

From different backgrounds to homogeneity in cardiopulmonary resuscitation knowledge: a pre-post study on instructor-led training to healthcare professionals, medical students and laypeople

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Abstract

Background

Effective cardiopulmonary resuscitation (CPR) training is crucial, yet performance often remains suboptimal among both professionals and laypeople. While structured training improves skills and attitudes, traditional instructor-led sessions may be limited by subjective assessment of CPR quality.

Aim

To assess the acquisition of CPR knowledge after instructor-led certified training in healthcare professionals (HCP), medical students (MS) and laypeople (LP).

Methods

A cross-sectional pre-post study was implemented involving three independent groups registered for certified Basic Life Support (BLS) training courses: HCP, MS and LP. All participants were asked to complete a 12-question anonymous questionnaire based on the American Heart Association guidelines for resuscitation, before and immediately after training. Knowledge gain was assessed by comparing pre- and post-training scores.

Results

The study included 285 participants. Theoretical knowledge improved significantly across all groups ($p < 0.001$), with mean scores increasing from $80.35\% \pm 13.95\%$ to $90.88\% \pm 8.46\%$. While pre-test scores reflected baseline experience (HCP: 89.18%; MS: 80.34%; LP: 70.74%), post-test scores showed no significant difference between groups ($p = 0.378$), indicating a trend toward homogeneity. Analysis of specific items may suggest a "theoretical-practical dissonance" in LP, who struggled with the conceptual recall of hand positioning and depth despite practical training. Conversely, HCPs showed only marginal improvement in the BLS algorithm, likely due to cognitive interference from more complex clinical workflows.

Conclusion

Instructor-led BLS training effectively equalizes theoretical knowledge across diverse backgrounds. However, the nature of knowledge acquisition may vary: novices benefit most from standardized algorithms, while experts may experience interference from advanced frameworks. Furthermore, in LP, practical proficiency may develop through muscle memory even when theoretical recall remains biased, suggesting that educational assessments should increasingly integrate both cognitive and procedural metrics.

INTRODUCTION

Cardiac arrest is a medical emergency that occurs when the heart suddenly stops pumping blood effectively to the body [1, 2]. This life-threatening event can lead to rapid unconsciousness, cessation of breathing, and ultimately death if not promptly addressed. The annual incidence of out-of-hospital cardiac arrests (OHCA) has been estimated at 92.3 cases per 100 000 adults in the United States of America, with an average survival rate of 9.1% [2]. In Europe, the overall incidence of OHCA where cardiopulmonary resuscitation (CPR) is attempted is 56 per 100 000 population, per year, with a survival rate of 8% [18].

CPR is a lifesaving intervention that combines chest compressions with rescue breaths [3, 4]. CPR aims to maintain a minimal blood flow to vital organs [2]. Early initiation of CPR within the first minutes after cardiac arrest is recommended to optimize the chances of survival [3]. Bystander-initiated CPR can double or even triple the chances of survival [3, 5], underscoring the significance of public awareness and education regarding CPR techniques.

Chest compressions are a cornerstone of CPR. Both the American Heart Association (AHA) and the European Resuscitation Council (ERC) provide guidelines for high quality chest compressions [3, 4]. These include placing the hands on the lower half of the sternum; compression depth of at least 5 cm (2 inches) and no more than 6 cm (2.4 inches); rate of compressions between 100 and 120 compressions per minute, minimizing interruptions; allowing complete chest recoil after each compression; if possible, performing compressions on a firm surface.

By understanding the significance of effective chest compressions and promoting widespread CPR training, we empower individuals to respond immediately to cardiac arrest, potentially saving lives in critical situations.

However, the performance and CPR quality delivered by healthcare professionals and laypeople is usually suboptimal [6, 7, 8, 9], highlighting the need to implement CPR training to improve skills and promote better attitudes regarding CPR [10, 11, 12].

A standard CPR training session is provided by trained instructors for a specific period of time [13]; however, the instructor's ability to provide objective assessment of chest compressions quality is shown to be limited [14, 15].

The latest summary statement from the International Liaison Committee on Resuscitation (ILCOR) identified this knowledge gap, regarding "the best methods for training and retraining to achieve high attendance and skill retention" [16].

