Original Article

The general public's ability to operate automated external defibrillator: A controlled simulation study

Xue-jie Dong[1], Lin Zhang[1], Yue-lin Yu[1], Shu-xiao Shi[1], Xiao-chen Yang[1], Xiao-qian Zhang[2], Shuang Tian[2], Helge Myklebust[3], Guo-hong Li[1], Zhi-jie Zheng[4]

[1] *School of Public Health, Shanghai Jiao Tong University, Shanghai, China*
[2] *School of Medicine, Shanghai Jiao Tong University, Shanghai, China*
[3] *Laerdal Medical, Stavanger, Norway*
[4] *School of Public Health, Peking University, Beijing, China*

Corresponding Author: *Lin Zhang, Email: zhanglynn@sjtu.edu.cn*

BACKGROUND: Automated external defibrillators (AEDs) enable laypeople to provide early defibrillations to patients undergoing cardiac arrest, but scant information is available on the general public's ability to use AEDs. This study assessed the ability of laypeople to operate AEDs, the effect of a 15-minute training, and whether skills differed by age.

METHODS: From May 1 to December 31, 2018, a prospective simulation study was conducted with 94 laypeople aged 18–65 years (32 aged 18–24 years, 34 aged 25–54 years, and 28 aged 55–65 years) with no prior AED training. The participants' AED skills were assessed individually pre-training, post-training, and at a three-month follow-up using a simulated cardiac arrest scenario. The critical actions and time intervals were evaluated during the AED operating process.

RESULTS: Only 14 (14.9%) participants (eight aged 18–24 years, four aged 25–54 years, and two aged 55–65 years) successfully delivered defibrillations before training. AED operation errors were more likely to occur among the participants aged 55–65 years than among other age groups. After training, the proportion of successful defibrillations increased significantly (18–24 years old: 25.0% vs. 71.9%, $P<0.01$; 25–54 years old: 11.8% vs. 70.6%, $P<0.01$; 55–65 years old: 7.1% vs. 67.9%, $P<0.01$). After three months, 26.1% of the participants aged 55–65 years successfully delivered defibrillations, which was significantly lower than that of participants aged 18–24 years (54.8%) and 25–54 years (64.3%) ($P=0.02$). There were no differences in time measures among three age groups in each test.

CONCLUSIONS: The majority of untrained laypeople cannot effectively operate AEDs. More frequent training and refresher courses are crucial to improve AED skills.

KEYWORDS: Automated external defibrillator; Cardiac arrest; General public; Training; Simulation

World J Emerg Med 2020;11(4):238–245
DOI: 10.5847/wjem.j.1920-8642.2020.04.006

INTRODUCTION

Early defibrillation is an integral and critical component in the chain of survival for out-of-hospital cardiac arrest (OHCA).[1,2] Automated external defibrillators (AEDs) enable laypeople beyond emergency medical services personnel and healthcare professionals to provide early defibrillations.[3] Laypeople's use of AEDs has been shown to reduce time to first shock, resulting in a two- to three-fold increase in OHCA survival.[4-6]

With the increased availability and accessibility of AEDs, there have been reports of increasing numbers of AED failures in real-world scenarios. AED operation errors such as misplaced AED electrodes, failure to deliver a shock, and AED removal prior to shock delivery are common even among healthcare professionals and laypeople with adequate basic life support (BLS) and AED training.[7-9]

The European Resuscitation Council (ERC), American Heart Association (AHA), and International Liaison Committee on Resuscitation (ILCOR) recommended using an AED by lay cardiopulmonary resuscitation (CPR) providers for cardiac arrest.[1,2,10] AEDs can be used safely and effectively by laypeople without previous training.[11]

However, these studies were focused on AED skills among six-grade children,[12] medical students,[13,14] and healthcare professionals.[15] Few reports were available for the general public, including the elderly. The risk of cardiac arrest increases with age.[5,16] Seniors have higher risks of cardiac arrest and chances of witnessing an OHCA. Accordingly, the elderly population is more likely to be in a situation that requires providing early defibrillation with an AED. Training seniors to operate AEDs is necessary. This study assessed the skill levels of members of the general public aged 18–65 years operating an AED in a simulated cardiac arrest situation, the effect of a 15-minute video-based training, and whether their skills differed by age.

METHODS

Study population

A prospective, controlled simulation study was conducted from May 1 to December 31, 2018. Subjects aged 18–65 years with no prior BLS/AED training were randomly recruited from participants in the "WeCan CPR" training program. The "WeCan CPR" training project is a burgeoning Chinese general public BLS training program for high-quality and basic CPR training that was previously reported by the Global Resuscitation Alliance.[17]

The subjects were offered free training and fully understood that their AED operating performance would be tested before training, after training, and again after three months. To avoid participant dropout, alternative time and places were provided for the follow-up assessment. Written consent was obtained on arrival at the first test site. The study protocol was approved by the Joint Research Ethics Board of the Shanghai Jiao Tong University School of Public Health and Nursing (SJUPN-201714).

AED operation skill assessment

The participants' AED operation skills were assessed individually in an emergency situation that required their actions to rescue a cardiac arrest patient using an AED (Figure 1). The simulated scenario included a manikin (Resusci Anne QCPR, Laerdal Medical, Stavanger, Norway) lying on the floor and an AED training device (Laerdal AED trainer 2, Laerdal Medical, Stavanger, Norway) beside the manikin. The manikin was dressed in a T-shirt and jacket to better portray a cardiac arrest situation and provide a natural barrier to electrode placement. The AED was stored in a zippered carrying case. Two electrode pads adhered to one backing, disconnected with the device, were packed in a pouch that was placed on top of the AED. The device visually guides the user and provides voice prompts once it is powered on. A voice prompt instructed the participants to deliver a shock, with a flashing light on the shock button and loud alarms. A 10-second voice prompt was provided after the shock instructing the operator to resume CPR. The assessment started when the participants walked into the room and stopped when CPR resumed after a shock or when the participant expressed a desire to stop.

