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ORIGINAL RESEARCH

Education

SMARTSIM A multicenter prospective randomized trial of 3D virtual reality versus traditional patient simulation

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Abstract

Objective: Simulations are an integral part of paramedic education. Technological advancements have introduced three-dimensional virtual reality patient simulations (3DVRS), offering a low-cost, accessible alternative. This study compares the impact of 3DVRS and traditional simulation on paramedic students.

Methods: Students selected from a convenience sample of 11 cohorts in 10 accredited programs distributed across the United States were allocated to 2 groups using a stratified random sampling. One group received simulations via 3DVRS, the second used traditional in-person simulation. Students were exposed to 6 scenarios over 2 h from the National Association of Emergency Medical Technicians (NAEMT) Advanced Medical Life Support (AMLS) program. Altered mental status scenarios were selected a priori by the research team containing approximately 30 potential differential diagnoses. A 50-item posttest was administered using validated cognitive items provided by Fisdap.

Results: A multicenter prospective randomized trial of 174 paramedic students was undertaken from April until August of 2022. The traditional simulation group was comprised of 88 students and the 3DVRS group had 86 students. A Mann–Whitney U test ($U = 4064.5, n_1 = 88, n_2 = 86, p = 0.396$) detected no statistical difference between two distributions or median exam score (70%), the range of values and interquartile range (IQR) for both groups: TS IQR = 64–75 (range, 32–82); 3DVRS IQR = 64–76 (range, 34–86).

Conclusion: No difference in exam scores using 3DVRS versus traditional simulation was detected. Paramedic programs may have an effective new option when incorporating simulation with 3DVRS, potentially reducing financial and real-estate resources required with in-person simulations. Larger studies are needed to truly evaluate the impact and usability of virtual reality on paramedic education.

KEYWORDS
paramedic students, patient assessments, virtual reality

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1 | INTRODUCTION

Emergency medical services (EMS) clinicians encounter a variety of seriously ill or injured patients on a consistent basis.[1] The specific nature and circumstances around each patient's needs are unpredictable and wide ranging.[1] Simulation is an integral part of initial and continuing paramedic education, and supports paramedic students in their training to safely diagnose and treat a wide variety of patients.

1.1 | Background

EMS clinicians are required to make quick observations of dynamic environments, perform thorough patient assessments, establish a diagnosis, and create an evidence-based treatment plan in a matter of minutes which requires impeccable clinical reasoning ability. Clinical reasoning has been defined as the "thought process a clinician uses to evaluate a problem."[1] Simulation continues to show evidence of being one of the most effective ways to teach clinical reasoning and has shown to be as effective as lecture-based education.[2–10] The evidence presented in these and other studies led the National League of Nurses in 2003 to endorse the use of simulations to improve the critical thinking and self-reflection abilities of nursing students in preparation for complex clinical environments.[3]

Simulation can be defined as the imitation of clinical experience and has been used in the medical field including EMS education for more than 50 years.[11] Simulation helps prepare paramedic students for patient interactions in both clinical and prehospital emergency settings. Traditional simulation tools and techniques in paramedic education include the use of standardized patients, role playing, manikins, and high-fidelity patient encounters. Advancements in technology have offered new ways to implement simulation in education settings such as virtual and augmented realities that use virtual reality headsets, computers, or immersive projection simulation rooms. Despite the increasing use of virtual simulation in EMS education there is a paucity of evidence supporting its use.

1.2 | Importance

Recently, the Committee on Accreditation of Educational Programs for the EMS Professions (CoAEMSP) amended their standards to allow simulation and virtual simulation in place of most live patient encounters. The use of virtual reality simulations may offer students a chance to learn in an easily replicable, low stakes immersive environment.

During the COVID-19 pandemic there was a reduction in clinical education opportunities and many programs increased the use of advanced simulation technology without knowing if they would be successful, as such we sought to investigate the noninferiority of virtual simulation as compared to traditional simulation.