This gap is particularly relevant when considering different groups, including healthcare professionals, medical students, and laypeople, who may differ in baseline knowledge, previous exposure to resuscitation, and learning needs.

The primary goal of this study is to assess the acquisition of CPR knowledge, through instructor-led certified training, in healthcare professionals, medical students and laypeople.

METHODS

This cross-sectional pre-post study was conducted in the Porto region in Portugal across three population groups with varying levels of baseline Basic Life Support (BLS) knowledge - laypeople, medical students, and healthcare professionals – enrolled in American Heart Association (AHA) certified BLS training.

The study protocol received ethical approval from the Faculty of Medicine of the University of Porto (218/CEFMUP/2024). Written informed consent was obtained from all participants before data collection, and collected data was pseudonymized with unique study IDs.

The STROBE reporting guideline [17] was followed.

Participants and sample size

All BLS initiatives described were coordinated and implemented by the Faculty of Medicine of the University of Porto (FMUP). Recruitment for AHA certified courses was conducted at the Simulation Center of FMUP (SIMFMUP).

A convenience sample was used to recruit healthcare professionals (nurses and physicians), medical students and laypeople. Inclusion criteria required participants to be in good overall health and physical condition, and to be enrolled in a BLS initiative promoted by FMUP. Pregnant women and those reporting physical fatigue or muscle pain were excluded.

The sample size was calculated considering three independent groups, corresponding to the three population groups. An ANOVA test was used to estimate the sample size, with a significance level (α) of 0.05 and a power ($1-\beta$) of 0.95. An effect size of 0.25 was considered, based on an estimated medium effect size. The sample size was estimated to be 189 participants using G*Power software.

Study design

Participants were recruited from BLS initiatives offered by FMUP between October 2024 and June 2025 and voluntarily wished to participate in the study. Participants were divided according to their profile - laypeople, medical students, or healthcare professionals. Healthcare professionals and medical students were enrolled in AHA-certified BLS courses for healthcare professionals, while laypeople were enrolled in AHA-certified HeartSaver CPR & AED courses.

All courses were instructor-led, delivered in a hands-on course format, that included a video-based BLS course, cardiopulmonary resuscitation (CPR) training with emphasis on high-quality CPR skills development, and safe use of an automated external defibrillator (AED). The instructor-to-student ratio was 1:6, with Laerdal Little Anne manikins with feedback device. All participants had access to a study manual to prepare for the course.

Participants were asked to complete a 12-question anonymous questionnaire (Appendix A) before and immediately after training, based on the 2020 AHA guidelines for resuscitation. The questionnaire included demographic data, including gender, age, profile and previous training, as well as questions focused on the BLS algorithm and high-quality CPR for adults. All data were collected through electronic questionnaires.

Outcomes and Statistical Analysis

The primary outcome of this study was BLS knowledge on each group, given by a global knowledge score (%), calculated as the percentage of correct answers and derived from the equally weighted mean of all questionnaire items. Secondary outcomes included the difficulty index (di) calculated from the proportion of participants who answered each item correctly.

Covariates included gender, age (years), occupation and last CPR training. Although previous CPR training was assessed in 6 different periods (never, in the last 6 months, in the last year, in the last two years, in the last five years and more than five years ago), the participants' characteristics were analyzed using only 3 categories (never, in the last two years and more than 2 years ago) in accordance with the two-year validity of AHA certification (2 years).

Descriptive and inferential statistical analysis were conducted using IBM SPSS Statistics software (version 30.0). p -values < 0.05 were considered statistically significant.

RESULTS

Participants' characteristics

The study included 285 participants across three independent groups: healthcare professionals (HCP, $n = 47$); medical students (MS, $n = 195$); and laypeople (LP, $n = 43$). HCP included 10 medical doctors and 37 nurses.

The allocation of participants to each group was made based on their occupation, as shown in Table 1. The majority of the participants were female ($n = 212$, 74%). Most HCP reported previous training in cardiopulmonary resuscitation (CPR) / Basic Life Support (BLS) ($n = 45$, 96%), whereas most MS ($n = 76$, 39%) and LP ($n = 17$, 40%) reported no previous training. The mean age of the participants was 25.50 ± 8.27 years old.

