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How should we teach cardiopulmonary resuscitation? Randomized multi-center study

Running title: Teaching cardiopulmonary resuscitation

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Abstract

Background: A 2017 update of the resuscitation guideline indicated the use of CPR feedback devices as a resuscitation teaching method. The aim of the study was to compare the influence of two techniques of cardiopulmonary resuscitation teaching on the quality of resuscitation performed by medical students.

Methods: The study was designed as a prospective, randomized, simulation study and involved 115 first year students of medicine. The participants underwent a Basic Life Support course based on the American Heart Association guidelines, with the first group (experimental group) performing chest compressions to observe, in real-time, chest compression parameters indicated by software included in the simulator, and the second group (control group) performing compressions without this possibility. After a 10-minute resuscitation, the participants had a 30-minute break and then a 2-minute cycle of cardiopulmonary resuscitation. One month after the training, study participants performed cardiopulmonary resuscitation, without the possibility of observing real-time measurements regarding quality of chest compression.

Results: One month after the training, depth of chest compressions in the experimental and control group was 50 mm (IQR 46–54) vs. 39 mm (IQR 35–42; p = 0.001; Fig. 2)., compression rate 116 CPM (IQR 102–125) vs. 124 CPM (IQR 116–134; p = 0.034), chest relaxation 86% (IQR 68–89) vs. 74% (IQR 47–80; p = 0.031) respectively.

Conclusions: Observing real-time chest compression quality parameters during Basic Life Support training may improve the quality of chest compression one month after the training including correct hand positioning, compressions depth and rate compliance.

Key words: basic life support, learning, medial simulation, quality, chest compression

Introduction

Out-of-hospital cardiac arrest is a global health problem, with survival varying greatly between communities. Sudden cardiac arrest (SCA) is one of the leading causes of death in Europe. Depending how SCA is defined, about 55–113 per 100,000 inhabitants per year or 350,000–700,000 individuals each year are affected in Europe [1, 2]. On initial heart-rhythm analysis, about 25–50% of SCA victims have ventricular fibrillation (VF), a percentage that has declined over the last 20 years [3, 4]. However, regardless of the rhythm initiating cardiac arrest, the key is to implement resuscitation procedures as soon as possible [5].

The guidelines of the European Resuscitation Council (ERC) as well as the American Heart Association (AHA) indicate the need for high quality chest compression as an element closely correlated with the efficiency of cardiopulmonary resuscitation. Both the ERC and AHA guidelines provide a detailed description of how chest compression should be performed.

One of the key elements of the recent emphasis has been on minimizing chest compression interruptions [6]. According to Ewy et al. [7] the most optimal form of chest compression is continuous compression, which generates higher perfusion pressure than resuscitation based on 30 compressions to 2 rescue breaths. To this purpose, it may be essential to perform airway management with an endotracheal tube or supraglottic airway device and initiate asynchronous resuscitation, so that chest compression interruptions, necessary for ventilation with a face mask and a self-inflating bag, are minimized [8–10]. Further parameters indicated by the guidelines include the depth and the rate of compressions as well as the correctness of chest relaxation after each compression. However, regardless of whether resuscitation is based on European or American guidelines, as numerous studies indicate, the quality of chest compressions performed even by medical staff is insufficient [8, 11–14].

The 2017 update of the resuscitation guideline indicated the use of CPR feedback devices [15] as a resuscitation teaching method. Numerous studies indicate that chest compression using these devices is superior to standard resuscitation [16–18]. However, because of the relatively high cost of these devices they are encountered sporadically during real-life resuscitation activities as well as during training courses. It is therefore crucial to seek new methods of teaching both basic and advanced resuscitation procedures which will improve the performance of chest compressions.

The aim of the study was to compare the influence of two techniques of cardiopulmonary resuscitation teaching on the quality of resuscitation performed by medical students.

Methods

Study design

The study was designed as a prospective, randomized, simulation study. The study protocol was approved by the Institutional Review Board of the Polish Society of Disaster Medicine (Approval no.: 24.11.2017.IRB). Following IRB approval and written informed consent, 115 first year students of medicine took part in the study.

Study protocol

To simulate a patient with cardiac arrest requiring cardiopulmonary resuscitation, Resusci Anne® QCPR (Laerdal, Stavanger, Norway) was used, which was placed on a flat surface in a brightly lit room.