Implementation of virtual reality simulation in EMS education has the potential to mitigate educational and clinical staffing issues, reduce costs, reduce the time it takes for paramedic students to complete graduation requirements, and have a positive impact on graduation rates.[10] Research is needed in EMS education to determine if virtual reality (VR) is as effective in improving clinical reasoning as traditional simulation.

The Bottom Line

Simulation has an important role in paramedic and emergency medicine education. However, it can be resource heavy and require in person training. The availability of 3D virtual reality simulation can give immersive training and has the potential to reduce the resource burden, especially in high risk and low frequency clinical scenarios. This study concluded that 3D virtual reality clinical simulation was likely equally efficacious in medical knowledge retention. Further studies are needed to parse out more details on potential advantages and disadvantages of 3D virtual reality simulation in comparison to traditional simulation.

1.3 | Goals of this investigation

This study was designed for an in-depth comparison of 3D virtual reality patient assessment simulations to traditional in-person simulation and its associated changes on paramedic students' clinical reasoning.

2 | METHODS

2.1 | Study design and setting

This multicenter prospective randomized trial was designed to compare the effects of traditional and virtual reality simulation. This project was reviewed and approved by the institutional review board at the University of Arizona (FWA #00004218) and meets the criteria for exemption under 45 CFR Section 46.104[3] (i) (B). This study was conducted in 10 community colleges and universities (Figure 1) geographically distributed across the United States between February and August of 2022.

2.2 | Selection of subjects

Participants were selected from respondents to an email solicitation sent to a pre-established list of 50 volunteer educational institutions provided by Fisdap. Fisdap is a large, proprietary internet-based system of EMS student records designed to track clinical and procedural experiences. Fisdap also includes a range of educational tools that assess a candidate's readiness to take the national certification exam administered by the National Registry of Emergency Medical

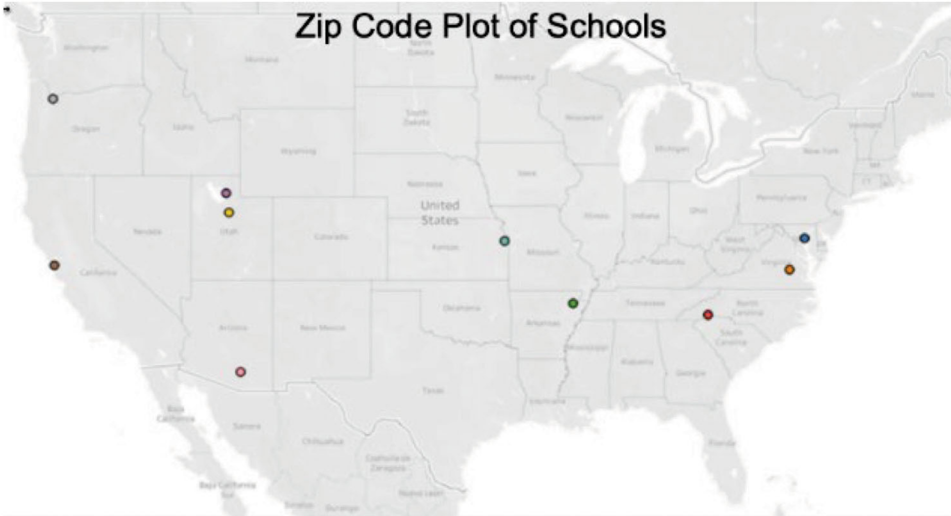

FIGURE 1 Zip code plot of participating schools.

Technicians. Currently Fisdap software is used by more than 175 of the 790 accredited paramedic training programs in the United States.[12]

Twenty-eight of the educational institutions responded by completing the survey. Of the responding institutions, 3 chose to opt out of the project, 13 were ineligible due to the timing of their class curriculum, and 1 was used as a pilot program for this project. During the pilot phase, a pretest and post-test were used, with the exception of this detail, the pilot was completed without change to the study design detailed here. Participants expressed that due to fatigue they were unable to complete the post-test to the best of their ability. Due to this feedback, the pretest was removed for the study phase.