Table 1
– Participants' characteristics. Age is presented as mean $\pm$ standard deviation (SD).

		Healthcare Professionals (n = 47)	Medical Students (n = 195)	Laypeople (n = 43)	p-value*
Gender	Female (n = 212)	33	145	34	0.630
	Male (n = 73)	14	50	9	
Previous Training	< 2 years (n = 72)	14	51	7	< 0.001
	> 2 years (n = 66)	31	25	10	
	Never (n = 147)	2	119	26	
Age (mean $\pm$ SD, years)		32.66 $\pm$ 6.49	20.99 $\pm$ 2.05	38.09 $\pm$ 9.09	< 0.001
*Pearson's chi-squared test for categorical data (gender and previous training) was used. For the variable Age it was used a non-parametric test: Kruskal–Wallis. p-value < 0.05 is statistically significant.					

Subsequent analysis revealed no significant associations in gender; however, there were statistically significant differences between groups regarding age and previous training.

Knowledge Scores

There was a statistically significant improvement ($p < 0.001$), in all participants, from 80.35% $\pm$ 13.95% to 90.88% $\pm$ 8.46%. The improvement in the mean knowledge score was also accompanied by a decrease in the standard deviation (SD), indicating a trend towards homogeneity in the study population, as shown in Table 2 and Fig. 1.

Table 2

– Results from Pre-Test and Post-Test Scores (%). Results presented as mean $\pm$ standard deviation (SD).

Occupation	Pre-Test Score (mean $\pm$ SD, %)	Post-Test Score (mean $\pm$ SD, %)	p-value*
Healthcare Professionals (n = 47)	89.18 $\pm$ 10.12	91.31 $\pm$ 9.19	0.055
Medical Students (n = 195)	80.34 $\pm$ 12.87	91.20 $\pm$ 7.95	< 0.001
Laypeople (n = 43)	70.74 $\pm$ 16.00	88.95 $\pm$ 9.75	< 0.001
p-value**	< 0.001	0.378	
All Participants (n = 285)	80.35 $\pm$ 13.95	90.88 $\pm$ 8.46	< 0.001
*Non-parametric test: Wilcoxon Signed Ranks. p-value < 0.05 is statistically significant			
**Non-parametric test: Kruskal–Wallis. p-value < 0.05 is statistically significant.			

As expected, HCP revealed a high mean pre-test knowledge score (89.18% $\pm$ 10.12%), while MS and LP revealed lower mean values, with 80.34% $\pm$ 12.87% and 70.74% $\pm$ 16.00%, respectively. These differences between groups were statistically significant ($p < 0.001$). Also, in pre-test, the SD was lower in HCP and higher in LP, suggesting that healthcare training was associated with higher scores and lesser heterogeneity between participants.

In post-test, there were no statistically significant differences between groups ($p = 0.378$); however, except for HCP, there was a statistically significant improvement in MS and LP ($p < 0.001$). These results suggest that participants starting with different backgrounds reached comparable levels of knowledge after a single American Heart Association-certified instructor-led BLS course.

There were no statistically significant differences between participants regarding different timing of previous BLS training.

Difficulty Index

Results related to the difficulty index (di) are shown in Table 3. This index was calculated for each questionnaire item, in both pre-test and post-test, for each study group. Higher di values represent an easier question (with more correct answers), while lower values represent more difficult questions (with

less correct answers). In general, in both pre-test and post-test, all questions were considered easy ($d_i > 0.60$). The most difficult question was Q11, related with the BLS algorithm.

Table 3

– Difficulty Index for each questionnaire item, in pre-test, post-test and difference between both, for each study group: Healthcare Professionals (HCP, n = 47); Medical Student (MS, n = 195); and Laypeople (LP, n = 43). C:V corresponds to compression:ventilation, CC corresponds to chest compressions, CPR corresponds to cardiopulmonary resuscitation, and AED corresponds to automated external defibrillator.

