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Strengths and weaknesses of chest compression training – a preliminary retrospective study

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Summary

BACKGROUND: High quality chest compression is one of the key factors in successful resuscitation. A high standard of training is therefore decisive. We aimed to investigate the strengths and weaknesses of teaching chest compression in a study designed to highlight where targeted improvements in the quality of our chest compression training can and must be made.

METHODS: Retrospective analysis of prospectively documented data with 234 participants, and recording and analysis of chest compression variables before and after a BLS training course.

RESULTS: The results after the course were good for compression depth (94% correct), moderate for compression frequency (83% correct) and decompression (82% correct), unsatisfactory for hand positioning (74% correct) and poor for the compression/decompression ratio (32% correct). Practical instruction brought about improvements of between 9% and 48%. The greatest improvement was seen for hand positioning (48%), followed by compression depth (32%), compression rate (32%), and the compression/decompression ratio (20%). Training had only a slight effect on the degree of decompression (9%). Significant deteriorations were also noted after the course, for compression rate (11%) and the compression/decompression ratio (12%).

CONCLUSIONS: Chest compression training showed weakness for four out of five variables. Only the end results for compression depth were satisfactory. The deficits observed in the training on chest compression were relevant and must be remedied. One possibility would be initial step-by-step training and assessment of each component of chest compression, concentrating in particular on hand positioning and compression/decompression ratio.

Key words: *BLS training; CPR; chest compression; lay persons; health professionals*

Introduction

Much greater importance has been increasingly attached to high quality chest compression since the ILCOR resuscitation guidelines were issued in 2005 [1]. The following are currently regarded as essential in adults: a compression frequency of at least 100/min, a compression depth of at least 5 cm, complete decompression of the thorax after each compression, reduction of interruptions in chest compression to a minimum and the avoidance of excessive ventilation [2]. In addition to this, the hands must be positioned correctly and the compression/decompression (C/D) ratio must be 1:1.

The scientific rationale behind these recommendations draws on a range of observations. There is a clear relationship between the frequency of compression and a successful outcome of resuscitation [3]. Furthermore, the compression depth is directly correlated to cardiac output, aortic pressure and coronary perfusion [4]. Inadequate, shallow depth compression of the thorax therefore significantly decreases the success of defibrillation [5]. It has also been demonstrated in pigs that incomplete thorax wall decompression decreases venous return and the coronary and cerebral perfusion pressure [6]. Furthermore, the correct ratio of compression to decompression is important for the maintenance of adequate coronary and cerebral perfusion [4]. Since these key variables have a decisive influence on outcome, proper training is of paramount importance. Reports in the literature show that the outcomes of traditional BLS courses are often unsatisfactory, regardless of whether health professionals [7–10] or members of the general public [3, 7–9, 11–21] were trained.

The reports available, however, are generally limited to the documentation and analysis of group results after training, or the comparison of different methods [7–21]. We found only one paper with data that enabled a group comparison before and after a BLS course [22]. Furthermore, we were unable to find any papers that evaluated the actual learning effect of the course, i.e. the improvement or deterioration of the quality of chest compression before and after the course for each participant. Also, as far as we are aware, no studies have investigated all five key components of chest compression (hand position, compression frequency and depth, complete decompression and a C/D ratio of 1:1). Generally only 2–4 components are included, and the C/D ratio was assessed in only one of the papers we found [13].

It is therefore unclear which components of chest compression cause problems when training and which are easier to learn. Establishing the weaknesses and strengths, however, would be an important factor in improving training on chest compression and performing it correctly.
We were therefore interested in establishing the strengths and weaknesses in training on the five key components of chest compression in our BLS courses.