In the pre-training test, the participants were told to use the AED to save the patient's life following the AED device's instructions. In the post-training test, AED skill assessment was conducted immediately after training to assess the individually attained level of AED operation skills. The participants were contacted after three months to take the AED operation skill retention test.

AED training session

A 10-minute video lecture and 5-minute hands-on practice were provided in the AED training section of the "WeCan CPR" training course. The video lecture included the rationale for using the AED to save OHCA patients, the AED's functions, and how to operate the AED, that is, turning on the machine, correctly attaching pads on a patient's bare chest, standing clear, pushing the shock button, and resuming CPR after shock. During the practice session, the participants operated the AED trainer on the manikin and received individual feedback from the instructors.

Data collection and outcome measures

The participants' AED operation performances

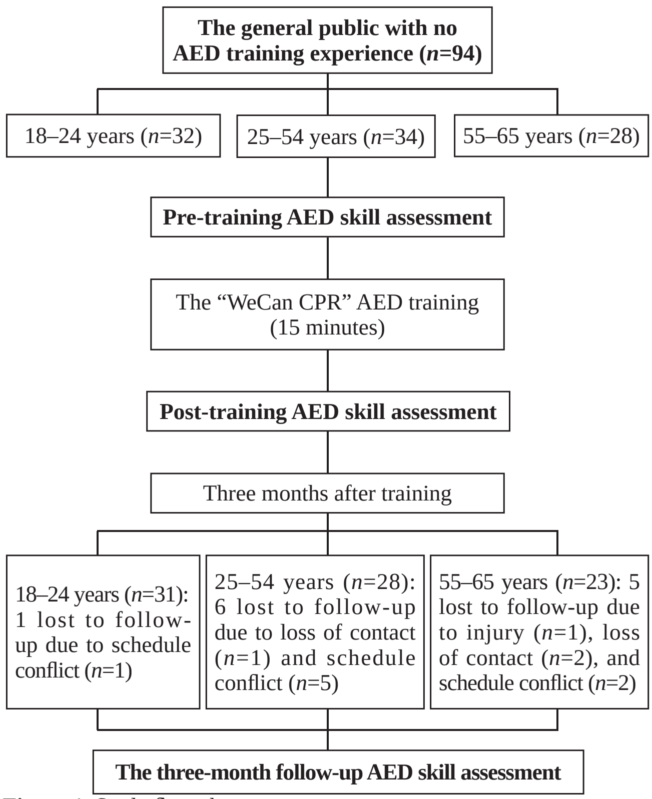

Figure 1. Study flow chart.

were videotaped. The front of the manikin's chest was photographed to evaluate the electrode positions. The AED operation skills were assessed by researchers using a dichotomous (yes/no) format and evaluated using the following steps: (1) turning on the AED (opening the carrying case and pressing the power on button); (2) fully baring the chest by removing the manikin's jacket and shirt; (3) placing the electrodes by opening the pad pouch, peeling the backing sticker, and attaching both electrodes to the chest; (4) correctly placing the electrodes (both electrodes attached within a 5-cm range of the electrode positions recommended by the ERC guidelines[18]); (5) attaching the connector by inserting the plug into the socket; (6) clear while the AED analyzes the rhythm; (7) clear while the AED delivers the shock; (8) pressing the shock button; and (9) resuming CPR after shock. The successful defibrillation was defined as the subject properly completed steps (1) to (8).

The time intervals during the AED performance were assessed after successful defibrillations, including: (1) time for power on (from the simulation scenario onset to pressing the power on button); (2) time for baring the chest (from starting by removing the clothes to fully baring the chest); (3) time for electrode placement (from starting by opening the pad pouch to electrode attachment); (4) time for plug insertion (from touching the plug to plug insertion); (5) time for AED indicating a shock (from onset of the simulation scenario to AED indicating a shock); (6) time for response to shock instruction (from AED indicating a shock to pressing the shock button); (7) time for shock (from onset of the simulation scenario to pressing the shock button); and (8) time for resuming CPR after shock (from pressing the shock button to the beginning of CPR).

The primary outcome was the proportion of successful defibrillations. The secondary outcomes included the proportion of correct electrode placement, the proportion of participants who resumed CPR after shock, time for power on, time for shock, and time for resuming CPR after shock.

Sample size and power analysis

The study sample size was calculated based on the results of an unpublished pilot study in addition to participant availability considerations. We conducted a pilot test comparing the AED operation skill pre-training and post-training in 24 volunteers (eight were 18–24 years old, eight were 25–54 years old, and eight were 55–65 years old). A change in the proportion of successful defibrillations in each age group was considered as a relevant difference. With a statistical power of 90% and a two-sided alpha level of 0.05, the minimum numbers of participants in each age group were eight (18–24 years old), 11 (25–54 years old), and nine (55–65 years old), respectively. Considering the possibility of loss to follow-up and the participants' availability, we recruited 32 participants aged 18–24 years, 34 aged 25–54 years, and 28 aged 55–65 years, which fully outweighed the estimated sample size.

