Health&Caring
journal of health and caring

education for life

Received: October 25, 2024
Accepted: December 3, 2024
Published: December 16, 2024

Health & Caring 3 (2), 2024
DOI: 10.46585/hc.2024.2.2572

A Pilot Randomized Crossover Study on Stress Responses in Paramedicine Students: Virtual Reality Versus Live Simulation

Ondřej Kounovský[1 2*], Petr Bureš[2], Miroslava Kuklová[2]

[1] *Czech Technical University in Prague*
[2] *Emergency Medical Services of the Ustecky Region*

* kounovsky.ondrej@zzsuk.cz

Abstract

Introduction: *Emergency Medical Workers frequently encounter high-stress situations, such as traffic accidents and sudden deaths, which can negatively affect their mental health. Building psychological resilience through training is essential, and recent methods like virtual reality (VR) gamification have been introduced to improve learning outcomes.* ***Aim:*** *This pilot randomized crossover study aims to compare the stress responses of third-year Paramedicine students during a severe traffic accident scenario using either a live actor simulation or a VR-based platform (XVR simulation).* ***Methods:*** *Ten third-year Paramedicine students were randomly assigned to start with either a live actor simulation or a virtual reality scenario using the XVR program. After completing the first scenario, participants underwent a 7 -10 day washout period before switching to the alternate scenario. Physiological stress markers, including salivary cortisol, testosterone, and heart rate variability (HRV), were measured before and after each scenario. Subjective stress was assessed using a ten-point visual analog scale (VAS).* ***Results:*** *No significant differences were observed in cortisol concentration changes (p = 0.576), testosterone levels (p = 0.878), or HRV (p = 0.156) between the virtual reality and live actor simulations. However, students perceived the live actor scenario as more stressful than the virtual reality simulation (p = 0.001).* ***Conclusion:*** *Both virtual reality and live simulations effectively recreate high-stress scenarios, but students reported higher stress during live actor simulations. These results indicate that VR could be a viable and cost-effective alternative for training Paramedicine students. Larger studies are needed to confirm these findings and assess the long-term impact of VR training on stress adaptation.*

Keywords

paramedicine, salivary cortisol, salivary testosterone, stress, virtual reality

1 INTRODUCTION

Emergency Medical Workers frequently face challenging and traumatic situations, such as traffic accidents and sudden deaths, including those involving children, which can have a detrimental impact on their mental health (Dixon et al., 2016). Over 40% of emergency service workers have taken leave due to psychological issues, with many experiencing prolonged absences throughout their careers as a result of post-traumatic stress disorder (Hayes, 2018). As a result, fostering psychological resilience has become a key focus in training programs for emergency medical personnel in the UK (Darling-Hammond & Snyder, 2015; Givati et al., 2016). Gamification has emerged as a promising approach to promote adaptive behaviors during training (Hayes, 2018). Building resilience is particularly crucial for students preparing for careers in emergency medical services. Gamification is widely employed in training, with simulated scenarios involving live actors being the most common method. However, this approach can be both time-consuming and costly, leading to an increased use of virtual reality-based training platforms in recent years (Hayes, 2018). One such tool, XVR Simulation, is widely utilized in training programs for emergency medical personnel. Despite its growing adoption, there is a lack of data objectively measuring the stress responses of students using various gamification methods. This pilot study aims to compare changes in stress markers (salivary cortisol and testosterone levels) among third-year students managing a serious traffic accident scenario, either in a simulated environment with live actors or in a virtual setting using the XVR platform.

2 METHODS

2.1 Study Design

This pilot randomized crossover study aims to compare changes in physiological stress markers among third-year students in the Paramedicine program when responding to a severe traffic accident scenario, both in a simulated environment with live actors and in a virtual reality environment using the XVR program. The study focuses on key physiological indicators, including salivary cortisol, testosterone, and heart rate variability (HRV). HRV was represented by determining the Standard Deviation of NN intervals (SDNN) from a 30-second ECG recording. Subjective stress levels were measured using a ten-point visual analog scale (VAS).

Randomization was conducted using a computer-generated sequence to assign participants to begin with either the live actor scenario or the virtual reality XVR simulation. After completing the first scenario, participants underwent a washout period of 7 to 10 days to allow stress levels to return to baseline before proceeding to the second scenario. Each participant completed both scenarios, enabling a direct comparison of stress responses across conditions. CONSORT 2010 checklist (Schulz et al., 2010) was used to report the study.