Participants, material and methods

This was a retrospective analysis of data prospectively collected in 2003 from a cluster-randomized and controlled interventional study that investigated the effects of music and rhythm on the learnability of chest compression [23]. Inclusion criteria for this study were occupation (lay person or nurse) and earlier attendance of BLS courses (none or one). All participants gave informed consent and were enrolled into this study consecutively over a period of five months. The training was conducted according to the 2000 Guidelines.
The inclusion criteria were fulfilled in 312/387 participants. 78/312 sets of records were not evaluable, 50 because of technical problems with recording (interruption of the cable connection between the manikin and the computer) or the computer printout, and 28 because the questionnaire on occupation and earlier attendance of BLS courses had not been filled out. Table 1 summarizes the characteristics of the remaining 234 participants.
The present study is regarded as a preliminary study to supply data as a basis for the prospective evaluation of new training methods aiming to improve the performance of chest compression in practise. This is because the 2000 ILCOR guidelines were revised in 2005 (ratio of chest compression to ventilation from 15:2 to 30:2) and in 2010 (compression frequency from 100/min to at least 100/min; compression depth from 3.5–5 cm to at least 5 cm) and because the courses were carried out at only one centre.

Description of course

The course lasted four hours for lay participants and 2.5 hours for nurses. All participants were asked to give informed consent at the beginning of each training event. The ratio of participants to trainers was 6:1 in this study. Fourteen instructors conducted the courses.
All instructors (qualified paramedics or nurses) had undergone a two day course for instructors for BLS-AED conducted according to the guidelines of the Swiss Resuscitation Council (SRC) at our hospital. The course has two parts. Part 1 covers theoretical aspects with lectures on presentation techniques, conduct of the course, teaching on the patient, evaluation and feedback. Part 2 consists of practical exercises with instruction on the use of the manikins, role play, evaluation and feedback.
The courses followed a strict set of modules. First, participants were required to watch a 10 minute video of a resuscitation attempt. The participants then had to perform the first BLS test as single resuscitators (15 compressions and 2 ventilations) with mouth-to-nose respiration for five minutes. This was followed by the practical part of the BLS course. Raising the alarm and the diagnostic ABC were practised in a first phase. This was followed by instruction on chest compression and ventilation. Each participant's exercises were continuously recorded. This meant that the instructor was always in a position to review the curves for the five chest compression variables (compression frequency, C/D ratio, compression depth, hand position and decompression) and ventilation on his/her monitor. Any corrective action was taken as the course progressed. As a last step, chest compression and ventilation were combined and the entire resuscitation sequence was practised. A second five minute test was conducted at the end of the course, also with the participants as single resuscitators with mouth-to-nose ventilation.
A pilot course with six persons was conducted to ensure that the courses proper ran smoothly.

Figure 1
Test setting.

Table1: Demographic data

Characteristic		Lay n	Lay %	Nurses n	Nurses %	p	Total n	Total %
Sex	Male	33	37	10	7	<0.001**	43	18
	Female	55	63	136	93		191	82
Age	Mean	31		33		ns***		
	Median	26		31		ns****		
Previous BLS course	None	64*	81	50*	43	ns**	114*	58
	One	15*	19	66*	57		81*	42

* = No information for 9 lay persons and 30 nurses
** = Chi-square test
*** = Student's t-test
**** = Mann-Whitney U test
ns = not significant

Measurements

6 Ambuman®-Modell C manikins were arranged around a computer in a semicircle and linked up (see fig. 1). The compression and ventilation performance of all participants were recorded on the PC using software from Ambu. Each participant had their own manikin.

Outcome variables

The following variables of compression and ventilation were recorded for each participant: compression rate, C/D ratio, compression depth, breaks between two compression cycles, wrong hand positioning, absence of decompression, respiratory minute volume, initial ventilation, ventilation rate, ventilation volume and air insufflation into the stomach. The ventilation variables were not evaluated.
Since we were unable to establish internationally recognized normal ranges for the compression variables in 2003, we set our own threshold values: the correct compression rate was between 80 and 120 per minute, and the correct C/D ratio was 1:1 [24]. A window of 0.66:1.33 was regarded as acceptable, thus compression times 2/3 and 4/3 of the length of the decompression time and vice versa were documented as correct. A compression depth between 35 and 55 mm was acceptable. The variables hand positioning and decompression were evaluated as correct if fewer than 5% of each were wrong or absent, respectively.