Statistical analysis

The data were presented as frequencies with percentages for categorical variables and mean±standard deviation or median (interquartile range, IQR) [M (P_{25}–P_{75})] for continuous variables. Normal distribution was confirmed using the Kolmogorov-Smirnov test. Categorical variables were compared using the Chi-square test or Fisher's exact test to explore differences in the age groups and test phases. The two-sample *t*-test was used to compare the differences in age between those who completed the three-month follow-up and those who did not. The time intervals were analyzed using the Kruskal-Wallis test to compare differences among the age groups and the Mann-Whitney *U*-test to compare differences between the test phases. A *P*-value of <0.05 was considered statistically significant. The data were analyzed using IBM SPSS 22.0 software (SPSS, Chicago, IL, USA). Digital data analysis for the correct electrode placement was conducted using ImageJ software (version 1.52a).

RESULTS

Characteristics of the participants

Ninety-four of the participants completed the pre-training and post-training tests, and 82 of the participants completed the three-month follow-up. Twelve did not complete the follow-up due to injury (*n*=1), loss of contact (*n*=3), and scheduling conflicts (*n*=8) (Figure 1). There were no significant differences in age or gender between those who completed the three-month follow-up and those who did not.

Proportion of successful defibrillations and correct critical actions

Only 14 (14.9%) participants successfully delivered defibrillations without AED training. During the pre-training test, 59 (62.8%) participants bared the manikin's chest, 66 (70.2%) placed the electrodes, but only 17 (18.1%) correctly placed the electrodes at the specified location (Table 1).

Grouped by age, 8 (25.0%) aged 18–24 years, 4 (11.8%) aged 25–54 years, and 2 (7.1%) aged 55–65 years delivered successful defibrillations (*P*=0.14). The participants aged 55–65 years did the worst in the category of "baring the chest" and "placing the electrodes" compared with the other two age groups (Table 2).

After training, AED skills significantly improved among the participants. The proportion of successful defibrillations in the three age groups was 71.9%, 70.6%, and 67.9% (*P*=0.96), respectively (Table 2). At the three-month follow-up, AED skills declined in all groups. Only 26.1% of the participants aged 55–65 years successfully delivered defibrillations, which was significantly lower than those aged 18–24 years (54.8%) and 25–54 years (64.3%) (P=0.02). The proportions of "correct pad placement" and "resuming CPR after shock" were the lowest in the participants aged 55–65 years (Table 2).

There were significant variations in electrode placements by age groups during the three assessment phases (Figure 2).

Time measures in successful defibrillations

The AED operation time, including time for power on (pre-training 50.5 [16.8–106.8] seconds vs. post-training 21.5 [11.0–51.3] seconds, P=0.02), time for shock (106.5 [100.5–131.0] seconds vs. 79.5 [69.0–87.5] seconds, P<0.01), and time for resuming CPR after shock (12.0 [1.0–16.0] seconds

Table 1. Assessment of correct critical actions in the general public aged 18–65 years, *n* (%)

Critical actions	Pre-training (*n*=94)	Post-training (*n*=94)	Three-month follow-up[a] (*n*=82)	*P*-value[b] (pre-training vs. post-training)	*P*-value[b] (post-training vs. follow-up)
Successful defibrillations	14 (14.9)	66 (70.2)	41 (50.0)	<0.001	0.01
Turning on the AED	94 (100.0)	94 (100.0)	82 (100.0)	-	-
Baring the chest	59 (62.8)	94 (100.0)	75 (91.4)	<0.001	0.01
Placing the electrodes	66 (70.2)	94 (100.0)	78 (95.1)	<0.001	0.05
Correct electrode placement	17 (18.1)	72 (76.6)	44 (53.7)	<0.001	<0.01
Attaching the connector	94 (100.0)	94 (100.0)	82 (100.0)	-	-
Clear while AED analyzes the rhythm	72 (76.6)	86 (91.5)	76 (92.7)	0.005	0.79
Clear while AED delivers the shock	87 (92.6)	93 (98.9)	79 (96.3)	0.070	0.34
Pressing the shock button	94 (100.0)	94 (100.0)	82 (100.0)	-	-
Resuming CPR after shock	9 (9.6)	82 (87.2)	46 (56.1)	<0.001	<0.01

AED: automated external defibrillator; CPR: cardiopulmonary resuscitation; [a]: twelve participants were lost to three-month follow-up; [b]: *P*-values were derived using the Chi-square test. A *P*-value <0.05 was considered statistically significant.

Table 2. Proportion of successful defibrillations and correct critical actions by age groups (years) and three skill assessment phases, *n* (%)

