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Repetitive sessions of formative self-testing to refresh CPR skills: A randomised non-inferiority trial☟

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Objectives: To investigate whether repetitive sessions of formative self-testing (RFST) result in an equal cardiopulmonary resuscitation (CPR) skill level compared to repetitive sessions of formative self-testing with additional practice (RFSTAP).
Methods: In a non-inferiority trial, 196 third-year medical students were randomised to an RFST or RFSTAP group. Testing and practising took place in a self-learning station equipped with a manikin connected to a computer. Each cycle of RFST consisted of a 2-min CPR test followed by feedback and feedforward. In the RFSTAP group, additional practice consisted of CPR exercises with a computer voice feedback. To be successful, a combined score consisting of ≥70% compressions with a depth of ≥50 mm and ≥70% compressions with complete release (<5 mm) and a compression rate of 100–120 min^{-1} and ≥70% ventilations with a volume of 400–1000 ml had to be achieved within 6 weeks. Skill retention was measured after 6 months. The non-inferiority margin was predefined as a 10% difference in success rate.
Results: After six weeks the success rate in both groups was 96%: 99/103 (RFST) and 89/93 (RFSTAP). After 6 months, the success rate in the competent students was 26/96 (27%) for RFST and 32/86 (37%) for RFSTAP (three students dropped out in each group). The difference in the success rate between RFSTAP and RFST was 10% and 90% (CI −2 to 23%), respectively. As the upper bound exceeded 10%, non-inferiority was inconclusive. For each CPR skill separately, RFST was non-inferior for ventilation and complete release, superior for compression depth and inferior for compression rate.
Conclusions: RFST and RFSTAP were equally effective to refresh skills within 6 weeks. After 6 months, non-inferiority was inconclusive for the combined score. Our results indicate the potential of RFST to refresh CPR skills.

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1. Introduction

Cardiopulmonary resuscitation (CPR) skills deteriorate in as little as 3–6 months[1] underpinning a need for the development of effective learning and retraining strategies. Learning strategies should be cost-effective and time-efficient. In order to achieve this, efficient educational strategies need to be developed with reduced training time, whilst being at least as effective as current practices. To learn CPR skills, testing in combination with retraining has proved to be more effective than training alone.[2] Frequent assessments help one to identify individuals requiring refresher training,[1] and the retrieval of information during testing appears to strengthen the retention of this information.[3] Also, several educational studies have shown that testing is superior to restudying for an equivalent amount of time, thus underpinning its efficiency.[3–6] Testing seems especially effective in promoting long-term knowledge retention.[7,8] Providing an immediate and accurate test result (=feedback) together with information on how to further

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improve (=feedforward) is known to be a powerful tool for learning improvement.[9–12] The combination of testing and providing feedback and feedforward to guide learners towards improvement is called formative testing.[13] Previous research demonstrated the efficacy of repetitive sessions of formative self-testing followed by additional practice to achieve high-quality CPR skills.[14]

In the present study, we hypothesise that in a self-learning (SL) station, repetitive sessions of formative self-testing (RFST) results in an equal CPR skill level compared to repetitive sessions of formative self-testing with additional practice (RFSTAP) within 6 weeks and after 6 months. Because formative testing alone would make additional training redundant and thus could save time, we adopted a non-inferiority research design. By reducing training time while maintaining high quality, the training model could become time-efficient and cost-effective.

2. Methods

The study was approved by the Ethics Committee of Ghent University Hospital. Informed consent was obtained from a study population consisting of 218 third-year medical students. During a 6-week study period, a self-learning station, as described previously, was made available in a small room accessible 24 h a day and 7 days a week.[14–17] In Google calendar, participants booked an individual session limited to a maximum of 30 min. If needed, additional sessions of 30 min could be booked until proficiency was achieved.

