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# VIRTUAL REALITY OR VIDEO-BASED SELF-INSTRUCTION: COMPARING THE LEARNING OUTCOMES OF CARDIOPULMONARY RESUSCITATION TRAINING

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Most of the existing virtual reality (VR) Cardiopulmonary Resuscitation (CPR) self-instruction training methods are based on low embodied and noninteractive 360-degree videos, and the effects of the highly immersive embodied VR CPR training system lack rigorous experimental verification. In our study, we compare the learning outcomes of self-instruction CPR training based on a highly immersive and interactive VR system (experimental group) with self-instruction training based on 2D videos (control group) in terms of willingness to perform CPR, knowledge of CPR, self-efficacy and CPR test performances. We conducted a prepost between-group experiment in a local college in Yixin, Jiangsu Province, China. Sixty undergraduate students (30 male and 30 female) aged from 18 to 25 were randomly assigned to the video group or the VR group. There were no significant differences in demographic variables and baseline pretest between the two groups. Both groups received training on cardiac compressions and automated external defibrillator (AED) assisted CPR. Our results revealed that both the VR and video methods significantly improved the participants' CPR knowledge, self-efficacy and willingness to perform CPR. Our results showed that the immersive VR group had a significant disadvantage in their grasp of compression depth compared with the non-immersive media group. The correct compression depth of the video group was significantly higher than the VR group, and there was no difference between the two groups in terms of compression speed and full rebound rate. Our study suggested that both self-instruction training based on VR and self-instruction training based on video were effective methods, and the highly immersive and embodied VR method did not achieve better results than the video method.

*Keywords: cardiac arrest, self-instruction training, basic life support, virtual reality, motion tracking technology, video, cardiopulmonary resuscitation, college students.*

## Introduction

In China, more than 550,000 people experience cardiac arrest each year [28]; however, only 17.1 percent of the out-of-hospital cardiac arrest patients achieve prehospital heartbeat recovery [10], and the survival rate is less than 1 percent [12], which is much lower than the average global survival rate of 9.9 percent [23]. A recent survey in which 73.4% of the interviewees expressed their willingness to learn Cardiopulmonary Resuscitation (CPR) showed that Chinese people had high acceptance of CPR training [29]. However, the effects of CPR training and the actual penetration rate were quite unsatisfactory. Only 27% of Chinese students reported having taken CPR training courses [7]. There were two main reasons for this. First, there was a shortage of professional CPR training institutions and teachers. Second, traditional CPR training courses require not only human resources but also time, space, and a large amount of money to purchase helpful equipment for the participants to use to perform and practice CPR [1].

Researchers have proposed many new training methods to alleviate the obstacles in CPR training. For example, there is evidence that video-based self-instruction courses can reduce training costs while increasing skill retention [9, 15, 26], and game-based training programs such as LISSA (http://lissa.udg.edu/en.html) and

Relive (https://store.steampowered.com/app/404580/Relive/) have also emerged as popular helpful teaching methods for CPR training [4, 20]. Especially during the Covid-19 period, how to avoid infection during face-to-face training gatherings was a thorny problem [3]. Multimedia-based remote training provided us with a solution.

With the development of virtual reality (VR) technology and its application in the field of medical education, immersive VR CPR training has been applied in first-aid training. Lifesaver is an interactive smartphone-based VR CPR training software that has been validated by researchers [19, 30]. Based on this software, Joyce Yeung et al. compared three CPR training methods, including face-to-face teaching, Lifesaver teaching, and the combination of face-to-face and mobile VR teaching. They found that the immediate CPR test results for the face-to-face teaching group were significantly better than those of the Lifesaver group; however, this difference disappeared after six months, and the combination of Lifesaver and face-to-face teaching achieved significantly better learning outcomes and retention than the other two methods [30]. Joris Nas et al. found that the VR group achieved significantly lower pressing depth performance than that of face-to-face instruction while there were no difference in pressing speed [19]. Immersive 360-degree instructional video is another application that has been frequently tested. Marion Leary et al. compared the effects of VR-based training and smartphone-based training and found that the number of participants that called 911 and required automated external defibrillator (AED) in the VR group significantly improved while there was no significant difference in CPR and AED operation, and the pressing depth of the VR group was even lower than that of the smartphone group [13]. Another recent study compared the training effects of watching an immersive virtual reality video and a 2D-video, and they found that the VR group achieved better CPR test results in compression depth and compression speed [6].