2.2 Participants

The study included third-year students from the Emergency Medical Services program at the Faculty of Health Studies, J. E. Purkyně University in Ústí nad Labem, consisting of 7 men and 3 women. Inclusion criteria required participants to be in good health, refrain from chronic medication, and not have experienced significant stress (e.g., family bereavement or personal loss) within 30 days prior to the study. The study adhered to the ethical principles outlined in the Helsinki Declaration. All participants provided written informed consent, and the study protocol received approval from the Ethics Committee of the Faculty of Health Studies, J. E. Purkyně University in Ústí nad Labem.

2.3 Experimental Procedure and Materials

The testing was conducted at the Education and Training Center of the Emergency Medical Services of the Ústí Region. Participants were familiarized with the XVR program controls prior to randomization. Testing commenced after a 50-minute resting phase, during which participants sat in a quiet room to stabilize their physiological parameters. The study was conducted between 8:30 AM and 11:30 AM, a period associated with higher baseline cortisol levels. Participants were instructed to abstain from food, caffeine, fruit juices, and smoking for 4 hours before testing, and from alcohol and strenuous physical activity for 24 hours prior (Cmorej et al., 2022).

Saliva samples were collected using Salivette tubes (Salivette Cortisol; Sarstedt, Germany) immediately before and after each scenario to measure salivary cortisol and testosterone levels. Heart rate and ECG recordings for HRV analysis were obtained using a Lifepak 15 monitor/defibrillator (Stryker Company; Michigan, USA). HRV analysis focused on time-domain measures, such as SDNN (Standard Deviation of NN intervals), to assess autonomic balance. Participants were allotted a maximum of 15 minutes to complete each scenario, during which they triaged injured individuals using the START method. Additional saliva samples and physiological measurements were taken 15 minutes after completing the scenario.

2.4 Data Analysis

Saliva samples were stored at 4°C in an Alpicool cooling box (Foshan Alpicool Electric Appliance; China) and analyzed at the Department of Biomedicine and Laboratory Diagnostics, Faculty of Health Studies, J. E. Purkyně University in Ústí nad Labem. Cortisol and testosterone levels were determined using electrochemiluminescence on a Cobas 6000 module e601 analyzer (Roche Diagnostics; Basel, Switzerland) and recorded in nmol/L. Data normality was assessed using the Shapiro-Wilk test. Differences in physiological parameters between measurements were analyzed using a paired t-test, allowing for a comparison of mean values before and after the intervention, while accounting for the dependency of repeated measurements within the same subjects.

3 RESULTS

The results of the comparisons are summarized in Table 1 and illustrated in Figures 1–4.

Table 1. The comparative results of physiological variables.

N=10	XWR Simulation			Figurant Simulation			p value
Cortisol (nmol/l)	Mean (SD)	Min	Max	Mean (SD)	Min	Max	
pre-test	8,9 (3,6)	4,5	15,1	9,4 (5,7)	3,2	20,5	
post-test	8,83 (3,3)	5,2	17,0	10,0 (5,2)	3,9	20,7	
pre-test/post-test difference	-0,07 (2,0)	-3,9	2,3	0,6 (4,3)	-8,3	8,1	0.576
Testosterone (pg/ml)	Mean (SD)	Min	Max	Mean (SD)	Min	Max	
pre-test	188.4 (118.2)	36,2	361,7	176,5 (111,3)	27,2	330,7	
post-test	210,7 (140,9)	34,3	437,2	197,3 (125,1)	31,9	360,4	
pre-test/post-test difference	22.3 (33,0)	-21	75,5	20,8 (21,8)	-4,0	70,4	0.878
Heart Rate Variability (ms)	Mean (SD)	Min	Max	Mean (SD)	Min	Max	
pre-test	60 (10)	20	100	55 (15)	25	90	
post-test	50 (8)	15	80	30 (20)	5	60	
pre-test/post-test difference	-14,5 (11)	-20	2	-25 (5)	-20	-30	0.156
VAS Stress	Mean (SD)	Min	Max	Mean (SD)	Min	Max	
pre-test	3,9 (1,2)	2	6	4,5 (0,85)	3	6	
post-test	4,6 (0,7)	4	6	6,4 (0,97)	5	8	

No significant differences were found in cortisol concentration changes when students managed the simulated accident using the XVR program compared to the live actor simulation ($p = 0.576$). Similarly, no significant changes were observed in testosterone concentration ($p = 0.878$) or heart rate variability ($p = 0.156$). However, students perceived the simulation with live actors as more stressful compared to the same scenario in the XVR program ($p = 0.001$).