Before starting the study, the participants were divided into two groups and ResearchRandomizer (randomizer.org) was used for this purpose. In both groups a 5 min. standardized training on how to perform cardiopulmonary resuscitation of an adult was performed prior to the study. Both groups then underwent a Basic Life Support course based on the American Heart Association guidelines, with the first group (experimental group) performed chest compressions to observe, in real-time, chest compressions parameters indicated by software included in the simulator, and the second group (control group) performed compressions without the possibility of observing simulator indications. After a 10-minute resuscitation, the participants had a 30-minute break and then a 2-minute cycle of cardiopulmonary resuscitation based on a scheme of 30 compressions: 2 rescue breaths. The first group performed compressions on the basis of simulator indications, while the second group did not.

The next phase of the study was conducted one month after training. At that time study participants in the same groups performed cardiopulmonary resuscitation, this time both experimental and control groups were not able to observe real-time measurements regarding quality of chest compression.

Measurements

During the study, parameters of chest compression were analyzed, including total compression score, calculated by simulator software on the basis of parameters of chest compression. Additionally, compression depth, compression depth compliance, compression rate per minute (CPR), compression rate compliance, full release as well as correctness of chest position during compression were evaluated. As reference values for depth and rates of chest compressions, the values recommended by the American Heart Association were used, this states that the optimal depth of adult chest compressions is between 50 and 60 mm and the optimal rate of compressions should be between 100 and 120 compressions per minute [19]. All chest compression parameters were recorded by dedicated software included in the SkillReporter (Laerdal, Stavanger, Norway).

Statistics

Data were analyzed with the use of Statistica software v.13.3EN (TIBCO., Tulsa, OK). The results are shown as medians and interquartile ranges (IQR). The occurrence of normal distribution was confirmed by the Kolmogorov-Smirnov test. Analysis of variance (ANOVA) post hoc tests with the Bonferroni correction for metric data were used for univariate analysis to compare the two study groups. The Kruskal-Wallis test was used to compare non-normally distributed data. Multivariate ANOVA was also applied. The results were considered significant at the level of $p < 0.05$.

Results

115 students in their first year of medical studies were enrolled in the study, however, in the initial phase of the study 4 persons decided not to participate in the study. Randomization took place for 111 participants.

A detailed summary of data obtained in the study is presented in Table 1. The initial chest quality assessment performed before the training did not show statistically significant differences between the experimental group and the control group.

After training, study participants had access to a monitor indicating the quality of chest compression and a statistically significant better total compression score was obtained in comparison with non-real time monitoring of chest compression ($p = 0.001$). The depth of chest compression in the experimental and control group showed statistically significant differences (51 mm [IQR 48–57] vs. 40 mm [IQR 39–44]; $p < 0.001$) respectively. Chest compression rate for the experimental group was 110 [IQR 103–121] CPM, and for the control group 124 (IQR 110–128; $p = 0.019$). Resuscitation with a possibility to observe chest compression parameters was associated with better chest relaxation and better hand positioning (Table 1).

In the second phase of the study (1 month after the training) the depth of chest compressions in the experimental and control group was different and was 50 mm (IQR 46–54) *vs.* 39 mm (IQR 35–42; $p = 0.001$; Fig. 1). The chest compression rate achieved was 116 CPM (IQR 102–125) for the experimental group and 124 CPM (IQR 116–134; $p = 0.034$; Fig. 2) for the control group. The correctness of chest relaxation in the experimental group was 86% (IQR

68–89) and a statistically significant higher measure than in the control group — 74% (IQR 47–80; $p = 0.031$; Fig. 3).

The correct hand positioning, as well as compression depth compliance, compression rate compliance, and total compression score were significantly better statistically than in the experimental group in comparison with the control group ($p < 0.05$ for all parameters).

Discussion

The present study showed the validity of using systems which indicate the quality of chest compression during teaching of basic resuscitation procedures because the correction in real time of the chest quality performed significantly improves overall quality of chest compression. Evaluation of chest compression quality with and without chest compression indicating software showed that subjects adjust to chest compression parameters in real time, and had significantly better results for all analyzed parameters compared to the group that could not observe the quality of their resuscitation.