Critical actions	Pre-training				Post-training				Three-month follow-up[a]			
	18–24 (*n*=32)	25–54 (*n*=34)	55–65 (*n*=28)	*P*-value[b]	18–24 (*n*=32)	25–54 (*n*=34)	55–65 (*n*=28)	*P*-value[b]	18–24 (*n*=31)	25–54 (*n*=28)	55–65 (*n*=23)	*P*-value[b]
Successful defibrillations	8 (25.0)	4 (11.8)	2 (7.1)	0.15	23 (71.9)	24 (70.6)	19 (67.9)	0.96	17 (54.8)	18 (64.3)	6 (26.1)	0.02
Turning on the AED	32 (100.0)	34 (100.0)	28 (100.0)	-	32 (100.0)	34 (100.0)	28 (100.0)	-	31 (100.0)	28 (100.0)	23 (100.0)	-
Baring the chest	27 (84.4)	25 (73.5)	7 (25.0)	<0.01	32 (100.0)	34 (100.0)	28 (100.0)	-	30 (96.8)	26 (92.9)	19 (82.6)	0.37
Placing the electrodes	31 (96.9)	26 (76.5)	9 (32.1)	<0.01	32 (100.0)	34 (100.0)	28 (100.0)	-	31 (100.0)	27 (96.4)	20 (87.0)	0.06
Correct electrode placement	10 (31.3)	4 (11.8)	3 (10.7)	0.06	27 (84.4)	24 (70.6)	21 (75.0)	0.41	17 (54.8)	18 (64.3)	6 (26.1)	0.02
Attaching the connectors	32 (100.0)	34 (100.0)	28 (100.0)	-	32 (100.0)	34 (100.0)	28 (100.0)	-	31 (100.0)	28 (100.0)	23 (100.0)	-
Clear while AED analyzes the rhythm	27 (84.4)	27 (79.4)	18 (64.3)	0.17	27 (84.4)	33 (97.1)	26 (92.9)	0.18	28 (90.3)	28 (100.0)	20 (87.0)	0.17
Clear while AED delivers the shock	31 (96.9)	34 (100.0)	22 (78.6)	0.01	31 (96.9)	34 (100.0)	28 (100.0)	0.38	28 (90.3)	28 (100.0)	23 (100.0)	0.11
Pressing the shock button	32 (100.0)	34 (100.0)	28 (100.0)	-	32 (100.0)	34 (100.0)	28 (100.0)	-	31 (100.0)	28 (100.0)	23 (100.0)	-
Resuming CPR after shock	3 (9.4)	4 (11.8)	2 (7.1)	0.91	26 (81.3)	30 (88.2)	26 (92.9)	0.43	22 (71.0)	20 (71.4)	4 (17.4)	<0.01

AED: automated external defibrillator; CPR: cardiopulmonary resuscitation; [a]: twelve participants were lost to three-month follow-up. [b]: *P*-values were derived using the Chi-square test. A *P*-value <0.05 was considered statistically significant.

Table 3. Comparison of time intervals in successful defibrillations by age groups (years) and three skill assessment phases, seconds, M (P_{25}–P_{75}) [a]

Time intervals	Pre-training				Post-training				Three-month follow-up			
	18–24 (*n*=8)	25–54 (*n*=4)	55–65 (*n*=2)[b]	*P*-value[c]	18–24 (*n*=23)	25–54 (*n*=24)	55–65 (*n*=19)	*P*-value[c]	18–24 (*n*=17)	25–54 (*n*=18)	55–65 (*n*=6)	*P*-value[c]
Time for power on	79 (20–155)	28 (13–92)	18, 39	0.06	26 (11–52)	17 (10–43)	20 (12–56)	0.38	31 (22–53)	29 (17–52)	32 (9–41)	0.07
Time to start baring chest	42 (31–65)	44 (41–51)	1, 19	0.55	12 (4–17)	16 (6–25)	14 (1–22)	0.48	4 (1–11)	9 (3–24)	15 (10–31)	0.14
Time for baring the chest	12 (8–15)	8 (7–10)	4, 5	0.08	7 (6–8)	7 (6–9)	6 (6–7)	0.54	6 (6–10)	8 (6–10)	8 (7–8)	0.78
Time for placing the electrodes	24 (18–36)	23 (17–45)	14, 17	0.03	16 (13–23)	17 (11–23)	16 (13–19)	0.60	20 (18–22)	19 (14–23)	16 (13–18)	0.02
Time for inserting the plug	8 (4–11)	6 (3–8)	5, 7	0.94	4 (2–4)	3 (2–6)	3 (3–5)	0.10	4 (3–7)	3 (2–5)	6 (4–6)	0.41
Time for AED indicating a shock	113 (99–177)	105 (100–125)	81, 88	0.09	73 (62–83)	79 (66–86)	76 (72–82)	0.96	78 (73–87)	74 (63–90)	86 (72–103)	0.33
Time for response to shock instruction	3 (3–4)	5 (3–5)	4, 4	0.31	2 (1–3)	3 (2–4)	3 (2–4)	0.01	4 (2–4)	4 (2–5)	5 (3–6)	0.56
Time for shock	117 (102–181)	110 (105–128)	85, 92	0.09	76 (63–86)	82 (69–91)	79 (77–86)	0.90	80 (76–90)	78 (68–95)	93 (75–106)	0.38
Time for resuming CPR after shock	6 (1–12)	15 (12–15)	16, 16	0.23	9 (6–10)	9 (8–10)	10 (9–12)	0.01	12.5 (6–20)	9 (8–11)	9 (9–9)	0.16

AED: automated external defibrillator; CPR: cardiopulmonary resuscitation; [a]: M (P_{25}–P_{75}): median (interquartile range); [b]: two participants in the 55–65 year age group delivered successful defibrillation pre-training, and exact values were shown; [c]: *P*-values were derived using the Kruskal-Wallis test; A *P*-value <0.05 was considered statistically significant.

vs. 9.5 [8.0–11.0] seconds, *P*=0.32) was shorter after training. Compared to post-training, the operation time was retained after three months (time for power on: post-training 21.5 [11.0–51.3] seconds vs. follow-up 30.0 [16.5–52.5] seconds, *P*=0.19; time for shock 79.5 [69.0–87.5] seconds vs. 80.0 [72.0–94.0] seconds, *P*=0.25; and time for resuming CPR after shock 9.5 [8.0–11.0] seconds vs. 9.0 [8.0–14.3] seconds, *P*=0.69) (Figure 3). There were no differences in time use among the age groups during the three phases (Table 3).