Researchers have believed that VR CPR self-instruction training was less dependent on instructors and had irreplaceable advantages over face-to-face training [2, 21]. In addition, the immersive and interactive training provided by VR technology had more advantages in allowing the trainees to experience the whole CPR process in a simulated scenario [27]. Nevertheless, most of the existing VR CPR self-instruction training methods are based on smartphone-based VR software or 360-degree video, and the effects of the highly immersive embodied virtual reality CPR training system lack rigorous experimental verification [2, 22]. In our study, we compare the learning outcomes of self-instruction CPR training based on a highly immersive and interactive VR system with self-instruction training based on a 2D-video in terms of willingness to perform CPR, knowledge of CPR, self-efficacy and CPR test performance.

**Methods**

We conducted a prepost between-group experiment at a local technical college in Yixin, Jiangsu Province, China. The participants were randomly assigned to a video self-instruction training (VSI) group or a virtual reality self-instruction (VRSI) group. Both groups received training on cardiac compressions and AED assisted CPR. The experiment received University IRB approval.

*Participants*

The student union of the college helped us enroll students to participate in our study. Sixty Chinese students, including 30 male students and 30 female students, participated in this experiment. Their average age is 20 ± 1 years old, their average weight is 62 ± 12 kg, their average height is 172 ± 9 cm, and their average BMI is 21 ± 3 kg/m$^2$.

*Procedures*

All participants were required to finish an online pretest survey one week before the experiment. On the day of the experiment, they received either video-based or VR-based self-instruction CPR training in the school lab. After the training, they completed a posttest questionnaire and performed a simulated human heart compression test.

**Materials**

The experimental material used by the virtual reality group is a VR game called VR-CPR Personal Edition, developed by Studio Evil and IRC Edu [21] (the download link: https://store.steampowered.com/app/1023940/VR Cardiopulmonaryresuscitation_Personal_Edition/). The game provides three different immersive scenarios for CPR training: in-hospital CPR, out-of-hospital CPR, and child CPR. There is a visual and auditory guidance at the beginning of the game (such as hand model guidance and pressing rhythm beats). We chose the out-of-hospital scenario; established an automated external defibrillator (AED) with a 15 second arrival time, two rounds of compression, and 30 seconds per round; and the external automatic defibrillator was used after each round of compression. The specific process of the game includes the following: assessing consciousness, checking breathing, calling for help, implementing cardiopulmonary resuscitation and using an external automatic defibrillator. We recorded a successful CPR game video completed by a professional CPR trainer as the self-instruction training material for the video team. The scenario and other settings of the video group were consistent with the virtual reality group.

The wearable devices used by the virtual reality group are an HTC Vive Pro 2.0 and HTC Vive Tracker 2.0. The video group used a Samsung 900X5N-K02 laptop to watch the self-instruction video. Both groups used pillows to perform compression during the training.

*Measures*

The pretest questionnaire included the variables of the participants' age, gender, height, previous CPR learning experience, willingness to perform CPR, knowledge of CPR and self-efficacy. The posttest questionnaire included the variables of the willingness to perform, knowledge of CPR and self-efficacy. The willingness to perform CPR was measured by asking participants whether they would be willing to perform CPR when they met a person experiencing cardiac arrest on a five-point Likert scale ranging from very unwilling (1) to very willing (5). We borrowed Yoon et al.'s measurements of self-efficacy [31]. The participants were asked "If you see a person in cardiac arrest, do you think you are capable of performing CPR on him?" There were three answers to choose from, including "I can perform CPR correctly", "I can complete it roughly", and "I cannot perform CPR". Both correct implementation and rough implementation are considered to represent self-efficacy.

After the training, the participants performed CPR tests on the half-length Anne Manikins, and their compression level data were collected through the LITTLE Anne QCPR software. The indicators of their learning outcomes were chest compression depth, effective compression depth, chest compression rate, effective compression rate, complete chest recoils rate.

