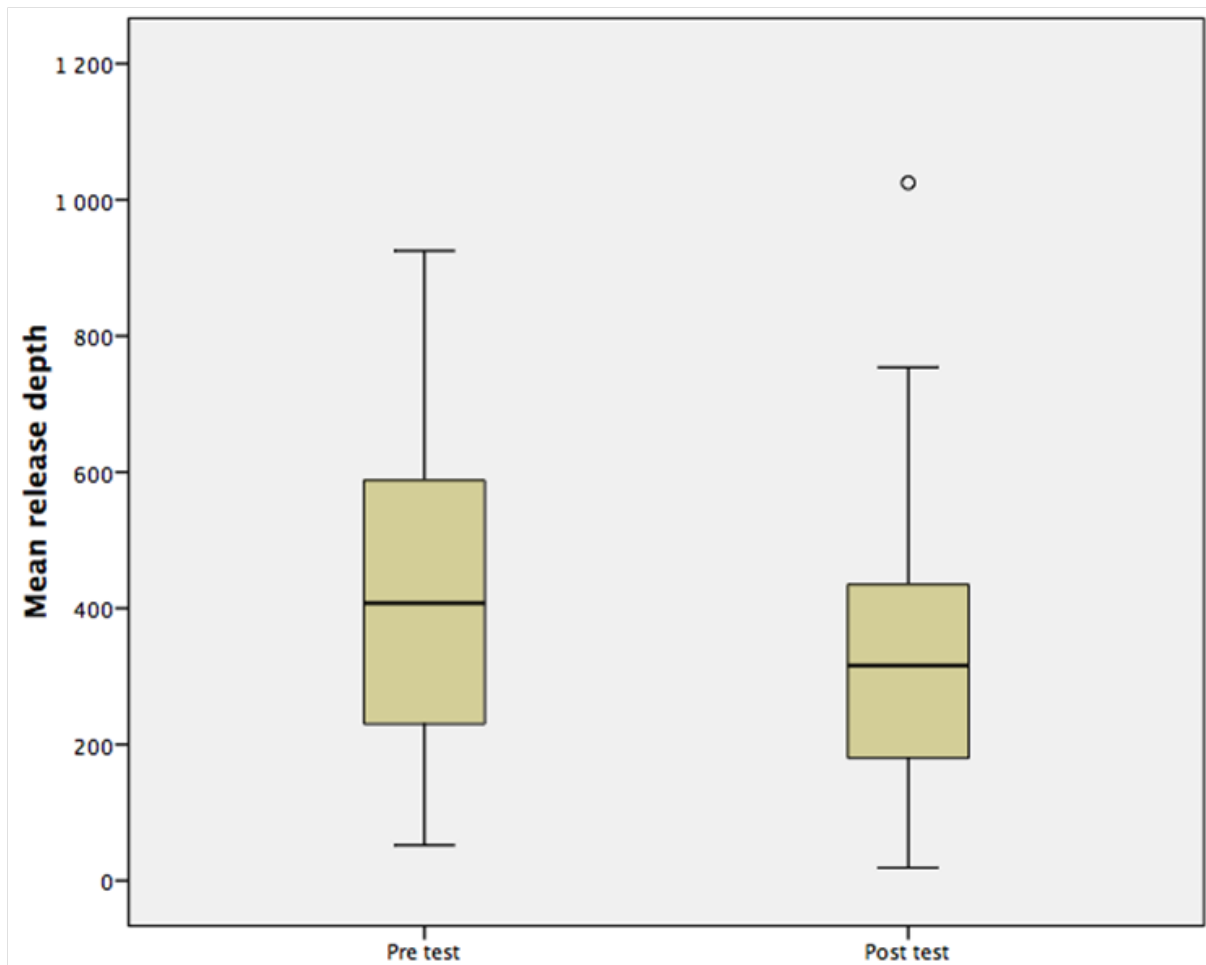


Fig. 3. Individual mean compression recoil, optimally 0 mm recoil (Pre/Post-test, n = 38).

Ventilation volume

Participants statistically significantly reduced the ventilation volume of the patient to a correct volume ($p = .007$) at the CPR at post-measurement as compared to a pre-measurement (Fig. 4, Table 2).