DISCUSSION

AEDs are intended to enable the lay public to provide early defibrillations. It has been suggested by the ERC, AHA, and ILCOR that for witnessed cardiac arrest when an AED is available, the defibrillator should be used as soon as possible.[1,2,10] The ability of laypeople to use AEDs effectively and promptly is of the utmost importance to deliver successful defibrillation and improve OHCA survival.[19,20] In our study of the general

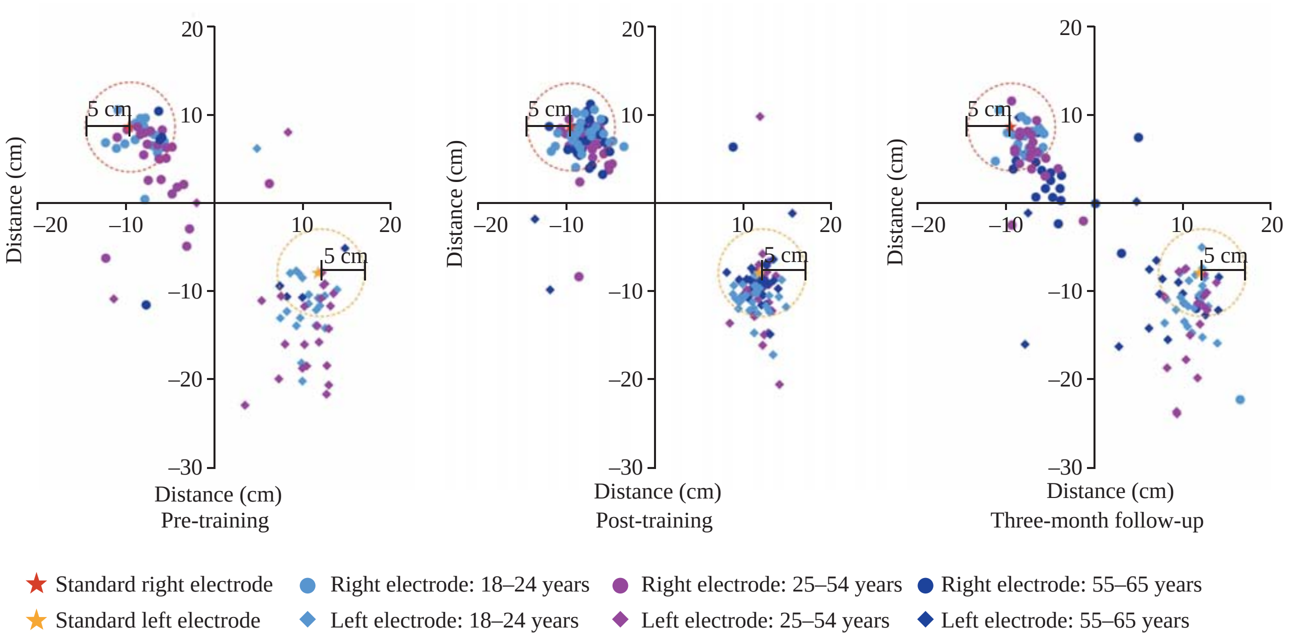

Figure 2. Assessment of AED electrode placement in the study participants by age group. The star icons represented the standard electrode positions that were placed according to the AED's instructional diagrams. Placement of AED electrode by participants within 5 cm of this standard was defined as correct. The coordinates (10, 0) and (–10, 0) represented the manikin's left and right nipples, respectively.