Responding institutions with a class scheduled to complete the medical emergencies unit of their paramedic curriculum between February and August of 2022 were selected to participate. Those institutions had a total of 203 paramedic students enrolled at the beginning of this project. Consenting students from each cohort were placed in 1 of 2 groups using a stratified random sampling procedure. Figure 2 shows the site and participant selection process.

The principal investigator met with participating classes via an online web conference (Zoom; Grosse Pointe Farms, MI) to explain the process, answer questions, and obtain informed consent. The principal investigator also met with the instructors of each institution to provide details on how to use the equipment, the software, and how to manage the scenarios for the day the research was to be conducted.

2.3 | Sample size calculation

The web application G*Power was used to determine the number of participants required to power this study based on a medium effect size. Results indicated between 57 and 110 participants were required to detect a medium effect (Cohen's d value 0.5–0.79, using $\alpha = 0.05$).

2.4 | Interventions

Both groups were given the opportunity to complete 6 patient assessment simulations created based on scenarios provided by the National Association of Emergency Medical Technicians (NAEMT) that are regularly used in the Advanced Medical Life Support (AMLS) program. Scenarios were selected a priori by the authors based on altered mental status complaints. Of the scenarios provided, the students would consider 30 potential differential diagnoses while completing the scenarios.

Traditional simulation, for the purposes of this study, was an instructor-led simulation using original AMLS scenarios that were provided on paper. During these scenarios, a second instructor acted as the patient. The traditional simulation group was comprised of 88 students. Details of vital signs and physical assessments were provided by the instructor only when the patient in each scenario was physically unable to do so. Each instructor who acted as a live patient was given the scenarios in advance so that they could properly imitate the patient and were instructed not to break character or volunteer any information not specified in the scenarios provided.

The virtual reality scenarios were created using the same NAEMT scenarios by developers using the web application VR Patients and reviewed by the principal investigator. VR Patients is an online platform that immerses students in virtual reality and computer-based simulations allowing them to interview, assess, diagnose, and treat patients in real-time. This platform was created for EMS education and focuses on placing students in life-like environments using equipment and vehicles designed to replicate those used by EMS clinicians in the field (Figure 3). The virtual reality group, comprised of 86 students, experienced the scenarios in 3DVRS using Oculus Quest Gen 2* headsets (Figure 4) that were loaned by VR Patients for this research effort.

To control for different types of debriefing, all students completed a debrief instrument that contained questions on the patient's