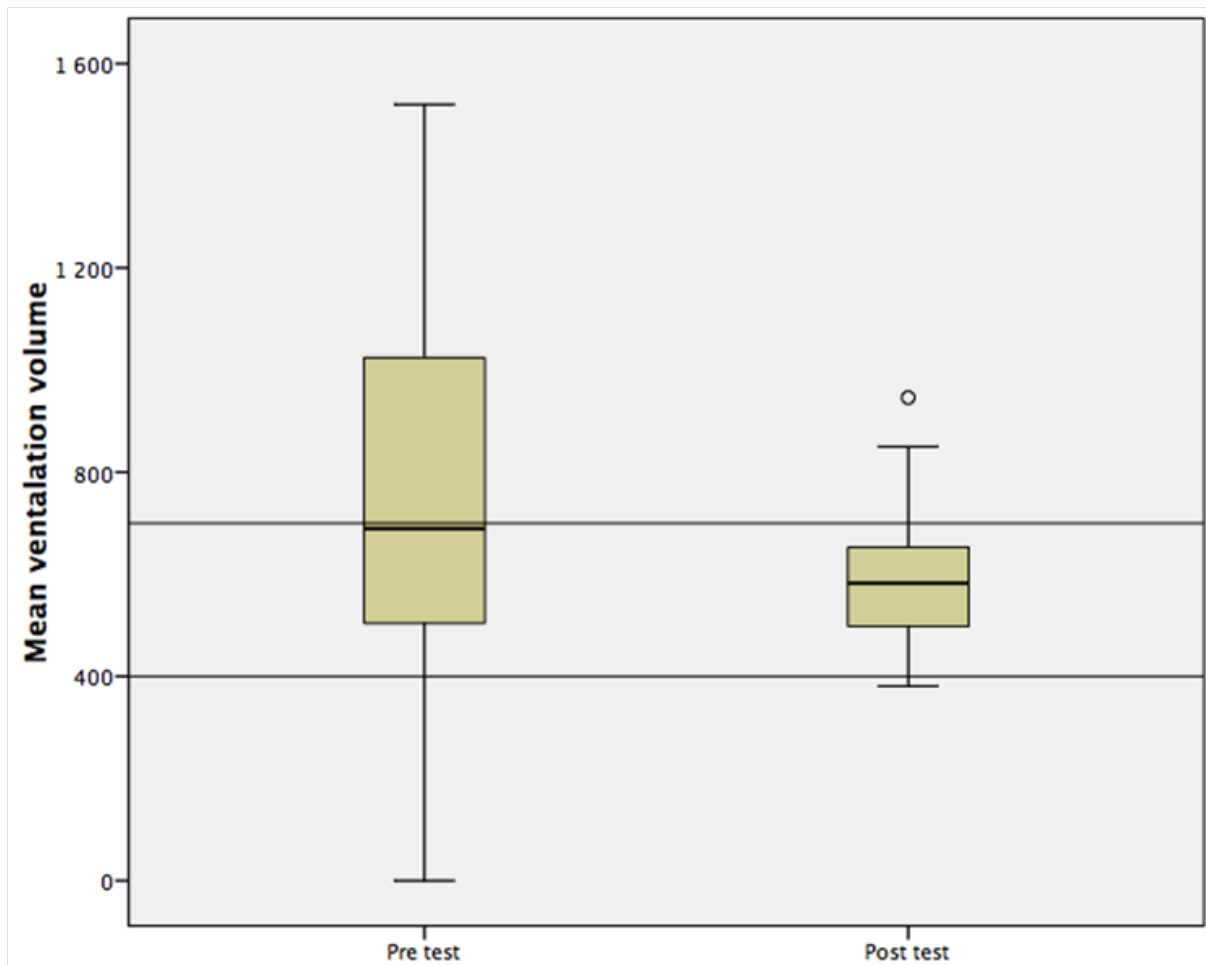


Fig. 4. Individual mean ventilation volume in ml (Pre/Post-test, n = 38).

Table 2. Statistical measures on individual mean ventilation volume in ml (Pre/Post-test, n = 38).

	Mean	SD	95% Confidence interval		Median	Minimum	Maximum
			Lower	Upper			
Pre test	755.45	334.15	645.62	865.28	689.5	0	1520
Post test	592.76	128.05	550.68	634.85	582.5	381	946

Discussion

The result suggests that objective feedback during training enhances the firefighters' CPR skills and therefore performance, and in the long run, patient outcome. Continuous CPR training gives the firefighters the opportunity to learn, through direct feedback, to know how correct CPR is performed, and to create muscle memory. This would apply to all prehospital staff including police and ambulance which is also confirmed by previous studies (Monsieurs et al., 2015; Smart et al., 2015).