**Results**

*Demographics*

Demographic variables (age, gender, weight, height, and BMI) were tested via Chi-square test to see if there were significant differences between groups. In terms of gender (53% vs. 47% males), age (20 ± 1 vs. 20 ± 1), education level (all participants are students at the school), weight (62 ± 12 kg vs. 61 ± 12 kg), height (172 ± ± 9 cm vs. 172 ± 9 cm), BMI index (21 ± 3 kg/m$^2$ vs. BMI index), and the percentage of people who received CPR trainings within two years (23% vs 37%), there were no significant differences between the two groups (Table 1).

*CPR test performance*

To compare the training performance results between the two groups, a series of one-way ANOVAs were conducted. The average chest compression depth of the virtual reality group reached 46 ± 9 mm, and the average depth of the video group was 51 ± 10 mm (p = NS). The VR group had an average effective compression depth of 44 ± 43 (%) while the video group had an average effective compression depth of 66 ± 40 (%) ($p = 0.041 < 0.05$; 95% CI). The frequency of chest compressions averaged 104 ± 30 compressions per minute in the VR group and 111 ± 23 compressions per minute in the video group (p = NS). The effective compression ratio was 26% ± 31% in the virtual reality group and 45% ± 42% in the video group (p = NS).

**Table 1**

**Demographic variables**

| | Total | VRSI | VSI | P-value |
|---|---|---|---|---|
| N | 60 | 30 | 30 | |
| Gender, n (%) | | 30 | 30 | NS |
| Male | 30 (50) | 16 (53) | 16 (47) | |
| Female | 30 (50) | 14 (47) | 16 (53) | |
| Age (yrs) | 20 ± 1 | 20 ± 1 | 20 ± 1 | NS |
| Current CPR training (≤ 2 years), n (%) | 18 (30) | 7 (23) | 11 (37) | NS |
| Weight (kg) | 62 ± 12 | 62 ± 12 | 61 ± 12 | NS |
| Height (cm) | 172 ± 9 | 172 ± 9 | 172 ± 9 | NS |
| BMI (kg/m$^2$) | 21 ± 3 | 21 ± 3 | 21 ± 3 | NS |

Table 2

**CPR test performances**

| | VRSI | VSI | P-value |
|---|---|---|---|
| Chest compression depth, mm | 46 ± 9 | 51 ± 10 | NS |
| Effective compression depth, % | 44 ± 43 | 66 ± 40 | p = 0.041 |
| Chest compression rate, no./min | 104 ± 30 | 111 ± 23 | NS |
| Effective compression rate, % | 26 ± 31 | 45 ± 42 | NS |
| Complete chest recoils rate, % | 90 ± 26 | 89 ± 23 | NS |

The average rebound rate was 90% ± 26% in the virtual reality group and 89% ± 23% in the video group (p = NS). In conclusion, in terms of the CPR test performances, the video group achieved better compression depth accuracy results than the VR group, and there was no significant difference in the other indicators between the two groups (Table 2).

*Willingness to perform CPR*

In the pretest, the willingness of participants in the virtual reality group to perform bystander cardiopulmonary resuscitation was 3.07 ± 1.17, and the willingness of the video group was 3.67 ± ± 1.24. There was no significant difference between the two groups in the baseline willingness (p = NS). In the posttest, the participants in the VR group increased their willingness to perform bystander CPR to 4.07 ± 0.94 ($p < 0.001$; 95% CI), and the willingness of the video group increased to 4.60 ± 0.68 ($p < 0.001$; 95% CI). The willingness of the video group was significantly higher than that of the virtual reality group ($p = 0.011 < 0.05$; 95% CI). This shows that the willingness of the participants to help others after video self-direction increased more than that after virtual reality self-instruction training (Fig. 1.)

*Knowledge of CPR*

In the pretest of the virtual reality group, 30% of the people knew the correct compression frequency for CPR, 30% knew the correct compression depth for CPR, 50% knew the correct compression position for CPR, 46.7% knew how to judge whether people were conscious, 53.3% knew that they could not continue to press an AED during defibrillation, 16.7% knew that nonprofessionals cannot use an AED, 43.3% knew that the first round of compressions should be started while waiting for the arrival of an AED, and 26.7% knew the indicators for the general public to judge whether someone was experiencing cardiac arrest.