	Pre-Test			Post-Test			Difference		
	HCP	MS	LP	HCP	MS	LP	HCP	MS	LP
Q1 C:V Ratio	1.00	0.98	0.86	1.00	0.99	1.00	0.00	0.01	0.14
Q2 CC Position	0.79	0.62	0.51	0.83	0.79	0.51	0.04	0.17	0.00
Q3 CC Rate	1.00	0.89	0.74	1.00	1.00	0.95	0.00	0.11	0.21
Q4 CC Depth	0.79	0.72	0.40	0.85	0.85	0.86	0.06	0.13	0.47
Q5 CC Recoil	0.89	0.81	0.67	0.94	0.92	0.91	0.04	0.12	0.23
Q6 CC Only	1.00	0.91	0.72	1.00	0.96	0.91	0.00	0.05	0.19
Q7 Pause Time	0.89	0.73	0.67	0.94	0.90	0.91	0.04	0.16	0.23
Q8 Safety	1.00	0.98	0.95	1.00	0.99	0.98	0.00	0.01	0.02
Q9 Stop CPR	0.83	0.75	0.65	0.81	0.84	0.81	-0.02	0.09	0.16
Q10 Call Number	1.00	0.97	0.98	1.00	0.99	1.00	0.00	0.03	0.02
Q11 Algorithm	0.53	0.30	0.35	0.60	0.70	0.84	0,06	0.40	0.49
Q12 AED	0.98	0.97	0.98	1.00	0.99	1.00	0,02	0.02	0.02

Apart from Q11, participants revealed more difficulties on Q2, related with chest compression (CC) hand positioning, and Q4, related to CC depth. While HCP and MS presented improvements in Q2, LP revealed no changes, suggesting that while less experienced participants may struggle with theoretical knowledge acquisition, this does not necessarily preclude practical proficiency.

While MS and LP showed significant gains in BLS algorithm knowledge (Q11), HCP exhibited only marginal improvement.

DISCUSSION

The present study aimed to evaluate the acquisition of Basic Life Support (BLS) knowledge across three distinct populations - healthcare professionals (HCP), medical students (MS), and laypeople (LP) - following instructor-led, American Heart Association-certified training. Our findings demonstrate a significant overall improvement in theoretical knowledge, with post-test scores reaching a high level of homogeneity regardless of the participants' initial background.

The primary outcome of this study was a statistically significant increase in the global knowledge score across the entire cohort ($p < 0.001$). Notably, while pre-test scores reflected a predictable hierarchy - where HCPs scored highest and LP lowest—the post-test results showed no statistically significant differences between groups ($p = 0.378$). This convergence toward a mean score of approximately 91% suggests that standardized, instructor-led training may reduce baseline differences in cardiopulmonary resuscitation (CPR) knowledge across heterogeneous learner groups.

From a pedagogical perspective, the reduction in standard deviation post-training is particularly telling. It indicates that the educational intervention narrowed the knowledge gap, bringing participants with minimal prior exposure to a level of theoretical proficiency comparable to that of practicing professionals. This suggests that the acquisition of core BLS concepts is achievable in a single high-intensity session, provided that the training includes evidence-based components such as videos, certified instructors and feedback devices.

An intriguing finding emerged regarding specific aspects of high-quality CPR, particularly chest compression (CC) hands positioning (Q2). While MS and HCPs showed improvements in these theoretical areas, LP demonstrated no apparent improvement. This observation may suggest a theoretical-practical dissonance. In the case of LP, a lack of improvement in a written questionnaire does not necessarily translate to poor performance in a clinical or simulation setting. As noted in the results, a LP's conceptual perception of CC hand placement may be biased or difficult to articulate in a test. However, through the repetitive, hands-on nature of instructor-led training, these participants often develop "muscle memory" or procedural fluency [19]. This suggests that, for non-professionals, the motor skills may outpace the cognitive acquisition of specific guidelines. Future research should utilize the feedback data from the simulators to correlate these theoretical deficits with actual compression metrics to determine if this cognitive gap impacts rescuer efficacy.