To prevent loss of CPR skills, low-dose, high-frequency CPR can be performed continuously (Abella, 2013; Smart et al., 2015). Previous research describes how repetition is needed within one year to optimally maintain acquired CPR quality (Grant et al., 2007). There is a significant amount of research that shows that skills and hence the quality of CPR deteriorate already after three months (Abella, 2013; Greif et al., 2015). However, all people do not need the same repetition interval, but some individuals may need more frequent repetitions (Greif et al., 2015). In our study, the low dose was on average 6 times a month (range 2-15 times), which had a positive impact on the skills and the quality of ventilation volume, compression depth, rate, and recoil.

For each mm increased compression depth within the guidelines, the survival rate of patients increases (Monsieurs et al., 2015). In our study, participants had a tendency to compress 2 mm deeper than guidelines. The fact that the spring simulating the thoracic resistance was randomly changed without the participants' knowledge may have affected the compression depth. Had only one spring resistance been used, maybe the participants would have had a better feeling for the compression depth. Regardless, it is a valid observation, because too deep compressions are a negative stretch on the patient's sternum, resulting in a reduced blood volume return to the heart (Zhou et al., 2014).

Studies show that a large proportion of successful cardiopulmonary resuscitated patients has a good neurological outcome, suggesting that prehospital CPR is of good quality (Duchateau et al., 2017; Kim et al., 2017). In contrast, Irfan et al., (2017) show a lower number of survivors with out-of-hospital cardiac arrests. The patient outcome may be affected by the fact that pre-hospital staff, such as firefighters, police and ambulance, often perform CPR under difficult circumstances. CPR is often performed during transport, both on a moving stretcher and during ambulance transport. Cheskes et al, (2017) have shown that high-quality chest compressions can be performed by prehospital care providers regardless of the patient's location. However, other studies show that it may be difficult to maintain a good quality of prehospital CPR during transport (Gordon et al., 2015).

Limitations

A manikin-based study cannot mimic real life resuscitation situations. A manikin has no variations as humans have. The duties of a firefighter are versatile and include dealing with danger, acts of violence and threats during life-saving interventions (Dean, 2016). In the study, participants had full focus on CPR and not on the events in the surrounding environment as it would have been during a real cardiac arrest. Furthermore, the participants did not wear their firefighter clothes, but according to Kim et al., (2016), this does not affect the quality of compressions.

Conclusion

Prehospital staff such as firefighters, police, and ambulance perform CPR under less than optimal circumstances. It is therefore of the utmost importance that these professionals are trained in the best possible way. The result of this study shows that low-dose, high-frequency CPR training with an average of 6 training sessions per month improves ventilation volume, compression depth, rate, and recoil. This study concludes that objective feedback during training enhances the firefighters' CPR skills which in turn also could be applied to police and ambulance CPR training.

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Conflicts of interest The authors declare that there is no conflict of interest regarding the publication of this article.

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Reference

Abella, B.S. (2013). “The importance of cardiopulmonary resuscitation quality”. *Current opinion in critical care*. Vol. 19 No. 3, pp. 175-180.

Bobrow, B.J., Vadeboncoeur, T.F., Stolz, U., Silver, AE., Tobin, JM., Crawford, SA., Mason, TK, Schirmer, J, Smith, GA. and Spaite, DW. (2013). “The influence of scenario-based training and real-time audiovisual feedback on out-of-hospital cardiopulmonary resuscitation quality and survival from out-of-hospital cardiac arrest”. *Annals of emergency medicine*. Vol. 62 No. 1, pp. 47-56.

Bossaert, LL., Perkins, GD., Askitopoulou, H., Raffay, WI., Greif, R., Haywood, KL., Mentzelopoulos, SD., Nolan, JP., Van de Voorde, P. and Xanthos, TT. (2015). “European Resuscitation Council Guidelines for Resuscitation. (2015). Section 11. The ethics of resuscitation and end-of-life decisions”. *Resuscitation*. Vol. 95, pp. 302–311.

Cheskes, S., Byers, A., Zhan, C., Verbeeka, PR., Ko, D., Drennan, IR., Buick, JE., Brooks, SC., Lin, S., Taher, A. and Morrison, LJ. (2017). “CPR quality during out-of-hospital cardiac arrest transport”. *Resuscitation*. Vol. 114, pp. 34–39.

Dean, A. (2016). “Violence against firefighters2. *Fire Engineering*, Vol. 169 No. 10, pp. 40-46.

De Maio V.J., Stiell, I.G., Wells, G.A. and Spaite, D.W. (2003). “Optimal defibrillation response intervals for maximum out-of-hospital cardiac arrest survival rates”. *Annals of emergency medicine*, Vol 42 No. 2, pp. 242–250.