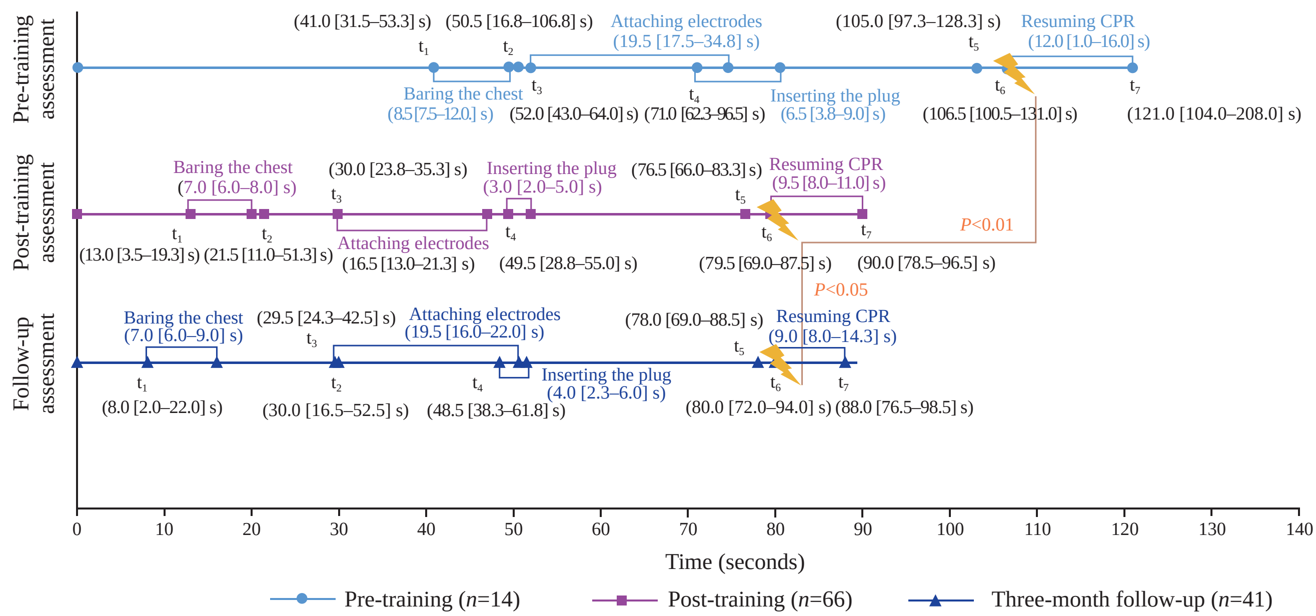

Figure 3. Timelines of successful defibrillations by the general public aged 18–65 years. t_1: start of baring chest; t_2: AED power on; t_3: start of attaching electrodes; t_4: start of inserting the plug; t_5: AED indicating a shock; t_6: delivering the shock; and t_7: resuming CPR. Median values are shown (interquartile range). *P*-values were derived using the Mann-Whitney *U*-test. A *P*-value <0.05 was considered statistically significant.

public aged 18–65 years, laypeople's ability and skill levels were undesirable when they initially used an AED with no training. This study suggested that lack of training could hamper the effectiveness of AED use, particularly under the burgeoning public access defibrillation (PAD) programs.[21]

The first-time AED users with no training could safely deliver a shock and supported that no training was needed for AED use.[11] Of note, the majority of studies were conducted on either students or healthcare professionals. Gundry et al[12] found that 15 untrained sixth-grade students could deliver shocks with a mean time of 90±14 seconds, and electrode placement and safety were acceptable for all of the subjects. Mattei et al[15] reported that 15 untrained nurses and physiotherapists could deliver a shock in 68.9±29.2 seconds. Becker et al[13,14] examined the use of AEDs by 295 first-year medical students who had no previous training and found that shocks were administered safely in 94.6% subjects, and pads were positioned correctly by 85.4%. Basanta Camiño et al[22] reported that the mean time taken by 129 university students to apply an AED discharge was 67.7±15.6 seconds with no training, demonstrating that AEDs were easy for laypeople to manage.

Because the risk of OHCA increases with age,[5,16] seniors are more likely to have cardiac arrest or witness an OHCA in their spouse or family members. Therefore, the elderly are more likely to be in real emergencies that require the use of an AED. Previous research by Brooks et al[23] demonstrated a trend toward less knowledge and confidence in using AEDs in older citizens. In the present study, we found a considerable discrepancy in AED skills among the age groups. Senior individuals did not fare well in their AED performance without training or after training. More frequent training may be required for older individuals to save lives.

During AED operation, the participants performed well on steps such as "pressing the power on button", "inserting the plug", and "pressing the shock button", which were fully displayed on the device. However, they were much more likely to disregard steps such as removing clothes, placing the electrodes, and resuming CPR after shock. These findings could help develop more focused AED audio guides to assist laypeople, especially first-time users, to properly operate this life-saving device.

Correct electrode placement is essential to maximize current distribution in the myocardium and optimize the potency of defibrillations.[18,24] In the pre-training and follow-up phases, incorrect electrode placement was the most common error, followed by failure to fully remove the patient's clothes and not opening the pad packing materials. In failed cases, mostly seniors attempted to defibrillate through the shirt or pad pocket. In accordance with previous studies, incorrect pad placement mostly occurred on the left side.[25,26] The left electrode was more likely to be attached medially and lower than the recommended position. This could be due to laypeople's inability to understand the diagrams.[27] Theoretically, electrode diagrams are the most intuitive instruction for laypeople to learn the correct position. However, Foster et al[28] found that the diagrams of 27 commercially available AEDs led to more than 5 cm variations from the optimal position as defined by guidelines, suggesting that AED instruction diagrams may be misleading. Improving AED electrode instruction is thus warranted, and a more clear and effective pad placement diagram is urgently needed.

Immediately resuming CPR after shock is critically important to minimize pauses in chest compressions.[1,2] We demonstrated that only 9.6% of the untrained subjects began CPR after they heard the voice instruction. Although significant improvements were observed after training, resuming CPR at the three-month follow-up was not optimal either, especially in seniors. In the participants who resumed CPR, we found a 10-second duration to start CPR, the same as the duration of the AED's voice prompt to start CPR. Laypeople depend on the device's instructions during operation. Mosesso et al[29] suggested that subjects were more likely to start CPR with devices that provided detailed and step-by-step CPR instructions. Although the voice prompt is easy to ignore, laypeople still rely on it to act. Alternative AED designs on the CPR performance instructions should be explored.

In the untrained participants, the median time for shock was 107 seconds. This time decreased to 80 seconds after training and was maintained at the three-month follow-up. Our results were consistent with findings by Mattei et al[15] and Becker et al[13,14] that medical students could deliver a shock in 70–80 seconds. Timelines showed that in three test phases, the time from AED power on to shock was approximately the same, with no significant differences among age groups. At laypeople's initial use of AED, delay in powering on the device was the main reason for prolonged time for shock. Before powering on the AED, the participants spent approximately one minute exploring the device, and they tended to remove the clothes or place the electrodes first. The laypeople were not familiar with the AED at first use, and this lack of skills could be ameliorated with training.