In the pretest of the video group, 26.7% of the people knew the correct compression frequency for CPR, 40% knew the correct compression depth for CPR, 56.7% knew the correct compression position for CPR, 36.7% knew how to judge whether people were conscious, 60% knew that they cannot continue to press an AED during defibrillation, 26.7% knew that nonprofessionals cannot use an AED, and 60% knew that they should start the first round of compressions while waiting for the arrival of an AED.

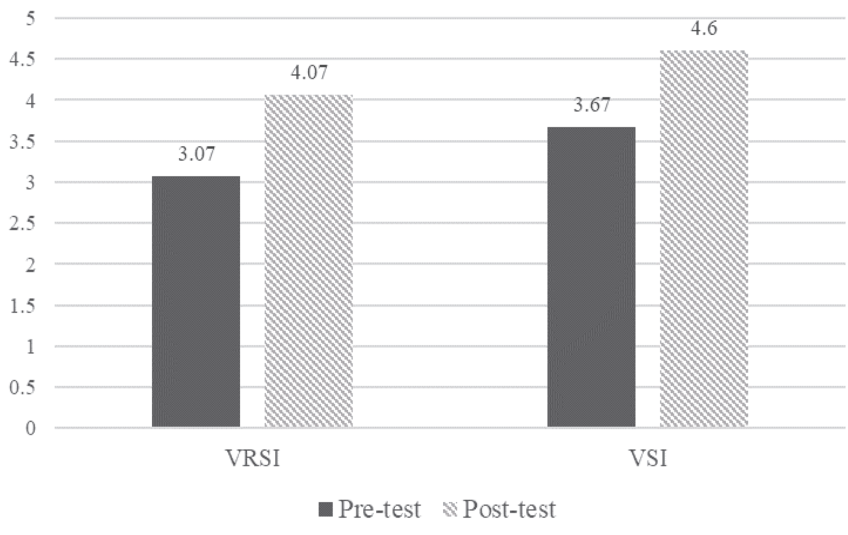


**Fig. 1. Means of Willingness to perform CPR between media (VRSI vs. VSI) and across time (pretest vs. posttest)**

20% of these people knew the indicators for the general public to judge whether someone was experiencing cardiac arrest.

In the post-test, 66.7% of the virtual reality group and 86.7% of the video group knew the correct compression frequency for CPR. 86.7% of the virtual reality group and 80% of the video group knew the correct compression depth for CPR. 93.3% of the virtual reality group and 96.7% of the video group knew the correct compression position for cardiopulmonary resuscitation. 100% of the people in the virtual reality group and 96.7% of those in the video group knew how to judge whether a person was conscious. 63.3% of the people in the virtual reality group and 60% of those in the video group knew that an AED cannot be continued to be pressed during defibrillation. 90% of the virtual reality group and 93.3% of the video group knew that nonprofessionals cannot use an AED. 66.7% of the virtual reality group and 70% of the video group knew to start the first round of compressions while waiting for the arrival of an AED. 76.7% of the people in the virtual reality group and 66.7% of those in the video group knew the general indicators of cardiac arrest.

In total, there were eight questions on CPR knowledge, and the right answer would get 1 point. The average CPR knowledge score of the virtual reality group was 2.93 ± 1.72 in the pretest and the 6.43 ± 1.28 in the posttest. After the virtual reality CPR training, their CPR knowledge score significantly increased ($p < 0.001$; 95% CI). The average knowledge score of the video group was 3.27 ± 1.84 in the pretest and 6.53 ± 1.33 in the posttest. After the video self-instruction training, their CPR knowledge score also significantly increased ($p < 0.001$; 95% CI) (Fig. 2).