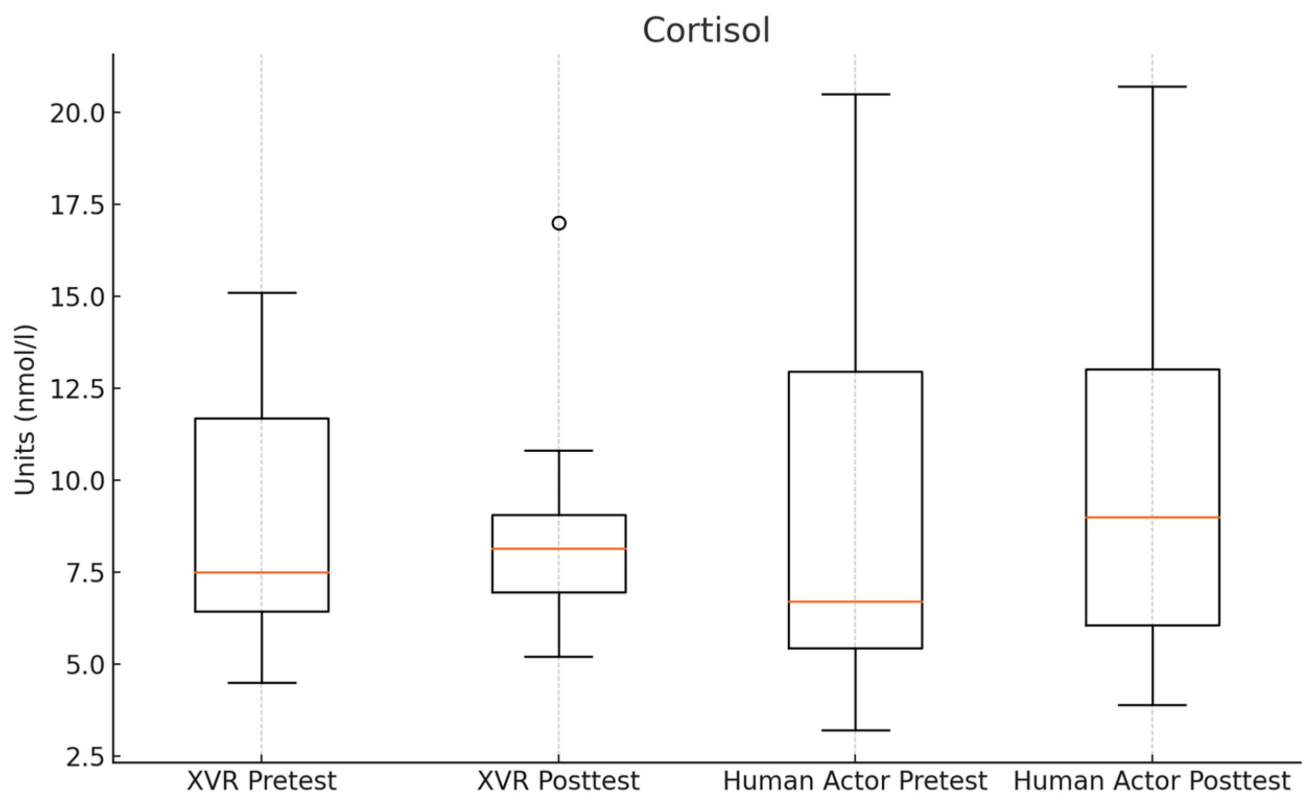

Figure 1. Changes in cortisol concentration during the management of a traffic accident in the XVR program and in the simulation with human actors.