Conversely, the data regarding the BLS algorithm (Q11) revealed a possible "expert paradox". While MS and LP showed the most substantial gains, HCP exhibited only marginal improvement. For MS and LP, the BLS algorithm represents a novel, linear roadmap that is easily internalized. For HCPs, however, the basic algorithm is often subsumed by more complex Advanced Life Support (ALS) frameworks. Professionals are accustomed to managing parallel tasks, such as vascular access, medication administration, and advanced airway management, which may occur concurrently with the BLS sequence. This complexity can lead to a possible "cognitive interference" where the rigid, simplified steps of a BLS questionnaire feel counterintuitive to the fluid, high-stakes reality of clinical practice. This suggests that, for experienced providers, training may need to focus less on the repetition of basic sequences and more on the integration of BLS within complex multi-professional team dynamics.

The lack of significant difference between participants with different previous training intervals (e.g., those trained within two years versus those never trained) may challenge the traditional biennial recertification model. The baseline knowledge remains relatively consistent across these timeframes, or conversely, it decays so rapidly that there is no difference between a person trained two years ago and a novice. These results support the ILCOR's call for more frequent, "low-dose, high-frequency" retraining strategies. However, it may also reflect differences in sample composition, baseline experience, or limited sensitivity of the questionnaire to detect long-term knowledge decay.

The shift toward homogeneity in post-test scores is an encouraging indicator for public health. If a single course can elevate a LP's theoretical understanding to a level comparable of a healthcare provider, the potential for bystander intervention may increase significantly. However, as the literature suggests, knowledge is only one precursor of "willingness to act". The high post-training scores observed in our population suggests that the American Heart Association-certified format can effectively build theoretical preparedness, which is an important component of the confidence required to initiate CPR, which is a critical factor in doubling or tripling survival rates in out-of-hospital cardiac arrest.

Limitations

Despite the significant findings regarding knowledge acquisition across different cohorts, several limitations must be considered when interpreting the results. The study utilized a convenience sample consisting of individuals already enrolled in BLS training at a university simulation center. This population may have had a higher baseline motivation or a more proactive attitude toward learning compared to the general public. Consequently, these participants may be more predisposed to successful knowledge acquisition, which could limit the generalizability of the findings to broader, less motivated populations.

This research focused exclusively on theoretical knowledge assessed through the use of written questionnaires. While theoretical understanding is a prerequisite for high-quality CPR, it does not always correlate directly with practical performance. The study did not assess practical skills acquisition - such as the compression depth, rate, recoil and hand position of chest compressions - meaning that "muscle

memory" and procedural proficiency were inferred rather than measured via objective simulator-derived data.

The 12-item questionnaire used to assess BLS knowledge was developed by the study team based on current AHA guidelines. Although the items were designed to reflect clinical standards, the instrument itself has not undergone a formal psychometric validation process. This lack of validation may affect the reliability and internal consistency of the scores across different demographic groups.

The post-test was administered immediately following the training session, capturing only the short-term effect of knowledge acquisition. This study did not evaluate knowledge retention over time. Given that BLS skills are known to decay rapidly - often within months of training - the absence of follow-up data prevents conclusions regarding the long-term educational impact of the instructor-led courses on these specific groups.

CONCLUSIONS

Instructor-led, certified Basic Life Support training evaluated in this study suggests that it is highly effective at equalizing knowledge levels across diverse populations. While novices benefit most from adopting new algorithms, healthcare professionals may experience interference from advanced frameworks.

Furthermore, the discrepancy in laypeople's theoretical scores regarding some cardiopulmonary resuscitation quality parameters suggests that practical competence in this group may rely partly on motor-sensory feedback, rather than only on the cognitive recall of guidelines. These insights emphasize the need for tailored educational strategies that consider different learning profiles of professionals (and their cognitive requirements) and non-professional rescuers (and their procedural requirements).

Declarations

CONFLICTS OF INTEREST

AND FUNDING

The authors declare that there is no conflict of interest.

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Author Contribution

• AN, IJ and CG contributed to the conception and design of the study;• AN, IJ, IL, GM and CG implemented the study and collected the data;• AN, IJ, IL, GM and CG analysed and interpreted the data;•

AN drafted the article. IL, IJ and CG made important and critical contributions to the content;• All authors reviewed it critically;• All authors have approved the manuscript version submitted and agree with its submission.