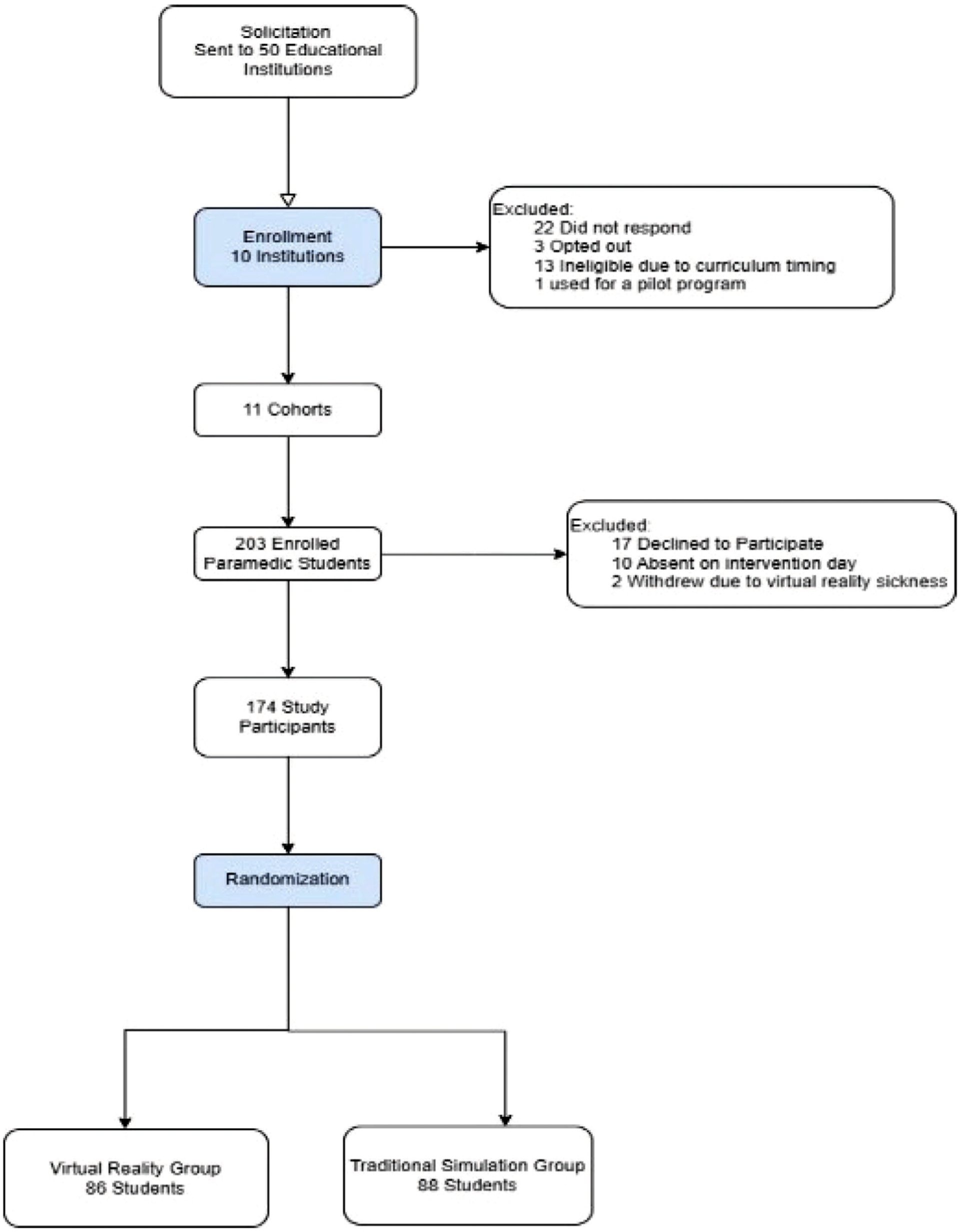

FIGURE 2 Flowchart of site selection.

criticalities, potential differential diagnoses, and educational summaries based on the learning outcomes and teaching points outlined by the NAEMT AMLS course. Completing this debrief sheet allowed students from both groups to reflect on the scenarios, an important aspect of developing clinical reasoning ability.[13] The use of these forms also ensured that the participants assigned to the virtual reality group took a break from the Oculus Gen 2 headsets, an attempt to mitigate cybersickness. Each instructor was given explicit instructions not to provide verbal debriefs or engage in conversation with the students at any time during the intervention to ensure each group received only the feedback and learning points provided by the authors.

2.5 | Measures

The stratified random sampling procedure was employed to account for differences in achievement associated with various paramedic programs.[14] Each program submitted an alphabetical list of participants in Excel, which was then randomized using Excel's random number generator. The total number of participants for each site was divided into two equal (or nearly equal in cases with an odd number of participants) strata. Subsequently, participants were randomly allocated to each stratum using the random integer generator from Random.org.

FIGURE 3 Screenshot of VR Patients platform. Abbreviation: VR, virtual reality

2.6 | Outcomes and data analysis

The data obtained from the examinations were parsed through a rigorous process of quantitative evaluation, incorporating both descriptive and inferential statistical analysis. Descriptive statistics provided an overview of the data set, allowing us to analyze the magnitude, dispersion, and central tendency of the results. Meanwhile, inferential statistics allowed us to make generalizations about the population based on our sample and draw conclusions regarding potential relationships between variables and identify any underlying trends in the data set.