Analysis and statistics

The results before and after the course were compared for all participants (n = 234), lay persons (n = 88) and nurses (n = 146), and those who had previously done one course (n = 81) or not (n = 114). The outcome before and after the course between and within the occupational groups was also compared by previous training status. Systat for Windows® Version 11.00.01 was used for the statistical analysis. The modules 'Descriptive statistics' and 'Tables' were used with the following statistical tests: Student's t-test for unpaired comparison of means, the Mann-Whitney U test for unpaired comparison of medians, chi-squared test for nominal data and independent samples (where the expected frequencies were small, Fisher's exact test) and 95% confidence intervals for nominal data.

Results

The overall results for the group are given in table 2. The results for compression rate, C/D ratio, compression depth and hand positioning were significantly better after the course. No improvement was seen for decompression. Overall, only the results for compression depth were good, and those for the C/D ratio were extremely bad.
Table 3 shows the results of the intraindividual comparisons. Practical training brought about an increase of between 9% (decompression) and 48% (hand positioning). The major improvements achieved by practical instruction were in hand positioning, compression depth and compression rate. These results were, however, unfortunately tempered by marked deteriorations in compression rate and – although to a lesser extent – hand positioning, and compression depth. The results for the C/D ratio and decompression were poor although decompression was adequate after the video presentation.
The subanalysis 'lay participants vs. nurses' showed no relevant differences, although for individual components the lay participants did show significantly less poor results (table 4). The same was found for the comparison 'no previous course vs. one previous course' (table 5). The pre-post comparison by occupation and previous training in and between each occupational group also showed no significant differences (data not shown). Bias introduced by occupational status or number of previous courses was therefore able to be ruled out.

Discussion

Unlike studies already published, our study measured the actual success of training measured as the outcome of learning in terms of an improvement or deterioration in chest compression. The performance of the whole group and of each participant before and after the course were analyzed and compared. Quantification of the net benefit,

Table 2: Comparison of results before and after course

Variable	Threshold values	Before		After		p (Chi-square test)
		n = 234	%	n = 234	%	
Compression rate	80-120 (correct)	148	63	194	83	<0.00001*
	>120	19	8	33	14	
	<80	67	29	7	3	
Compression/decompression ratio	0.66-1.33 (correct)	49	21	74	32	<0.01*
	>1.33	6	3	0	0	
	<0.66	179	76	160	68	
Compression depth	35-55 mm (correct)	150	65	219	94	<0.000001*
	>55	1	0	10	4	
	<35	83	35	5	2	
Wrong hand positioning	<=5%	73	31	174	74	<0.000001**
	>5%	161	69	60	26	
Decompression absent	<=5%	195	83	193	82	ns***
	>5%	39	17	41	18	

* = Comparison of correct ranges versus incorrect ranges (< correct parameters and > correct parameters)
** = Comparison of < 5% wrong hand position versus > 5% wrong hand position
*** = Comparison of < 5% decompression absent versus > 5% decompression absent
ns = not significant

i.e. of the improvement and deterioration combined, assisted in highlighting better the strengths and weaknesses than just comparing the groups, where no differentiation is made between the proportion showing an improvement, deterioration or no change.

It appears that after a 10 minute video presentation, three components of chest compression (compression rate, depth and decompression) can largely be performed correctly without any practical training.

However, the net benefit of the course, i.e. subtracting deteriorations from improvements, was only moderate, with improvements of 43% in hand positioning (total 74% correct), 29% in compression depth (94%), 20% in compression rate (83%), 9% in C/D ratio (32%) and 0% in complete decompression (82%).

Overall, the course consisting of the video presentation and practical exercises was effective in achieving good scores for compression depth. The scores for compression rate and decompression were just barely adequate, the results for hand positioning unsatisfactory and those for the C/D ratio were poor. Instruction in chest compression therefore failed to achieve the desired result in four out of five components, i.e. less than 90% of participants achieved the criterion 'fulfilled'. Except for the C/D ratio, our findings were similar to or better than those of other studies (table 6). This indicates that our centre ranks high in the international context and that our results and conclusions are of a conservative nature, and that similar performances are likely to be seen at other training centers.