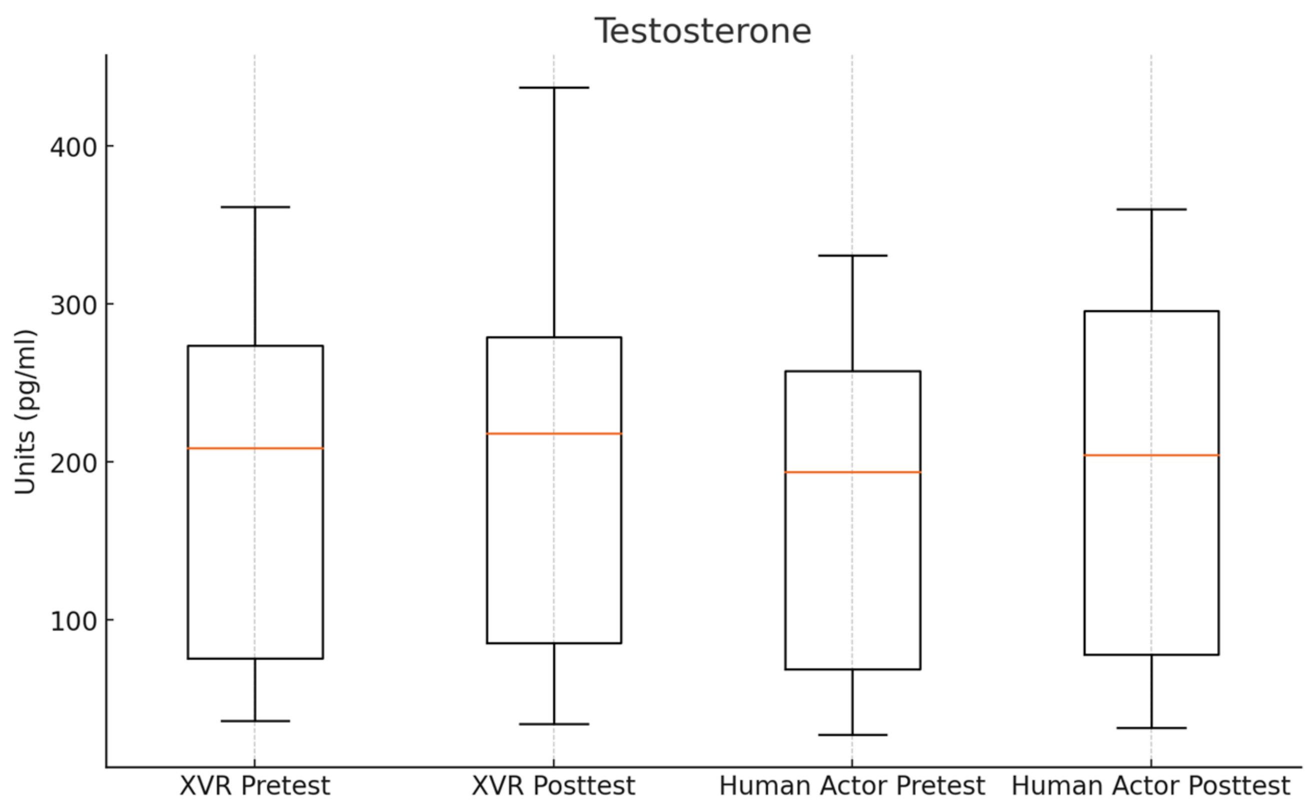

Figure 2. Changes in testosterone concentration during the management of a traffic accident in the XVR program and in the simulation with human actors.