Practising and testing were done on a full-size torso and using a face shield (Laerdal, Norway), while performance chest compression depth, complete release, compression rate and ventilation volume were registered. At the beginning of the first session, an automated 2 min test asked the participant to resuscitate a victim of cardiac arrest for 2 min in order to assess baseline compression and ventilation skills.[18] To allow calculation of a meaningful test result, we defined that a minimum of 120 compressions over 2 min had to be recorded. If not achieved, a message was displayed asking the student to perform a new test. To be considered competent, participants had to achieve a 70% combined assessment score consisting of ≥70% compressions with a depth of ≥50 mm and ≥70% compressions with complete release (<5 mm) and a compression rate of 100–120 min^{-1} and ≥70% ventilations with a volume of 400–1000 ml.[14,17] After the test, feedback was automatically provided on-screen to the student accompanied by feedforward (i.e. how to improve in the future) in case the student was not successful (Fig. 1). The feedback consisted of a competent or not yet competent mark in relation to the combined assessment score described above, as well as the proportion of correct skills for each of the scoring components (depth, release, rate and ventilation volume).

Participants not achieving a 70% combined assessment score after the baseline test were automatically block randomised by the computer (block size $n = 220$) to repetitive formative self-testing (RFST) or to repetitive formative self-testing with additional practice (RFSTAP) (Fig. 1).

All students were expected to achieve competence within 6 weeks, using as many sessions as required.

When the student logged in for a new session, the result of his last test (= feedback) together with feedforward on how to improve during the following session was displayed. Participants could either perform a new test (RFST group) or practice CPR (30 compressions to two ventilations) on the manikin assisted by concurrent computer voice feedback (Resusci Anne Skills Station™) until they felt competent to perform a new test (RFSTAP group).[17] During the additional practice, voice feedback by the Skills Station™ was based on specific targets: compression depth of ≥50 mm; complete release <5 mm; compression rate of 100–120 min^{-1} and ventilation volume of 400–1000 ml (because the chest of the manikin visibly rises after insufflation of 400 ml).[16,17]

Students who passed the baseline test were considered competent in CPR and were excluded from the study. Non-competent participants were randomised and after achieving the 70% combined assessment score they were invited for a retention test six months later.

2.1. Objectives and outcome measures

The outcome measure was the attainment of a combined score consisting of ≥70% compressions with a depth of ≥50 mm and ≥70% compressions with complete release (<5 mm) and a compression rate of 100–120 min^{-1} and ≥70% ventilations with a volume of 400–1000 ml. We hypothesised that the RFST group could achieve similar skill levels as the RFSTAP group.

The primary endpoint was skill retention after 6 months. The secondary endpoint was to achieve a particular proportion of successful students after 6 weeks. For the primary outcome, the null hypothesis (H0) stated that repetitive formative self-testing (RFST) is inferior to repetitive formative self-testing with additional practice (RFSTAP) versus the alternative (HA) that repetitive formative self-testing is non-inferior. In analogy with a previous non-inferiority trial, a difference of 10% was defined as non-inferior.[15] To establish non-inferiority the upper limit of the 90% confidence interval (CI) for the difference in the proportion of students passing on RFSTAP and the proportion of students passing on RFST needed to fall below the predefined non-inferiority margin.

2.2. Statistical methods

A two-sided 90% confidence interval for the difference in success rates was calculated for the primary endpoint instead of a 95% CI for the purpose of a one-sided test. Assuming a true difference of 10% in favour of the RFST group, about 100 patients per group are required to achieve a 90% power to claim non-inferiority.[19] This methodological choice was made since assuming that no difference between the groups would have required more than 400 patients in each group, which would not have been feasible given the limited student population. Based on an explanatory analysis, confidence intervals were calculated for each of the CPR skills separately, and non-inferiority was assessed using the same non-inferiority margin.

3. Results

During the academic year 2012–2013, 218 third-year medical students, who had all followed a CPR course in their second year of medicine (1 year earlier), were enrolled in the study (Fig. 1). Twenty-two students passed the baseline test and were excluded from the study. The remaining 196 students were randomised into an RFST and RFSTAP group (Fig. 1). The mean age of the students was 20.5 years (SD = 2.1 years) and 60% were female.