We are of the opinion that our course results can be improved by concentrating on the proper training of chest compression. This has been shown in a randomized, controlled study from Japan [21] which compared a conventional CPR course with a compression only course (COC). Compression frequency, depth, decompression and hand positioning were significantly better in the COC group. This shows that it is worthwhile practising the individual components of chest compression separately. We suggest the following sequence: Correct hand positioning should be the first to be trained, followed by compression frequency, compression depth, decompression, C/D ratio, and then all components together. We also feel that we can positively influence the learning process by offering trainees the possibility of directly following their performance by projecting their compression curve onto a large screen. We have been using this as yet unvalidated technique for a few years. As soon as the participants master the individual components, no further curves are projected, and the trainees concentrate completely on the overall process of resuscitation.

Table 3: Results at end of course

Variables	**Results %**							
	Improvement		**Remained correct**		**Remained incorrect**		**Deterioration**	
Compression rate	32	(25–39)	51	(43–58)	5	(2–9)	12	(8–17)
Compression/decompression ratio	20	(13–27)	12	(7–18)	57	(49–65)	11	(6–17)
Compression depth	32	(26–40)	61	(53–68)	4	(1–7)	3	(1–6)
Hand positioning	48	(40–55)	27	(20–33)	20	(15–27)	5	(2–9)
Decompression	9	(5–13)	74	(67–80)	8	(5–13)	9	(5–14)

( ) = 95% confidence interval

Table 4: Comparison of results after the course for lay participants and nurses

Variables		**Result after course**				**p*** (Chi-square test)	**p**** (Chi-square test)
		Lay		**Nurses**			
		n = 88	**%**	**n = 146**	**%**		
Compression rate	Remained correct	50	57	70	47	ns	ns
	Improvement	28	32	46	32	ns	
	Deterioration	9	10	19	13	ns	
	Remained incorrect	1	1	11	8	<0.03	
Compression/decompression ratio	Remained correct	11	12	17	12	ns	ns
	Improvement	19	22	27	18	ns	
	Deterioration	5	6	21	14	<0.04	
	Remained incorrect	53	60	81	56	ns	
Compression depth	Remained correct	51	58	92	63	ns	ns
	Improvement	30	34	46	32	ns	
	Deterioration	1	1	6	4	ns	
	Remained incorrect	6	7	2	1	<0.04	
Hand positioning	Remained correct	24	27	38	26	ns	<0.02
	Improvement	49	56	63	43	ns	
	Deterioration	1	1	10	7	<0.05	
	Remained incorrect	14	16	35	24	ns	
Decompression	Remained correct	62	70	111	75	ns	ns
	Improvement	9	10	11	8	ns	
	Deterioration	12	14	10	7	ns	
	Remained incorrect	5	6	14	10	ns	

ns = not significant
* = Comparison of a single category (f.ex. remained correct) versus the rest (f.ex. improvement, deterioration and remained incorrect)
** = Comparison of percentage of those who remained correct or improved versus those who deteriorated or remained incorrect)

As already shown in other studies [9, 25], the results for nurses (health professionals) in our study were not better than those achieved by lay persons. One possible reason for this is the considerably shorter course duration by nurses, and that their medical knowledge was of only limited benefit, if any. Having attended a BLS course in the past did not improve the results. This observation agrees with the literature, where poor long term results have been reported [7, 16]. It appears that acquired knowledge that is not generally used frequently is quickly forgotten. It is unlikely that long term outcomes can be improved effectively by attending a course once, even if high-quality training is offered. We feel that such an improvement can only be achieved by attending refresher courses conducted at frequent and regular intervals.

One of the strengths of our study was that the results were documented using continuous computer-driven recording and evaluation of all compression variables. This enabled objective measurement of performance and therefore increased the readiness of the participants to be corrected. This approach has significant advantages over subjective evaluation, i.e. by observers, or over a cumulative printout of the performance without detailed information. It has been shown in a study that subjective assessment of trainees by instructors is very error prone [26]. For example, examiners wrongly assessed compression depth and hand position as correct in 55% and 49% of cases respectively. With our analysis we were able to exclude any bias from occupational status or previous training as confounding factors.