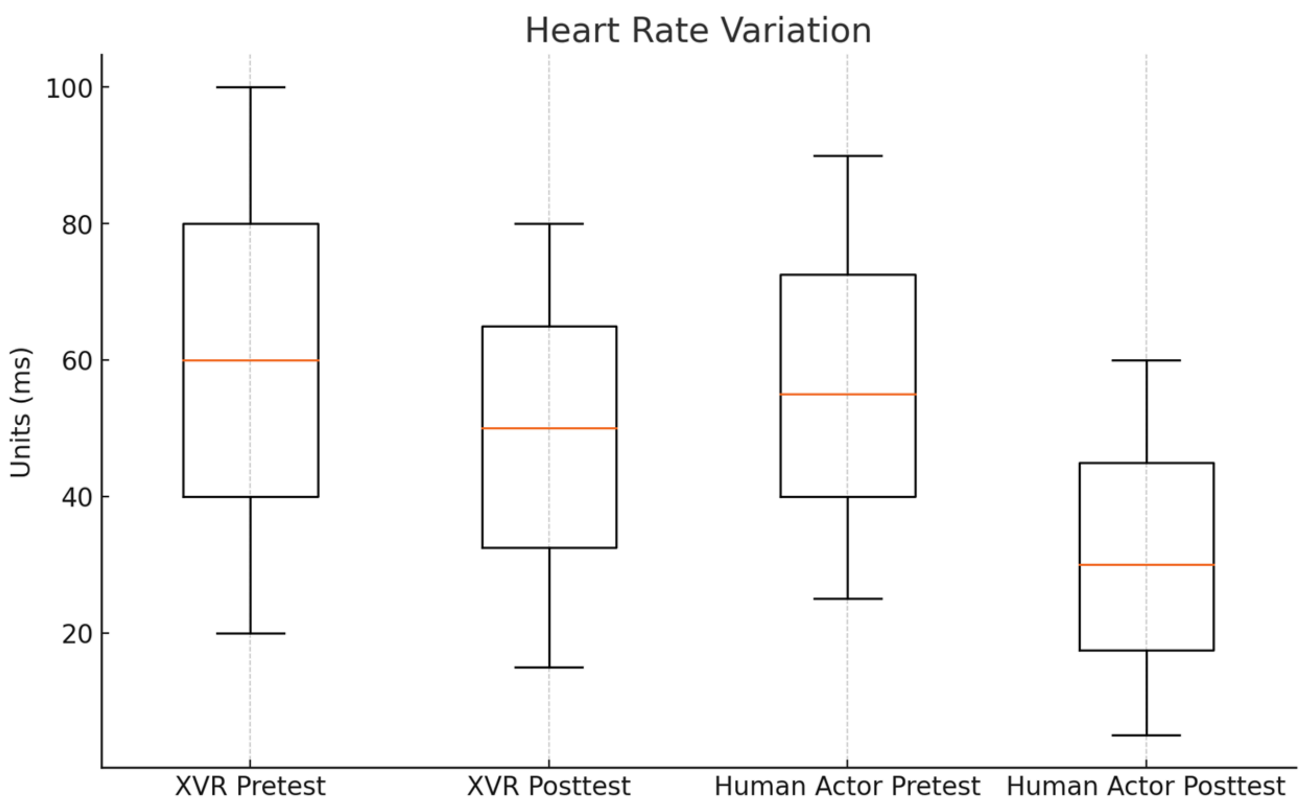

Figure 3. Changes in Heart Rate Variability during the management of a traffic accident in the XVR program and in the simulation with human actors.