3.1. Skill level after 6 weeks

After 6 weeks, the success rate in both groups was 96%: 99/103 (RFST) and 89/93 (RFSTAP). The difference in the success rate between RFSTAP and RFST was 0% (90% CI −5 to 6%). In each group, four students did not achieve competence and received instructor-led remedial. They were excluded from the retention analysis. Since the improvement after 6 weeks was equal in both groups, the efficacy of formative self-testing was confirmed. The mean number of sessions required to become competent was 2.7 (SD, 2.3; min., 1;

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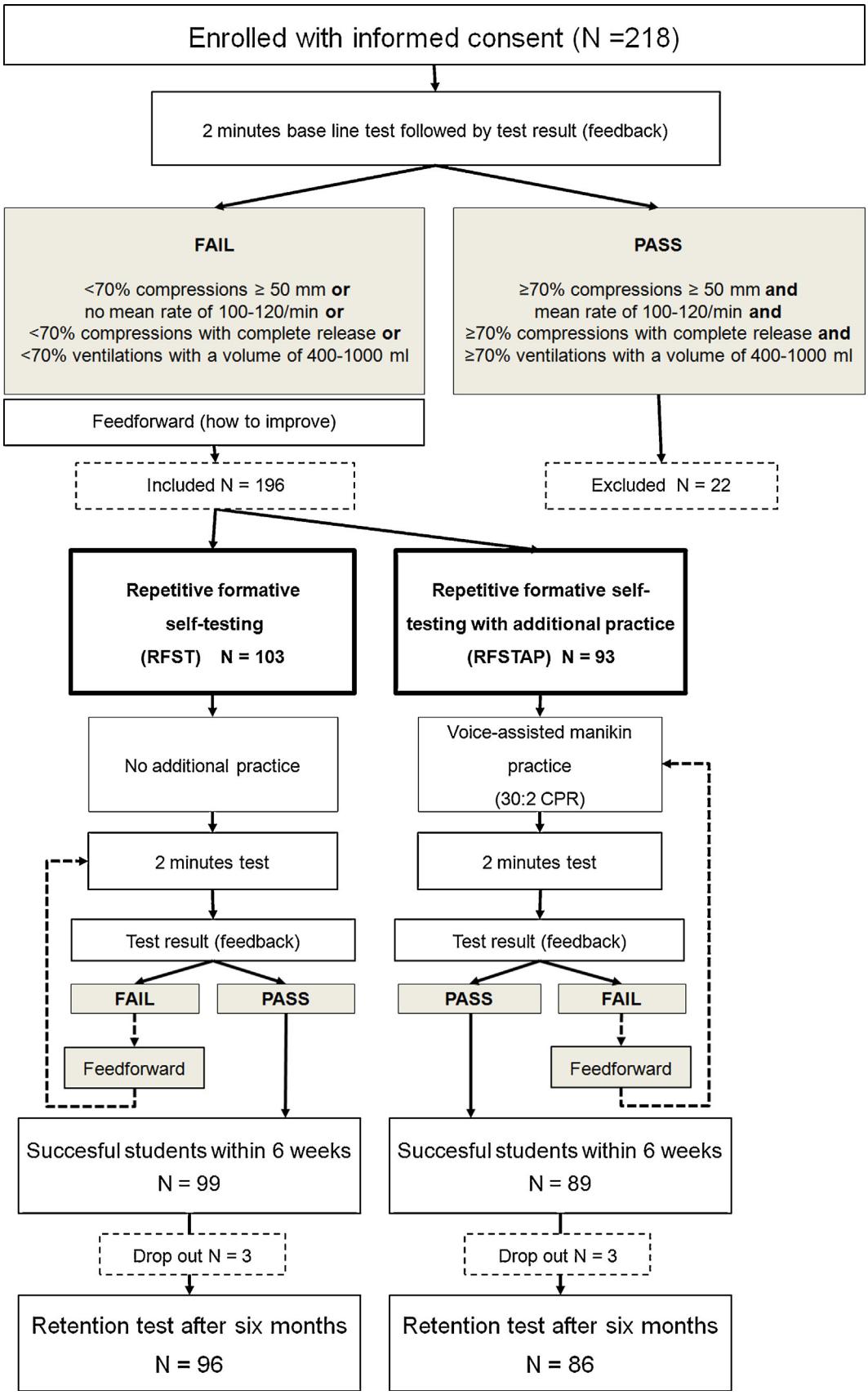

Fig. 1. Participant flow chart.