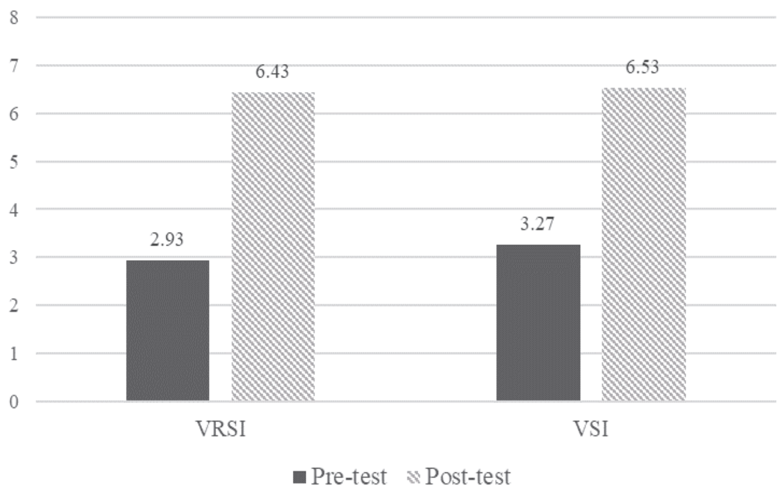


**Fig. 2. Means of Knowledge of CPR between media (VRSI vs. VSI) and across time (pretest vs. posttest)**

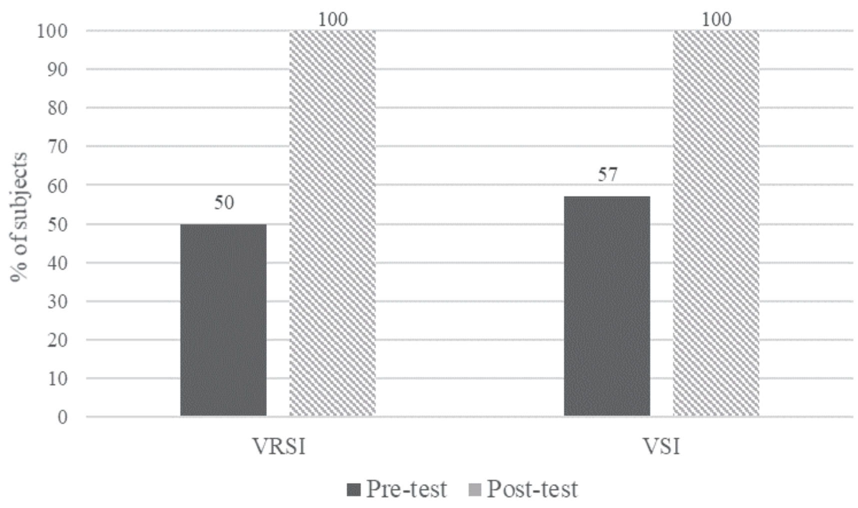


**Fig. 3. Percentage of participants with self-efficacy between media (VRSI vs. VSI) and across time (pretest vs. posttest)**

*Self-efficacy*

Regarding self-efficacy, 50% of those in the virtual reality group and 57% of those in the video group believed that they were capable of performing CPR during the pretest. In the posttest, all participants in the virtual reality group and the video group believed that they were capable of performing cardiopulmonary resuscitation, and the proportion of self-efficacy reached 100%. However, there was no significant difference between the pretest and posttest on self-efficacy (Fig. 3).

**Discussion**

Our study compared virtual reality-based self-instruction training and video-based self-instruction training using the same teaching content and sought to determine which CPR training method would achieve better learning outcomes. The results revealed that both the VR and video methods significantly improved the participants' CPR knowledge, self-efficacy and willingness to implement CPR rescue. Consistent with the findings of Marion Leary et al.'s study [16] conducted in 2019, our results showed that the immersive VR group had significantly lower performance grasping the pressing depth compared with the non-immersive media group. The correct pressing depth of the video group was significantly higher than that of the VR group, and there was no difference between the two groups in compression speed and full rebound rate. For those who were in the non-immersive media-based self-instruction CPR training group that performed better at CPR pressing depth, one of the possible explanations was that participants who participated in the video-based training might have concentrated more on pressing harder where they could see the surrounding environment in reality and press the pillow in front of them. The unfamiliarity and insecurities in the VR environment might prevent the participants from being fully focused on pressing when practicing in the real environment.

In fact, the application of virtual reality equipment in the field of education has not been fully proven to have better effects than traditional media-based teaching methods. Moreover, the comparison between different media-based training methods showed that the learning outcomes of VR-based training seemed to be even worse than the outcomes from video or other media-based training methods [11, 16, 18]. These results were often explained by the cognitive theory of multimedia learning or cognitive loads in learning [17]. Despite the impressiveness and other advantages of VR, the participants under the VR condition had higher cognitive loads compared with other forms of media condition. Furthermore, it might be too complicated for the participants to use this unfamiliar and interactive equipment, thus leading to greater cognitive loads [25].