The depth of chest compressions performed by the experimental group (with the possibility to assess the quality of compression in real time) was 51 mm, while in the case of groups without this possibility — 40 mm ($p < 0.001$). According to ERC and AHA guidelines, the depth of chest compression in adults should be between 50 and 60 mm [20]. Numerous studies indicate an improvement in the quality of chest compressions when using CPR feedback devices, including TrueCPR, PocketCPR, CPRMeter or EasyCPR [21–23].

Another parameter indicated in the resuscitation guidelines as important for the quality of chest compression is the rate of chest compressions, which should be between 100 and 120 compressions per minute [24]. In this post-training study, the rate of chest compressions was 124 CPM for the control group and 110 CPM for the experimental group. During the evaluation phase of the study, one month after the training, the rates were 124 *vs.* 116 CPM respectively. Jäntti et al. [25] as well as other authors' studies [13, 26, 27] also indicate that manual chest compression is performed too rapidly. As Solevåg and Schmölzer had indicated a rate higher than 120/min is also more fatiguing, which affects CC quality [28]. On the other hand, Zou et al. studies indicate that the optimal rate of chest compression is 120/min [29]. Studies published by Lee also indicate 120 compressions per minute as the optimal chest compression rate, while noting that higher compression rates can reduce chest relaxation [30]. Similar conclusions can also be drawn from studies by Smereka et al. [8], as well as from studies by other authors [31–33].

Another equally important parameter is the correctness of chest relaxation. It is the compression of the chest to the appropriate depth and then allowing it to return to its normal shape before compression determines the appropriate difference in pressure in the chest to generate organ perfusion [5]. In a study conducted both immediately after the training and a month after the training, a higher percentage of correctly performed relaxation was obtained by participants from the experimental group who had the opportunity to observe the parameters of chest compression in real time during the training.

The use of a system that indicates, in real time, the quality of resuscitation during basic life support learning has allowed participants to improve chest compression parameters and could therefore have a real impact on a patient's chances of survival. An important conclusion from the results is that those who have learned resuscitation using monitoring software perform higher quality chest compressions one month subsequent to training. This may indicate a higher level of familiarity with this important skill of chest compression.

A limitation in this study is the use of medical simulation in the research process, however, this fact was intended and dictated by the fact that only during medical simulation was it possible to conduct such a study without potential harm to the patient [34]. An advantage of the study, in turn, is its randomized multi-center design, a relatively large study group, as well as undertaking an evaluation of chest compression skills not only immediately after training, but also one month after training.

Conclusions

Observing real-time chest compression quality parameters during Basic Life Support training may improve the quality of chest compression one month after training including correct hand positioning, compression depth and rate compliance.

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Table 1. Chest compression (CC) data.