Training is the optimal solution to improve AED skills.[30,31] Our results corroborated the findings of previous studies that laypeople of all ages, including seniors, can be properly taught to use AEDs after a brief training period.[11,32,33] Skill declining following AED training was a commonly acknowledged fact, and a refresher course was always necessary.[34,35] By comparing three age groups, we found that skill decline was the most apparent in seniors. Their ability to place the electrodes correctly and resume CPR after shock remained the worst. Meischke et al[32] reported similar concerns that one-fourth of seniors were unable to deliver a shock three months after training, and half did not properly attach the pads. Although retraining can maintain skill performance levels, in practice, it is difficult to convince laypeople to return for a refresher course. [11,35] To date, in addition to effective training sessions and refresher courses, AEDs with more optimal designs,[28,36] providing real-time assistance,[37] or mobile apps[38] have been reported to improve AED capabilities in untrained laypeople in simulation settings. Further progress is necessary to improve the effectiveness of initial training to make AEDs more intuitive to use and provide assistance to help laypeople use AEDs.

This study had several limitations. First, it was not conducted in real-life settings considering ethical issues. It was carried out under simulated conditions, which may not reflect the same actions and thoughts as those obtained in an actual cardiac arrest situation. We set a single-rescuer scenario to better observe each individual's performance during operation. However, in real emergencies, it is recommended that two or more rescuers use the AED cooperatively.[1,2] Second, we recruited senior participants aged 55–65 years because those older than 70 years were less likely to participate in this trial considering their physical capacity. Third, our study utilized one type of AED trainer that might not be the same as those used in real situations. Nevertheless, we selected an AED trainer that was the most typical type of AED device with two electrodes, accessories, visual guidance, and voice prompts. Finally, the definition of correct electrode placement within 5 cm from the recommended position was used in accordance with previous studies;[24] however, the exact influence of this distance on successful defibrillation is unknown.

CONCLUSIONS

Untrained members of the general public, particularly seniors, are not capable of effectively operating AEDs. Training sessions and refresher courses are crucial to improve laypeople's AED skills and skill retention. Further progress should be pursued to improve the effectiveness of initial training to make AEDs more intuitive to use and provide assistance to help laypeople operate them.

ACKNOWLEDGEMENT

The authors express their appreciation to the participants from Shanghai Jiao Tong University and Chaoyang community who volunteered to take part in this study. Special thanks to Ms. Joyce Kong of Laerdal Medical for her review of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China (81703303); Shanghai Municipal Government Pujiang Research Development Program (17PJC070); HeartRescue Project China Program; and Innovative Research Team of High-level Local Universities in Shanghai.

Ethical approval: The study protocol was approved by the Joint Research Ethics Board of the Shanghai Jiao Tong University Schools of Public Health and Nursing (SJUPN-201714).

Conflicts of interest: We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work. One co-author of our study HM is an employee at Laerdal Medical. The manufacturer Laerdal Medical, Norway was not conflicted with the trial or in interpreting the results of the manuscript. There is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in, or the review of, the submitted manuscript.

Contributors: LZ conceptualized the study. XJD, YLY, SXS, XCY, XQZ, and ST performed the data collection. XJD and LZ analyzed the data. XJD and LZ contributed to writing. HM, GHL, and ZJZ provided administrative advice and consultations and critically revised the paper. All authors approved the final version of the manuscript.

REFERENCES

1 Kleinman ME, Brennan EE, Goldberger ZD, Swor RA, Terry M, Bobrow BJ, et al. Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2015;132(18 Suppl 2):S414-35.

2 Perkins GD, Handley AJ, Koster RW, Castren M, Smyth MA, Olasveengen T, et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 2. Adult Basic Life Support and Automated External Defibrillation. Resuscitation. 2015;95:81-99.

3 Baekgaard JS, Viereck S, Moller TP, Ersboll AK, Lippert F, Folke F. The effects of public access defibrillation on survival after out-of-hospital cardiac arrest: a systematic review of observational studies. Circulation. 2017;136(10):954-65.

4 Holmberg MJ, Vognsen M, Andersen MS, Donnino MW, Andersen LW. Bystander automated external defibrillator use and clinical outcomes after out-of-hospital cardiac arrest: a systematic review and meta-analysis. Resuscitation. 2017;120:77-87.

5 Sasson C, Rogers MAM, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. Circ Cardiovasc Qual Outcomes. 2010;3(1):63-81.

6 Kiyohara K, Kitamura T, Sakai T, Nishiyama C, Nishiuchi T, Hayashi Y, et al. Public-access AED pad application and outcomes for out-of-hospital cardiac arrests in Osaka, Japan. Resuscitation. 2016;106:70-5.

7 Zijlstra JA, Bekkers LE, Hulleman M, Beesems SG, Koster RW. Automated external defibrillator and operator performance in out-