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Data Availability

The dataset supporting the conclusions of this article is available and can be requested to the corresponding author.

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Figures

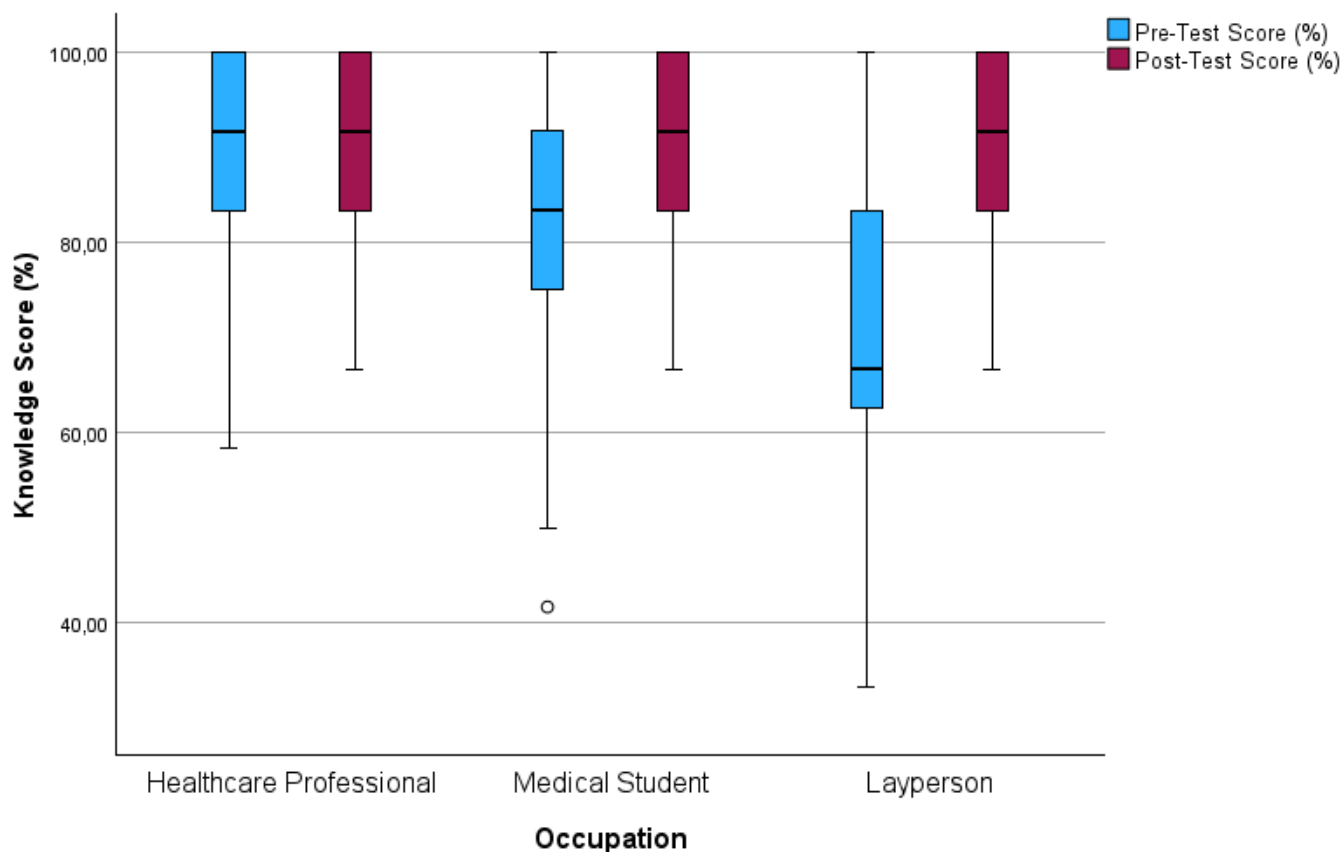


Figure 1

[COLOR] Figure 1 – Box-plot of CPR/BLS knowledge score (%) for each study group (healthcare professionals (n = 47), medical students (n = 195) and laypeople (n = 43)), in both pre-test and post-test.

Supplementary Files

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- [AppendixAv1.docx](#)