Duchateau, F., Hamada, S., Raux, M., Gay, M., Mantz, J., Paugam Burtz, C. and Gauss, T. (2017). “Long-term prognosis after out-of-hospital resuscitation of cardiac arrest in trauma patients: prehospital trauma-associated cardiac arrest”. *Emergency medicine journal*. Vol 34 No 1, pp. 34-38.

Grant, EC., Marczinski, CA. and Menon, K. (2007). “Using pediatric advanced life support in pediatric residency training: does the curriculum need resuscitation?” *Pediatric critical care medicine*. Vol 8 No. 5, pp 433–439.

Greif, R., Lockey, AS., Conaghan, P., Lippert, A., De Vries, W. and Monsieurs, KG. (2015). “European Resuscitation Council Guidelines for Resuscitation. Section 10. Education and implementation of resuscitation”. *Resuscitation*. Vol 95, pp. 288-301.

Irfan, FB., Consunji, R., El-Menyar, A., George, P., Peralta, R., Al-Thanic, H., Thomas, SH., Alinier, G., Shuaib, A., Al-Suwaidi, J., Singh, R., Castren, M., Cameron, PA. and Djarv, T. (2017). “Cardiopulmonary resuscitation of out-of-hospital traumatic cardiac arrest in Qatar: A nationwide population-based study”. *International journal of cardiology*. Vol 240, pp. 438–443.

Kim, TH., Kim, CH., Shin, SD. and Haam, S. (2016). "Influence of personal protective equipment on the performance of life-saving interventions by emergency medical service personnel". *Simulation*. Vol 92 No. 10, pp. 893–898.

Kleinman, M.E., Brennan, E.E., Goldberger, Z.D., Swor, R.A., Terry, M., Bobrow, B.J., Gazmuri, R.J., Travers, AH. and Rea, T. (2015). "Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care". *Circulation*, Vol 132 No. 18, pp. 414-435.

Meaney, PA., Bobrow, BJ., Mancini, ME., Christenson, J., de Caen, AR., Bhanji, F., Abella BS., Kleinman, ME., Edelson, DP., Berg, RA., Aufderheide, TP., Menon, V. and Leary, M. (2013). "Cardiopulmonary resuscitation quality: Improving cardiac resuscitation outcomes both inside and outside the hospital. A consensus statement from the American Heart Association". *Circulation*. Vol 128 No. 4, pp. 417–435.

Monsieurs, GK., Nolan, JP., Bossaert, LL., Greif, R., Maconochie, IK., Nikolaou, NI., et al. (2015). "European Resuscitation Council Guidelines for Resuscitation. Section 1. Executive summary". *Resuscitation*. Vol 95, pp. 1-80.

Mancini, ME., Diekema, DS., Hoadley, TA., Kadlec, KD., Leveille, MH., McGowan, JE., Munkwitz, MM., Panchal, AR., Sayre, MR. and Sinz, EH. (2015). "Part 3: Ethical Issues: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care". *Circulation*. Vol 3, pp. 383-396.

Rossi M., Mark M., Gregory A. and Ramirez R. (2016). "Think F.A.S.T. Firefighter Advanced Survival Techniques". *Fire Engineering*. Vol. 169 No. 3, pp. 20-38.

Safar, P., Brown, TC., Holtey, WJ. and Wilder, RJ. (1961). "Ventilation and circulation with closed-chest cardiac massage in man". *JAMA*. Vol 20 No. 176, pp. 574-576.

SFS 2008:192. *Act amending the Act (2003: 460) concerning the ethical review of research involving humans*. The Swedish Parliament, Stockholm.

Smart, JR., Kranz, K., Carmona, F., Lindner, TW. and Newton, A. (2015). "Does real-time objective feedback and competition improve performance and quality in manikin CPR training-a prospective observational study from several European EMS". *Scandinavian journal of trauma, resuscitation and emergency medicine*. Vol 23, pp. 79.

Truhlar, A., Deakin, CD., Soar, J., Khalifa, AEG., Alfonzo, A., Bierens, JJ., et al. (2015). "European Resuscitation Council Guidelines for Resuscitation. Section 4. Cardiac arrest in special circumstances". *Resuscitation*. Vol 95, pp. 148-201.

World Medical Association. (2013). "Declaration of Helsinki. Ethical Principles for Medical Research Involving Human Subjects". *JAMA*. Vol 310, pp. 2191-2194.

Zhou, XL., Duan, XV., Zhao, Y., Jiang, C., Xu, P., Jiang, S. and Ni, SZ. (2014). "Medical students do not adversely affect the quality of cardiopulmonary resuscitation for ED patients". *The American journal of emergency medicine*. Vol 32 No. 4, pp. 306–310.