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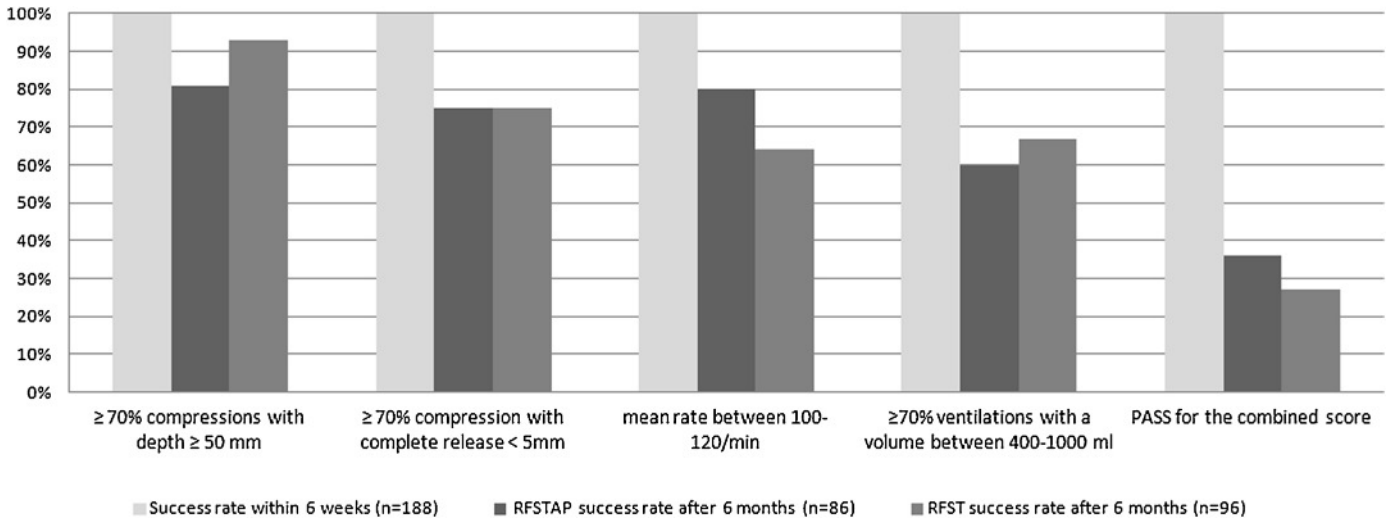

Fig. 2. Results after 6 weeks and after 6 months.

max., 15; median, 2) for the RFST group and 2.0 (SD, 1.5; min., 1; max., 7; median, 1) for the RFSTAP group.

3.2. Skill retention after 6 months

After 6 months, 96 students (RFST) and 86 students (RFSTAP) were retested. Three students dropped out in each group. The results for both groups are illustrated in Fig. 2.

In relation to the primary endpoint, the upper limit of the 90% confidence interval for the difference in the success rate between RFSTAP and RFST exceeded 10% (see Table 1). Since the CI included the 10% non-inferiority margin and zero, the difference is not significant and the result regarding non-inferiority was inconclusive.

Considering the confidence intervals for each of the CPR skills separately, formative self-testing was non-inferior to formative self-testing with additional practice (RFSTAP) for ventilation skills and complete release, superior for compression depth and inferior for compression rate (Table 1). For the compression rate, however, the true treatment difference was less than the 10% non-inferiority margin (included in the CI) but RFST was significantly worse than RFSTAP.