Outcomes were measured using a computerized exam comprised of 50 psychometrically validated multiple-choice items provided by Fisdap. This exam was offered from the Fisdap Pilot Testing website and proctored by local instructors. As an incentive to participate, the students with the top 10 scores on the exam were awarded $50 Amazon gift cards.

3 | RESULTS

A total of 174 of the possible 203 enrolled paramedic students participated from 11 cohorts in 10 educational institutions (community colleges and universities). Of the total available pool of potential participants 17 declined, 10 consented to participate but were absent on the day of the intervention, and 2 (2.3%) withdrew due to virtual reality sickness (Figure 2). This study achieved sufficient power to detect a medium effect size as numbers enrolled exceeded the predicted required number (total participants $n = 174 > 110$; $n_1 = 86$, $n_2 = 88$).

Visual inspection of the side-by-side box plot of the exam results (Figure 5) shows violation of normal distribution and a Shapiro–Wilk test (W = 0.90, $p < 0.001$) confirmed the distribution departed significantly from normality.

As such the nonparametric Mann–Whitney *U* test for independent sample analysis was used. Table 1 shows the median exam score for both groups was 70 (IQR TS: 64–75; IQR 3DVRS: 64–76) indicating the 2 cohorts had achieved a statistically comparative level of performance on the assessment instrument.

A Mann–Whitney *U* test for independent samples shows that there was no statistically significant difference ($U = 4064.5$, $n_1 = 88$, $n_2 = 86$, $p = 0.396$) in the distribution of exam results between the 2 groups (Figure 6). This finding implies a relative level of homogeneity with regard to their abilities and aptitudes in relation to the material presented on the examination.

4 | LIMITATIONS

4.1 | Study population

The study was conducted only in community colleges ($n = 6$) and universities ($n = 4$) in the United States, which may limit the generalizability of the findings to other contexts, such as nonacademic settings or other countries. The sample size of 174 paramedic students was not large enough to detect small differences between the virtual reality and traditional simulation groups. Although detecting small effect sizes can be of academic interest, it is important to note that they may have limited practical value. The participant demographic information contained a large amount of missing data, 29% of participants did not complete the demographic survey. Because this exceeded the critical value of 10%[15] the authors have not used this data in analysis due to concerns with bias.

Using stratified random sampling could help account for differences in achievement associated with various paramedic programs; however, selection bias may still exist if certain types of students or programs are overrepresented or underrepresented in the study. The study was conducted over a relatively short period (February to August of 2022), which may limit the ability to assess the long-term impact of the virtual reality simulation on student learning and clinical performance. The traditional simulation group relied on instructors to act as patients, which could introduce scenario variability and potentially limit the ability to compare the 2 groups.

4.2 | Methodological challenges

The lack of a pretest or control group presents the researchers with a number of methodological challenges. This is especially true in the context of experimental designs, which require comparison groups to be able to make reliable inferences regarding causal relationships

FIGURE 4 Students using Oculus Quest Gen 2 goggles.