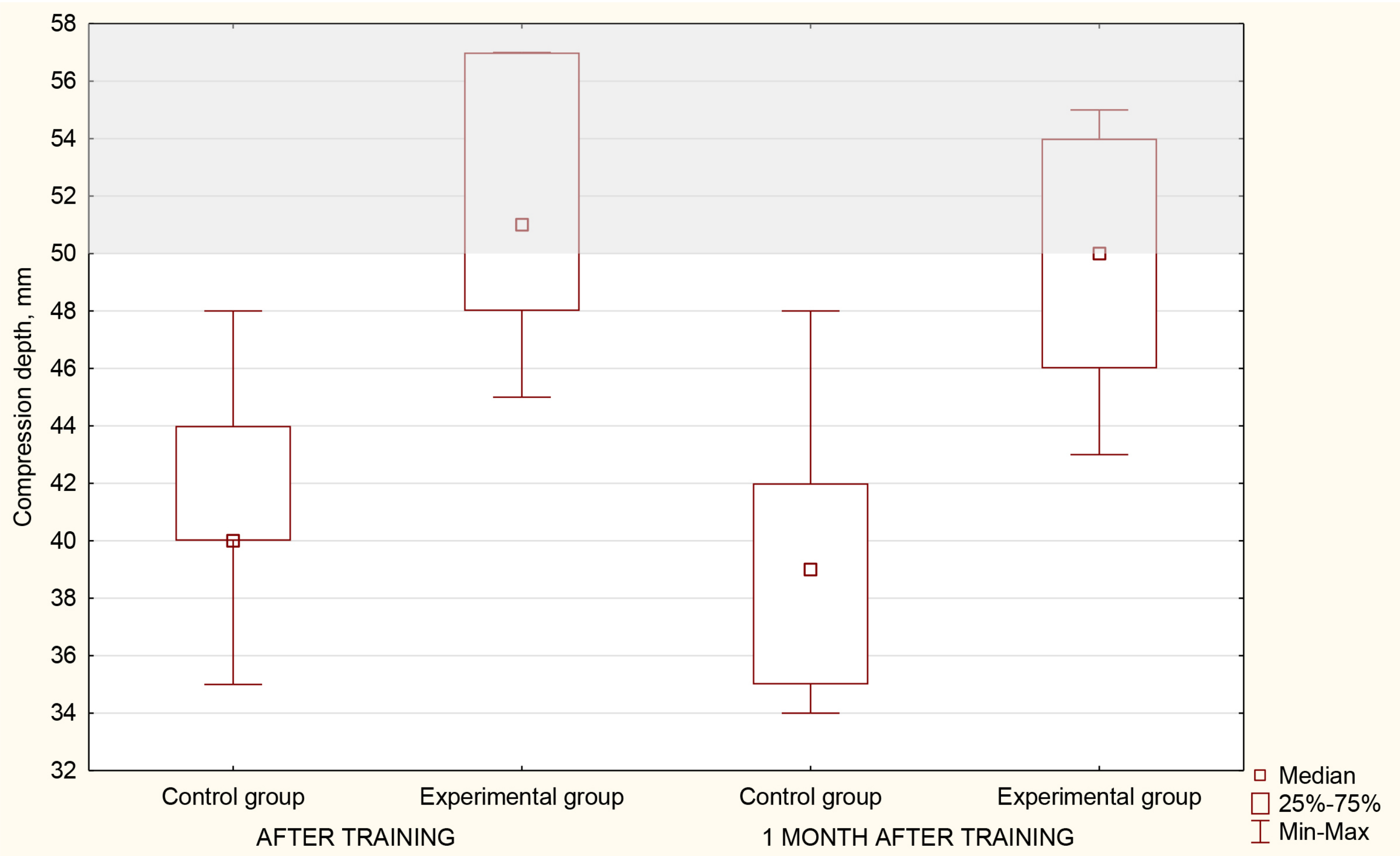
Parameter	Control group Manual CC (n = 56)	Experimental group The device feedback (n = 55)	P
Before practical training			
Total compression score [%]	70 (43–82)	69 (41–80)	NS
Compression depth [mm]	39 (37–42)	39 (36–42)	NS
Compression depth compliance [%]	68 (54–74)	69 (52–75)	NS
Compression rate [per min]	128 (116–131)	124 (114–130)	NS
Compression rate compliance [%]	70 (51–83)	71 (50–84)	NS
Full release [%]	76 (53–85)	77 (55–84)	NS
Correct hand position [%]	83 (71–90)	83 (70–92)	NS
After training			
Total compression score [%]	74 (51–85)	93 (87–100)	**0.001**
Compression depth [mm]	40 (39–44)	51 (48–57)	**< 0.001**
Compression depth compliance [%]	68 (60–89)	96 (90–100)	**0.001**
Compression rate [per min]	124 (110–128)	110 (103–121)	**0.019**
Compression rate compliance [%]	78 (54–88)	97 (92–100)	**0.001**
Full release [%]	76 (53–90)	91 (81–97)	**0.037**
Correct hand position [%]	83 (76–94)	96 (92–100)	**0.007**
1 month after training			
Total compression score [%]	74 (50–79)	90 (84–100)	**< 0.001**
Compression depth [mm]	39 (35–42)	50 (46–54)	**0.001**
Compression depth compliance [%]	64 (50–71)	94 (90–100)	**< 0.001**
Compression rate [per min]	124 (116–134)	116 (102–125)	**0.034**
Compression rate compliance [%]	72 (53–74)	97 (89–100)	**0.001**
Full release [%]	74 (47–80)	86 (68–89)	**0.031**
Correct hand position [%]	80 (70–91)	94 (81–100)	**0.017**