4. Discussion

Our results demonstrate non-inferiority for a combined assessment score using repetitive formative self-testing (RFST) compared to repetitive formative self-testing with additional practice (RFSTAP) after 6 weeks.

After 6 months, 73% (RFST) and 63% (RFSTAP) of the participants were unable to achieve the 70% combined assessment score for CPR skills. This was mainly due to inadequate ventilations skills: in the RFST group 33% and in the RFSTAP group 38% of students were unable to achieve the 70% threshold for ventilation volume. Additionally, in the RFST group, inadequate compression rate in 36% of the participants also contributed to the decay in combined assessment score. Regarding the poor retention of compression rate, we hypothesise that it is difficult to remember the rate of 100–120 min^{-1} during CPR, which was also observed in a previous study.[14] A possibility of improving the recalling of the correct chest compression rate might be to optimise feedback by introducing a beat or a song indicating the correct rate.[12,20]

Although the combined assessment score showed important decay in both groups, retention for both compression depth and complete release remained high. After 6 months, the 70% threshold was maintained in 93% (RFST) and 83% (RFSTAP) of the participants for compression depth and 75% (RFST) and 77% (RFSTAP) of the participants for complete release. The superiority of RFST compared to RFSTAP is an important finding since it has recently been confirmed that compression depth is the skill most influencing survival.[21,22]

Previous research demonstrated the efficacy of multiple training sessions with testing and feedback to achieve high-quality CPR skills mastery. However, given the important decay in combined assessment score, maintaining success after several months remains a challenge.[14] The same phenomenon was observed in the present trial, confirming the need for more frequent assessments. In

Table 1
Difference in proportion of successful students after 6 months (90% CI).

	Repetitive formative self-testing (RFST) ($N=96$) n (%)	Repetitive formative self-testing with additional practice (RFSTAP) ($N=86$) n (%)	Difference (%)	90% CI
PASS for the combined score	26 (27)	32 (37)	10	−2 to 23%
≥70% compressions with depth ≥50 mm	89 (93)	71 (83)	−10	−19 to −1%
≥70% compression with complete release <5 mm	72 (75)	66 (77)	2	−9 to 13%
Mean rate of 100–120 min^{-1}	61 (64)	70 (81)	17	6 to 29%
≥70% ventilations with a volume of 400–1000 ml	64 (67)	53 (62)	−5	−18 to 7%

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a review on competency assessment, Allen et al.[23] suggested testing once or twice a year. With the formative self-testing described in this study, this might even be achieved on a more frequent basis requiring limited time. The current results additionally underscore the potential of formative self-testing to refresh CPR skills effectively and in an efficient way, whilst achieving high quality.

The time on task for each formative self-test is 2 min. A limitation of this study is that the exact time spent in the self-learning station is unknown since the required time for additional practice was flexible and not recorded (although each session was limited to a maximum of 30 min). Therefore, only the total number of sessions could be reported.

A sample size limitation might explain the fact that a difference in the success rate between RFSTAP and RFST of 10% (90% CI −2 to 23%) was statistically inconclusive with regard to non-inferiority as the upper bound of the CI exceeded the 10%. However, making the usual no difference assumption between the experimental and control groups would have required a sample size of more than 800 participants which was not feasible given the available student population.

5. Conclusions

RFST and RFSTAP were equally effective to improve skills after 6 weeks. After 6 months, non-inferiority was inconclusive for the combined assessment score. Our results indicate the potential of RFST to refresh CPR skills. The substantial decay for the combined assessment score in both groups after 6 months indicates the need for more frequent assessments.

Conflict of interest statement

We received an unrestricted grant from the Laerdal Foundation. Laerdal (Stavanger, Norway) provided the manikin, the face shields and the Resusci Anne Skills Station™ licenses for the study. Laerdal has no role in designing the study, analysing data or writing of the manuscript.