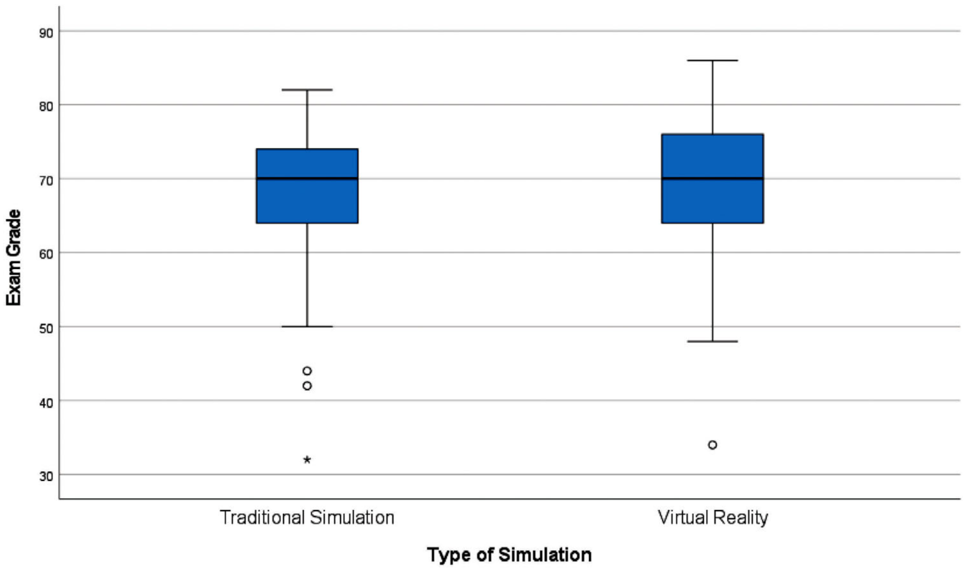

FIGURE 5 Side-by-side box plot of exam results.

TABLE 1 Descriptive analysis to the simulation group exam scores.

Simulation group	Participants	Median	IQR	Range
Traditional simulation	88	70	64–75	32–82
3DVRS	86	70	64–76	34–86

Note: Two 3DVRS (2.3%) students removed themselves from the study due to a history of VR sickness.
Abbreviations: IQR, interquartile range; VR, virtual reality.

between variables. Consideration was given to moving the posttest to a later date to allow the students an opportunity to rest. However, allowing a break of even a day would introduce confounding variables. Nevertheless, we feel the results still provide new and valuable information that deserves deeper exploration using pre/post-testing and critical thinking inventory (self-perceptions).

There was a small loss of participants ($n = 2$, 2.3%) due to a history of VR sickness that could indicate a small limitation to the use of this technology in education.

5 | DISCUSSION

5.1 | Traditional simulation

Although traditional simulation has been proven effective in medical education,[2,7,16–18] it has limitations. Building realistic scenarios, obtaining supplies and training instructors can be time consuming and

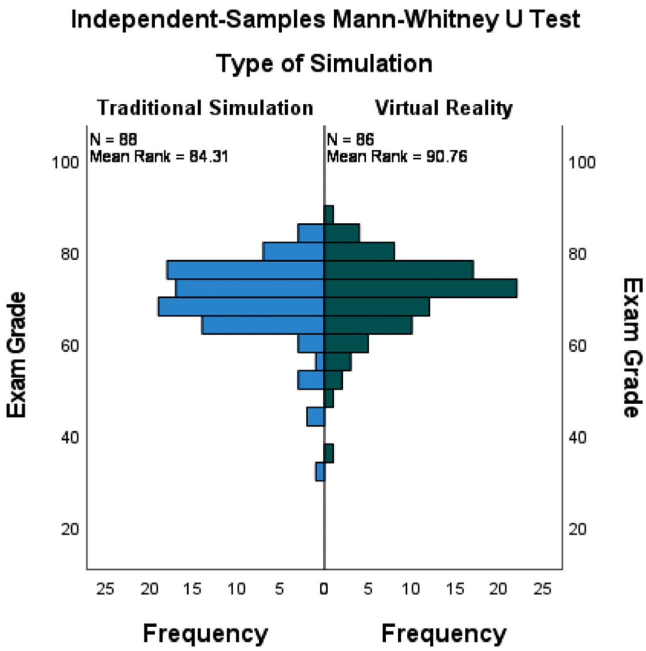

FIGURE 6 Distribution of exam results in each arm of the study.