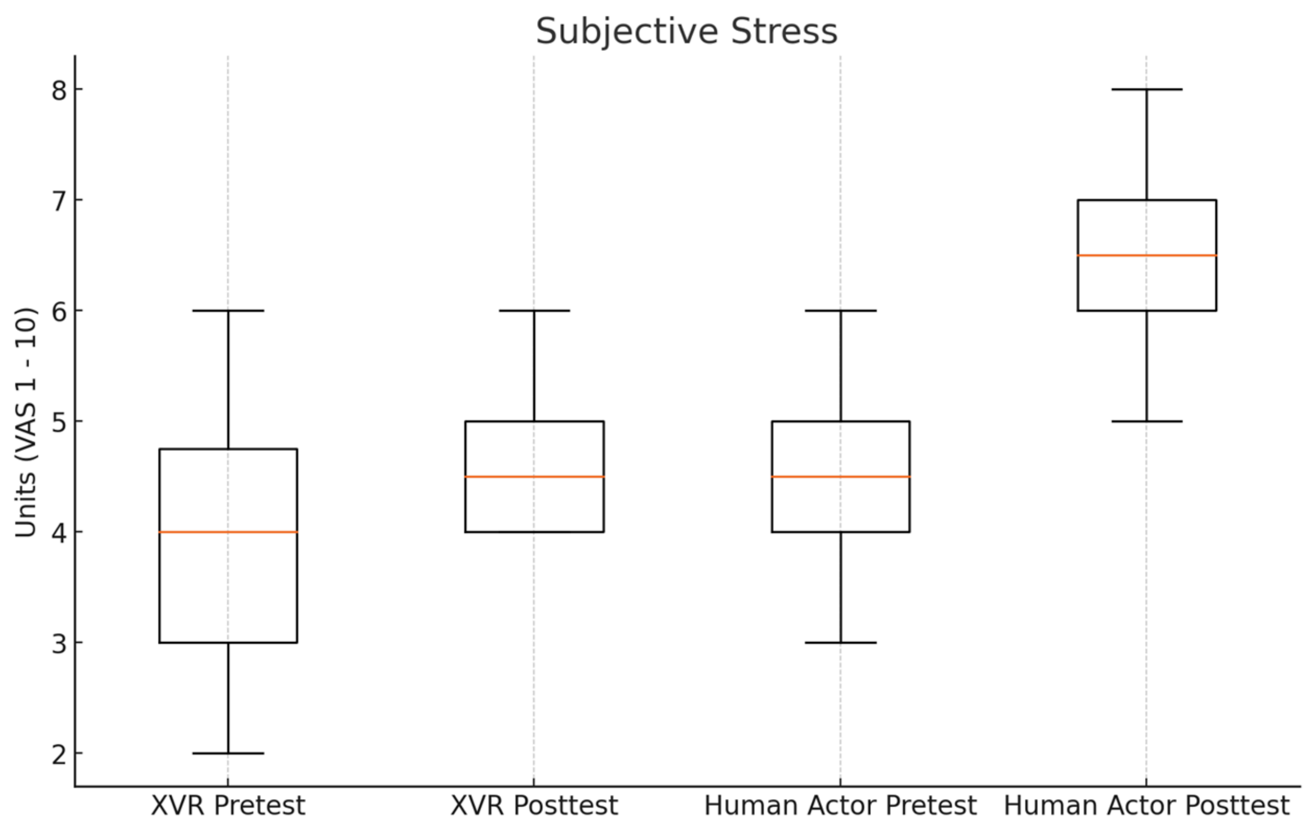

Figure 4. Changes in perceived stress levels during the management of a traffic accident in the XVR program and in the simulation with human actors.

4 DISCUSSION

In emergency response contexts, natural and human-made disasters, such as floods, large-scale accidents, and terrorist attacks, present substantial challenges. These events often occur suddenly and without warning, leading to significant loss of life, suffering, and damage to infrastructure (Naushad et al., 2019). The unpredictability of such disasters frequently overwhelms local emergency services, exceeding their capacity and resources to provide timely care. Emergency Medical Workers, responsible for initial prehospital care during crises, play a critical role in mitigating the impact of these events. However, many of these workers and other healthcare professionals often feel inadequately prepared for the complexities of these situations due to insufficient training (Dushek et al., 2019; Baetzner et al., 2022).

Research indicates that increasing the frequency and quality of training can significantly enhance the readiness of Emergency Medical Workers to manage crises. High-quality training is vital, as it enables them to perform effectively under pressure, ensuring accurate decision-making that is crucial for patient survival and recovery (Baetzner et al., 2022). This underscores the importance of training programs that not only build technical skills but also prepare responders for the high-stress environments typical of disaster scenarios.

Advancements in immersive training technologies, such as virtual reality (VR) and mixed reality (MR), offer new opportunities to improve the preparedness of healthcare professionals. These technologies enable realistic simulations that replicate the conditions of mass casualty events, providing responders with practical experience in a controlled environment. As these technologies become more widely accessible, they offer a promising approach to enhancing the readiness of Emergency Medical Workers to handle real-world emergencies (Baetzner et al., 2022).

Nevertheless, effective training programs require a systematic, goal-oriented approach, focusing on developing specific skills and competencies. The goal is to challenge the existing skill set of trainees with increasingly complex or novel content while avoiding overwhelming them. This approach allows for gradual adaptation and improved performance (Hill et al., 2020; Hill et al. 2021). Despite these advancements, implementing such training often faces practical constraints, such as limited time, budgets, and facilities. Therefore, it is essential to design training methods that maximize effectiveness while aligning with the resource capabilities of emergency services. By addressing these challenges, emergency services can better prepare their personnel for the unpredictable nature of large-scale disasters.

Current evidence suggests that excessive stress experienced by Emergency Medical Workers during challenging simulations, as indicated by increased salivary cortisol and the State-Trait Anxiety Inventory, leads to higher error rates, both in simulated patient care and in completing medical documentation. Quality and regular training foster adaptation to stressful situations and improve the efficiency of care provided (LeBlanc et al., 2012). Thus, implementing teaching methods that induce an optimal stress response in students is recommended. However, an excessive stress response may reduce efficiency in managing simulated scenarios. Simulation-based training methods are frequently used in emergency medical education, including highly realistic patient simulators, scenarios with role-players, and, more recently, virtual reality. In our pilot study, we did not observe significant differences in cortisol changes when managing a simulated traffic accident using live role-players or virtual reality. The question remains whether training in a virtual reality environment is less effective than simulations with live role-players. Andreatta et al. (2008) found no significant differences in START triage performance among students in both virtual reality and role-player scenarios. Another parameter used to measure hormonal responses to stress was the analysis of testosterone changes. Acute stress exposure can temporarily increase testosterone levels, while prolonged stress may decrease them. The dynamics of testosterone changes may indicate how the body adapts to stress (Zeuger et al., 2023; Afrisham et al., 2016).