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References

1. Soar J, Monsieurs KG, Ballance JH, et al. European Resuscitation Council Guidelines for Resuscitation 2010 Section 9. Principles of education in resuscitation. Resuscitation 2010;81:1434–44.
2. Kromann CB, Jensen ML, Ringsted C. The effect of testing on skills learning. Med Educ 2009;43:21–7.
3. Karpicke JD, Roediger III HL. The critical importance of retrieval for learning. Science 2008;319:966–8.
4. Roediger HL, Karpicke JD. Test-enhanced learning: taking memory tests improves long-term retention. Psychol Sci 2006;17:249–55.
5. Carrier M, Pashler H. The influence of retrieval on retention. Mem Cognit 1992;20:633–42.
6. Glover JA. The 'testing' phenomenon: not gone but nearly forgotten. J Educ Psychol 1989;81:392–9.
7. Roediger HL. The power of testing memory: basic research and implications for educational practice. Psychol Sci 2006;17:249–55.
8. Hogan RM, Kintsch W. Differential effects of study and test trials on long-term recognition and recall. J Verb Learn Behav 1971;10:562–7.
9. Hattie J. Visible Learning: A Synthesis of Over 800 Meta-analyses Relating to Achievement. Milton Park, Oxon: Routledge; 2009. p. 192.
10. Dine CJ, Gersh RE, Leary M, Riegel BJ, Bellini LM, Abella BS. Improving cardiopulmonary reuscitation quality and resucitation training by combining audiovisual feedback and debriefing. Crit Care Med 2008;36:2817–22.
11. Seethala RR, Esposito EC, Abella BS. Approaches to improving cardiac arrest resuscitation performance. Curr Opin Crit Care 2010;16:196–202.
12. Andriessen P, Oetomo SB, Chen W, Feijs LM. Efficacy of feed forward and feedback signaling for inflations and chest compression pressure during cardiopulmonary resuscitation in a newborn mannequin. J Clin Med Res 2012;4:274–8.
13. Roediger HL, Karpicke JD. The power of testing memory: basic research and implications for educational practice. Perspect Psychol Sci 2006;3:181–276.
14. Mpotos N, De Wever B, Cleymans N, Raemaekers J, Valcke M, Monsieurs KG. Efficiency of short individualised CPR self-learning sessions with automated assessment and feedback. Resuscitation 2013;84:1267–73.
15. Mpotos N, Lemoyne S, Calle PA, Deschepper E, Valcke M, Monsieurs KG. Combining video instruction followed by voice feedback in a self-learning station for acquisition of basic life support skills: a randomised non-inferiority trial. Resuscitation 2011;82:896–901.
16. Mpotos N, De Wever B, Calle PA, Valcke MA, Peersman W, Monsieurs KG. Acquiring basic life support skills in a self-learning station: video alone is not enough. Eur J Emerg Med 2013;20:315–21.
17. Mpotos N, Yde L, Calle PA, Deschepper E, Valcke MA, Peersman W, et al. Retraining basic life support skills using video, voice feedback or both: a randomised controlled trial. Resuscitation 2013;84:72–7.
18. Mpotos N, De Wever B, Valcke MA, Monsieurs KG. Assessing basic life support skills without an instructor: is it possible? BMC Med Educ 2012;12:58–66.
19. Blackwelder WC. "Proving the null hypothesis" in clinical trials. Control Clin Trials 1982;3:345–53.
20. Cason CL, Trowbridge C, Baxley SM, Ricard MD. A counterbalanced cross-over study of the effects of visual, auditory and no feedback on performance measures in a simulated cardiopulmonary resuscitation. BMC Nurs 2011;10:15.
21. Vadeboncoeur T, Stolz U, Panchal A, et al. Chest compression depth and survival in out-of-hospital cardiac arrest. Resuscitation 2013;85:182–8.
22. Stiell IG, Brown SP, Christenson J, et al. What is the role of chest compression depth during out-of-hospital cardiac arrest resuscitation? Crit Care Med 2012;40:1192–8.
23. Allen JA, Currey J, Considine J. Annual resuscitation competency assessments: a review of the evidence. Aust Crit Care 2013;26:12–7.

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