of-hospital cardiac arrest. Resuscitation. 2017;118:140-6.
8 Bodtker H, Rosendahl D. Automated external defibrillators and defibrillation electrodes from major manufactures depict placement of the left apical defibrillation electrode poorly! Resuscitation. 2018;125:e11-2.
9 Agerskov M, Nielsen AM, Hansen CM, Hansen MB, Lippert FK, Wissenberg M, et al. Public access defibrillation: great benefit and potential but infrequently used. Resuscitation. 2015;96:53-8.
10 Olasveengen TM, de Caen AR, Mancini ME, Maconochie IK, Aickin R, Atkins DL, et al. 2017 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations Summary. Resuscitation. 2017;121:201-14.
11 Yeung J, Okamoto D, Soar J, Perkins GD. AED training and its impact on skill acquisition, retention and performance—a systematic review of alternative training methods. Resuscitation. 2011;82(6):657-64.
12 Gundry JW, Comess KA, DeRook FA, Jorgenson D, Bardy GH. Comparison of naive sixth-grade children with trained professionals in the use of an automated external defibrillator. Circulation. 1999;100(16):1703-7.
13 Beckers S, Fries M, Bickenbach J, Derwall M, Kuhlen R, Rossaint R. Minimal instructions improve the performance of laypersons in the use of semiautomatic and automatic external defibrillators. Crit Care. 2005;9(2):R110-6.
14 Beckers SK, Fries M, Bickenbach J, Skorning MH, Derwall M, Kuhlen R, et al. Retention of skills in medical students following minimal theoretical instructions on semi and fully automated external defibrillators. Resuscitation. 2007;72(3):444-50.
15 Mattei LC, McKay U, Lepper MW, Soar J. Do nurses and physiotherapists require training to use an automated external defibrillator? Resuscitation. 2002;53(3):277-80.
16 Wissenberg M, Lippert FK, Folke F, Weeke P, Hansen CM, Christensen EF, et al. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. JAMA. 2013;310(13):1377-84.
17 Global Resuscitation Alliance. The WeCan CPR Training Program in China. Available at https://www.globalresuscitationalliance.org/wp-content/uploads/2019/12/China_Community_Training. pdf. July 20, 2020 update.
18 Soar J, Nolan JP, Bottiger BW, Perkins GD, Lott C, Carli P, et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 3. Adult Advanced Life Support. Resuscitation. 2015;95:100-47.
19 Smith CM, Lim Choi Keung SN, Khan MO, Arvanitis TN, Fothergill R, Hartley-Sharpe C, et al. Barriers and facilitators to public access defibrillation in out-of-hospital cardiac arrest: a systematic review. Eur Heart J Qual Care Clin Outcomes. 2017;3(4):264-73.
20 Smith CM, Perkins GD. Improving bystander defibrillation for out-of-hospital cardiac arrest: capability, opportunity and motivation. Resuscitation. 2018;124:A15-6.
21 Zhang L, Li B, Zhao X, Zhang Y, Deng Y, Zhao A, et al. Public access of automated external defibrillators in a metropolitan city of China. Resuscitation. 2019;140:120-6.
22 Basanta Camiño S, Navarro Patón R, Freire Tellado M, Barcala Furelos R, Pavón Prieto MP, Fernández López M, et al. Assessment of knowledge and skills in using an automated external defibrillator (AED) by university students. A quasi-experimental study. Med Intensiva. 2017;41(5):270-6.
23 Brooks B, Chan S, Lander P, Adamson R, Hodgetts GA, Deakin CD. Public knowledge and confidence in the use of public access defibrillation. Heart. 2015;101(12):967-71.
24 Esibov A, Chapman FW, Melnick SB, Sullivan JL, Walcott GP. Minor variations in electrode pad placement impact defibrillation success. Prehosp Emerg Care. 2016;20(2):292-8.
25 Staerk M, Bodtker H, Lauridsen KG, Lofgren B. Automated external defibrillation training on the left or the right side—a randomized simulation study. Open Access Emerg Med. 2017;9:73-9.
26 Bodtker H, Rosendahl D. Correct AED electrode placement is rarely achieved by laypersons when attaching AED electrodes to a human thorax. Resuscitation. 2018;127:e12-3.
27 Nurmi J, Castren M. Layperson positioning of defibrillation electrodes guided by pictorial instructions. Resuscitation. 2005;64(2):177-80.
28 Foster AG, Deakin CD. Accuracy of instructional diagrams for automated external defibrillator pad positioning. Resuscitation. 2019;139:282-8.
29 Mosesso VN Jr, Shapiro AH, Stein K, Burkett K, Wang H. Effects of AED device features on performance by untrained laypersons. Resuscitation. 2009;80(11):1285-9.
30 Greif R, Lockey AS, Conaghan P, Lippert A, De Vries W, Monsieurs KG, et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 10. Education and implementation of resuscitation. Resuscitation. 2015;95:288-301.
31 Bhanji F, Donoghue AJ, Wolff MS, Flores GE, Halamek LP, Berman JM, et al. Part 14: Education: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2015;132(18 suppl 2):S561-73.
32 Meischke HW, Rea T, Eisenberg MS, Schaeffer SM, Kudenchuk P. Training seniors in the operation of an automated external defibrillator: a randomized trial comparing two training methods. Ann Emerg Med. 2001;38(3):216-22.
33 Mitchell KB, Gugerty L, Muth E. Effects of brief training on use of automated external defibrillators by people without medical expertise. Hum Factors. 2008;50(2):301-10.
34 Christenson J, Nafziger S, Compton S, Vijayaraghavan K, Slater B, Ledingham R, et al. The effect of time on CPR and automated external defibrillator skills in the public access defibrillation trial. Resuscitation. 2007;74(1):52-62.
35 Woollard M, Whitfield R, Newcombe RG, Colquhoun M, Vetter N, Chamberlain D. Optimal refresher training intervals for AED and CPR skills: a randomised controlled trial. Resuscitation. 2006;71(2):237-47.
36 Mabrouk Z, Helmert JR, Müller MP. Evaluation of a usability optimized AED design. Resuscitation. 2018;130:e57-8.
37 Maes F, Marchandise S, Boileau L, Le Polain de Waroux JB, Scavee C. Evaluation of a new semiautomated external defibrillator technology: a live case video recording study. Emerg Med J. 2015;32(6):481-5.
38 Carballo-Fazanes A, Jorge-Soto C, Abelairas-Gómez C, Bello-Rodríguez J, Fernández-Méndez F, Rodríguez-Núñez A. Could mobile apps improve laypeople AED use? Resuscitation. 2019;140:159-60.

Received January 12, 2020
Accepted after revision June 1, 2020