The weaknesses of our study are that it was conducted at only one centre and we had 78 dropouts (25%). Selection bias cannot, therefore, be excluded. The technical problems leading to 50 dropouts played a less significant role in this than the 28 participants who did not complete the questionnaires properly, meaning that any bias might have had both a positive and a negative effect on the results. The participants were also not followed up after the course so that no information can be provided on long term results. We were not aiming, however, to evaluate long term results, but the immediate net effect of training.

The fact that the present study was based on the AHA 2000 Guidelines has little effect on the conclusion that the results were inadequate and poor. Tiredness and loss of strength due to the switch from 15:1 in the old guidelines to 30:2 in the new version, the new recommendations for continuous chest compression in certain situations, a minimum frequency of 100/min, and a minimum compression depth of 5 cm, only serve to have a more negative effect on trainee performance, as has been reported in the literature [27].

In the light of the strengths and weaknesses of this study, we regard its results as preliminary. As far as we know this is nevertheless the first study that has investigated the net effect of training on all components of chest compression.

Table 5: Comparison of results after the course between participants with and without a previous course

Variables		**Difference between no course and one course**				**p* (Chi-square test)**	**p** (Chi-square test)**
		No course		**One course**			
		n = 114	**%**	**n = 81**	**%**		
Compression rate	Remained correct	57	50	43	53	ns	<0.000001
	Improvement	39	34	23	28	ns	
	Deterioration	16	14	7	9	ns	
	Remained incorrect	2	2	8	10	<0.02	
Compression/ decompression ratio	Remained correct	14	12	6	7	ns	ns
	Improvement	23	20	15	19	ns	
	Deterioration	12	11	51	11	ns	
	Remained incorrect	65	57	9	63	ns	
Compression depth	Remained correct	71	62	48	59	ns	ns
	Improvement	36	32	28	35	ns	
	Deterioration	2	2	4	5	ns	
	Remained incorrect	5	4	1	1	ns	
Hand positioning	Remained correct	32	28	22	27	ns	ns
	Improvement	57	50	35	43	ns	
	Deterioration	6	5	4	5	ns	
	Remained incorrect	19	17	20	25	ns	
Decompression	Remained correct	83	73	60	74	ns	ns
	Improvement	11	10	6	7	ns	
	Deterioration	13	11	8	10	ns	
	Remained incorrect	7	6	7	9	ns	

ns = not significant
* = Comparison of a single category (f.ex. remained correct) versus the rest (f.ex. improvement, deterioration and remained incorrect)
** = Comparison of percentage of those who remained correct or improved versus those who deteriorated or remained incorrect)

Table 6: Results of literature comparison of chest compression outcomes

Studies	**Correct**				
	Frequency	**Depth**	**Hand position**	**Total decompression**	**C/D ratio**
References 7-21	42–63%	26–61%	55–100%	86–89%	52%*
Our study	83%	94%	74%	82%	32%

* 1 study only [13]

The same aims and methods could therefore be used in urgently required future studies. We hope that the publication of our findings encourages other centres offering courses to evaluate the quality of their chest compression training. Our findings could certainly be used to assist in the planning of a randomized study to compare the net effect of conventional training and training with a focus on the individual components of chest compression.

Conclusions

A 10 minute video presentation at the start of instruction was an effective measure. Training on chest compression, however, showed weakness for four out of five components. Good results were achieved only for compression depth. The deficits observed in the chest compression training, especially for hand positioning and C/D ratio, are relevant and urgent solutions must be found.

Our results indicate which components of chest compression are difficult to teach at training events and where the weaknesses in instruction might lie. We are of the opinion that the quality of chest compression can be markedly improved by ensuring that instructors receive training specifically designed to enable them to perform and assess the individual components as well as the overall procedure.

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