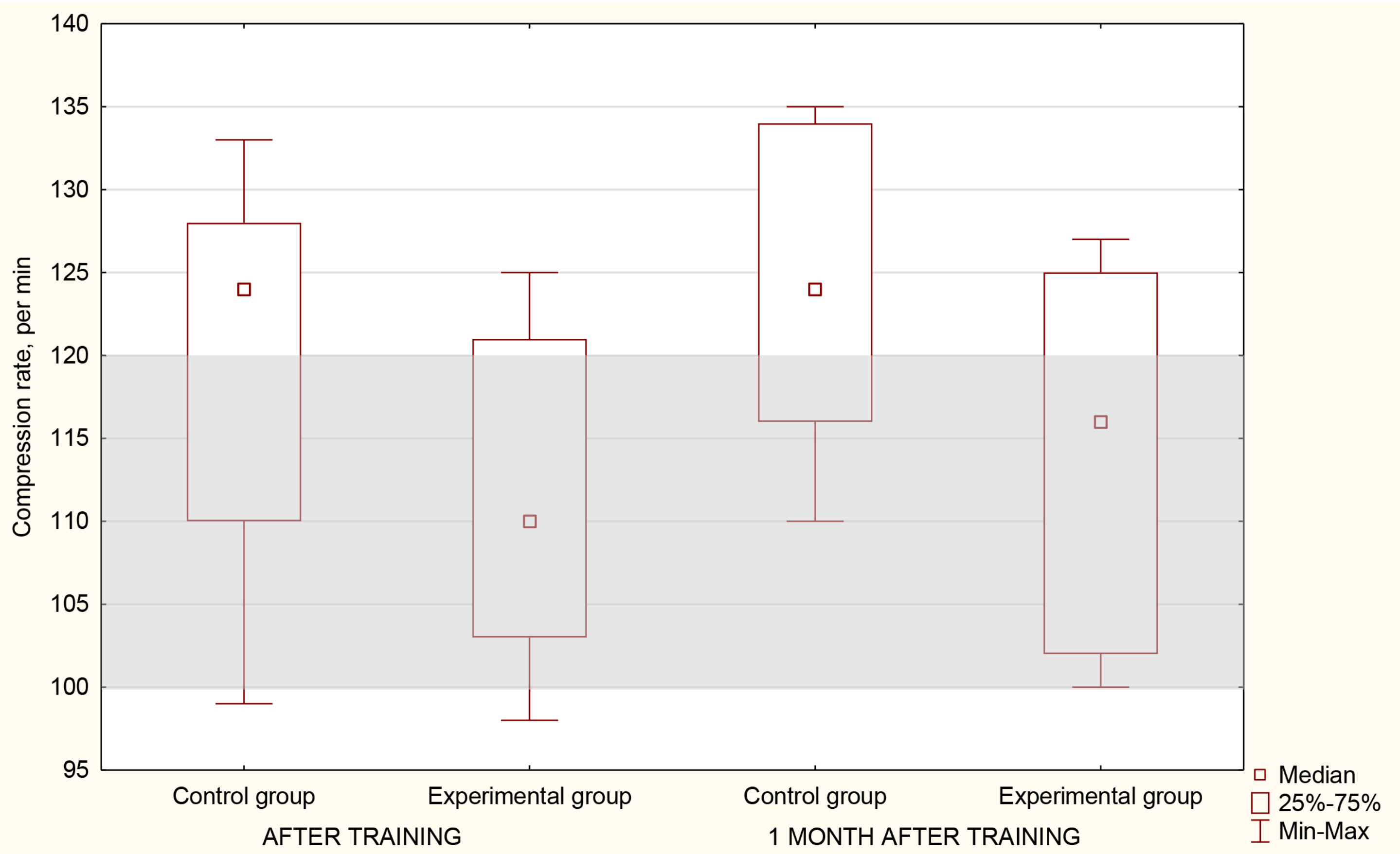
NS — not statistically significant

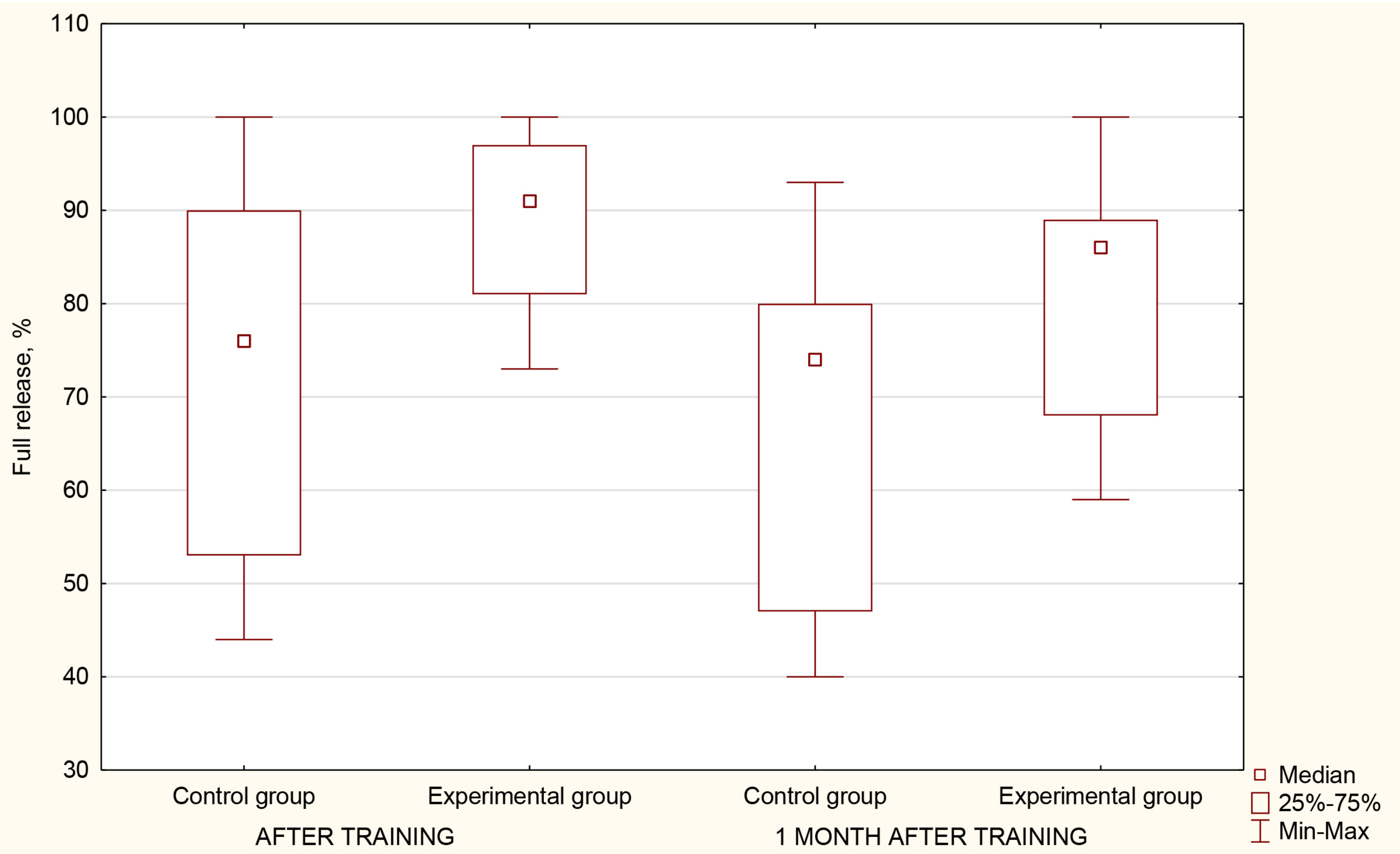
Figure 1. Median compression depth.

Figure 2. Median compression rate.

Figure 3. Median full release.


58
56
54
52
50
48
46
44
42
40
38
36
34
32
Compression depth, mm
Control group
Experimental group
Control group
Experimental group
AFTER TRAINING
1 MONTH AFTER TRAINING
Median
25%-75%
Min-Max


140
135
130
125
120
115
110
105
100
95
Compression rate, per min
Control group
Experimental group
Control group
Experimental group
AFTER TRAINING
1 MONTH AFTER TRAINING
Median
25%-75%
Min-Max


Full release, %
110
100
90
80
70
60
50
40
30
Control group
Experimental group
Control group
Experimental group
AFTER TRAINING
1 MONTH AFTER TRAINING
Median
25%-75%
Min-Max