expensive.[9] Ensuring consistency in student experiences across multiple cohorts is challenging. Prioritizing the student and instructor safety during potentially dangerous patient simulations without compromising the authenticity of the scenario is difficult. The use of virtual reality could reduce the risk of injury or property damage for complex simulations like drug overdoses, homicidal ideation, behavioral disturbances, and evacuation during a disaster.[19]

5.2 | Virtual reality

Virtual reality simulations allow institutions to provide scenario repetitions consistently between students and cohorts in a safe and realistic manner that is challenging to achieve in a more traditional manner.[16] Students are able to fully and independently immerse themselves in an environment with a patient in which they must rely solely on their individual cognitive process in assessment, diagnosis, and decision-making. Studies show that the adoption of virtual reality, while incurring potentially high up-front costs, can be significantly cheaper than traditional simulation.[10,19] One recent study noted that, although costs often depend on the provider and type of products used, virtual simulations are often one-tenth the cost of traditional simulation.[20] Additionally, the use of virtual reality simulation can reduce the space, time and number of instructors needed to complete a clinical education session.[20]

A potential drawback to the use of virtual reality simulation known as cybersickness or VR sickness was experienced in 2.3% (n = 2) of this studies participants. Cybersickness is the presentation of negative effects (headache, nausea, vomiting, and vertigo) during the use of 3D virtual reality.[21] Because the presentation of cybersickness is a relatively recent event, not much is known about it, including who may be at risk for it and why.[21]

Additionally, the adaptation to new technology can be time consuming, at times met with resistance from seasoned instructors. A review of 389 paramedic programs in the United States found that all programs had access to at least one and in most cases multiple forms of simulation.[11] However, a third of those programs found that due to lack of instructor training and understanding some of these tools were not regularly used.[11] To successfully implement advanced simulation technology and equipment, a financial, educational, and time-based commitment is required.

5.3 | Accreditation

In 2020, the COVID-19 pandemic reduced the availability of in-person and clinical-based educational opportunities for paramedic students[22] intensifying the EMS provider shortage in the United States.[12,23–25] In response to this critical need, CoAEMSPs adjusted the requirements of paramedic programs allowing virtual and traditional simulation to be used in place of patient encounters. Although the pandemic has come under control, the regulations have remained, and programs are now able to supplement paramedic students' education and count virtual simulations toward required clinical competencies.

This research has found evidence there may be an equivalency between the clinical reasoning outcomes of 3DVRS and traditional simulation. Results of the study indicated that there was no statistically significant difference in exam scores between 3DVRS and traditional simulation. This suggests that both 3DVRS and traditional simulation may be equally effective in terms of fostering higher-order cognitive skills. Although a slight advantage for one method cannot be ruled out, the current findings suggest that neither modality has a definitive advantage over the other in this regard. This is intriguing for a number of reasons. The use of 3DVRS could allow educators the ability to replicate high-fidelity simulations in a low cost, safe, and effective way that may reduce the preparation time, facility space, and instructor availability required. Potentially allowing paramedic students to complete required clinical competencies in a more time-efficient manner.

To further elucidate the potential advantages associated with the implementation of virtual simulation, it is necessary to conduct more extensive studies with larger sample sizes and the implementation of a control group. This approach could provide a more thorough understanding of the impact of 3DVRS on various outcomes, enabling researchers and policy makers to better assess the efficacy of this technology.

AUTHOR CONTRIBUTIONS

Erin Donathan: Primary authorship, conceptualization, study supervision, and data collection. Andrea LaLumia: Conceptualization, study supervision, review, and editing of paper. Charles Foat: Conceptualization, data analysis, study supervision, critical review and evaluation of results, review, and editing of paper. Nigel Barr: Data analysis, critical review and evaluation of results, review, and editing of paper. David I. Page: Conceptualization and procurement of grant.

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CLINICAL TRIAL REGISTRATION

This project meets the criteria for exemption under 45 CFR §46.1043 (i) (B). This project has been reviewed and approved by The University of Arizona (FWA #00004218).

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