In addition, the VR group had a lower willingness to rescue than the video group, which was inconsistent with our assumptions. The immersive and authentic experience made the participants more aware of the tension at an emergency scene, and over immersion might also increase their fear, as we found in another study [14]. This case may be a negative example of the results of some first-aid VR centers [32]. Those who spent considerable time and money to apply VR technology to popularize first aid among the public may be too optimistic.

Research on using VR as an experiential teaching medium for emergency training (such as earthquakes [24], fires [5], etc.) often believes that this kind of situational education can make trainees calmer when facing real dangers. C. Dede stated that one advantage of the virtual learning environment was that it could provide learners with immersive experiences, thereby reducing the difficulty of transferring existing knowledge and skills to new situations [8]. It was difficult for the researchers to follow and measure how the learners would respond later when they encountered cardiac arrest in real life. Therefore, although our study did not reveal that the highly immersive and interactive VR method was better than the video method, it is very likely that the real strength of VR in CPR training has not been discovered and revealed. In addition, future research could examine and analyze nonprofessional bystanders' real response behaviors after extensive VR CPR training.

Finally, our study has some limitations. Our experiment was performed only once, and the learning outcomes were examined immediately. Multiple training sessions and retesting the retention of knowledge and skills after two months may reveal different results.

**Conclusion**

Our study suggested that self-instruction training based on VR and video were both effective methods, but the highly immersive and embodied VR method did not achieve better results than the video method. This indicated that in terms of training media, choosing a current simpler method (such as video) that is more acceptable to the general public would be effective and efficient. However, in the long run, with the development and popularization of VR technology, we may have new answers.

**Conflict of interest statement**

None of the authors has a conflict of interest.

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# ВИРТУАЛЬНАЯ РЕАЛЬНОСТЬ ИЛИ ВИДЕОКУРС: СРАВНИТЕЛЬНЫЙ АНАЛИЗ РЕЗУЛЬТАТОВ САМООБУЧЕНИЯ СЕРДЕЧНО-ЛЕГОЧНОЙ РЕАНИМАЦИИ

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Большинство существующих методов самообучения по сердечно-легочной реанимации (СЛР) в виртуальной реальности основаны на 360-градусных видеороликах с низким уровнем интерактивности, а эффекты иммерсивной системы обучения не доказаны экспериментально. В нашем исследовании мы сравниваем результаты обучения методом самостоятельной тренировки СЛР на основе высокоиммерсивной интерактивной системы виртуальной реальности с самообучением на основе 2D-видео по критериям знания методики СЛР, готовности проводить искусственное дыхание, самооценки и тестовой оценки СЛР. Ранее было проведено недостаточное количество исследований, особенно на практике, так как в большинстве исследований реализовывались технологии, основанные на применении 2D-видео и панорамного видео (360 градусов). В нашем исследовании сравнивались технологии с использованием VR (экспериментальная группа) и 2D-видео (контрольная группа), так как с помощью VR достигается более высокое погружение в интерактивную виртуальную реальность, что было доказано и в предыдущих исследованиях. Предварительный и основной эксперименты проводились в институте города Исинь провинции Цзянсу. 60 участников, которые являются студентами бакалавриата (всего 30 девушек и 30 юношей от 18 до 25 лет), были разделены на две группы – группа «VR-видео» и группа «2D-видео». При этом никаких существенных различий в предварительном анализе демографических и базисных показателей между двумя группами нет. Обе группы прошли обучение компрессионному сжатию сердца и использованию автоматического внешнего дефибриллятора (АВД) с помощью СЛР. Результат показал, что использование как VR-видео, так и 2D-видео, значительно повысили знания, самооценку и также желание обучающегося спасать другого человека. По сравнению с 2D-видео VR-видео с точки зрения погружения объекта в виртуальность, показало более эффективный результат, глубина сжатия VR-видео значительно выше. Но две данные группы не отличаются друг от друга по скорости сжатия и полной скорости отскока. В нашем исследовании доказано, что самостоятельное обучение, основанное на использовании VR-видео и 2D-видео, является эффективным методом для самообучения. Было показано, что метод с использованием VR-видео не дает более эффективных результатов, чем 2D-видео.

*Ключевые слова: остановка сердца, самоподготовка, методы оказания помощи, виртуальная реальность, технология отслеживания движения, видео, сердечно-легочная реанимация, студенты института.*

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