In our study, we also focused on assessing heart rate variability (HRV). HRV, which measures variations in intervals between heartbeats, reflects the activity of the autonomic nervous system and can indicate the level of physiological and psychological stress an individual is experiencing. HRV can be used to assess the balance between sympathetic and parasympathetic influences on heart rhythm, shaped by both anticipatory inputs (e.g., from the motor cortex) and feedback mechanisms like the baroreflex that regulate the cardiovascular control center (Corrigan et al., 2021).

4.1 Limitation

This study has several limitations that should be considered when interpreting the results. First, the small sample size, consisting of only 10 participants (7 men and 3 women), limits the generalizability of the findings to a broader population. A larger sample would be necessary to detect subtle differences between the live simulation and virtual reality conditions, as the small group size increases the risk of statistical error. Additionally, the gender imbalance, with women representing only 30% of the sample, may have influenced the outcomes, as stress responses can vary by gender. This aspect was not sufficiently addressed in the analysis.

Another limitation lies in the study's design, specifically the limited duration and scope of the scenarios. Participants were allowed a maximum of 15 minutes to complete each simulation, which may not accurately reflect the conditions that emergency medical workers encounter during real-world crises. Furthermore, the study focused on a single type of scenario - a severe traffic accident - which limits the applicability of the findings to other types of emergencies.

The controlled testing conditions, including a fixed time frame (8:30–11:30 AM) and specific pre-test restrictions (e.g., abstaining from food, caffeine, and alcohol), also present limitations. While these measures helped to standardize conditions, they may not accurately represent the physiological stress responses that participants would experience in more varied and uncontrolled settings.

The study’s focus on a narrow set of physiological markers (salivary cortisol, testosterone, and heart rate variability) and subjective stress perception is another constraint. Other potentially relevant indicators, such as adrenaline levels or changes in cognitive performance, were not measured, which could have provided a more comprehensive understanding of stress responses.

Moreover, while the study found that students perceived the live-actor simulation as more stressful than the virtual reality scenario, it did not demonstrate significant differences in objective physiological responses between the two types of simulations. This makes it difficult to determine whether one method is truly more effective than the other for building stress resilience in training.

Finally, as this study was a pilot, the findings should be considered preliminary and a basis for further research. Larger sample sizes and the exploration of different types of scenarios would be necessary to confirm the results. The pilot nature of the study also means it may lack the statistical power to detect all relevant differences between conditions. These limitations highlight the need for caution when interpreting the study's conclusions and suggest directions for future research in the field of stress resilience training.

5 CONCLUSION

This study highlights the comparable effectiveness of virtual reality and live actor simulations in training Paramedicine students to manage high-stress scenarios, such as traffic accidents. While no significant differences were found in physiological stress markers (cortisol, testosterone, and

HRV) between the two methods, students perceived higher stress levels during live actor simulations. These findings suggest that VR can serve as a viable and potentially more cost-effective alternative to traditional live simulations. However, further research with larger sample sizes is needed to validate these results and explore the long-term effects of VR training on stress adaptation in emergency medical education. The project was supported by the Ústí Region Fund.

References

Afrisham, R., Sadegh-Nejadi, S., Far, O. S., Kooti, W., Ashtary-Larky, D., Alamiri, F., Aberomand, M., Najjar-Asl, S., & Khaneh-Keshi, A. (2016). Salivary testosterone levels under psychological stress and its relationship with rumination and five personality traits in medical students. *Psychiatry Investigation*, *13*(6), 637-643.

Andreatta, P. B., Maslowski, E., Petty, S., Shim, W., Marsh, M., Hall, T., Stern, S., & Frankel, J. (2010). Virtual reality triage training provides a viable solution for disaster-preparedness. *Academic Emergency Medicine*, *17*(10), 871-876.

Baetzner, A. S., Wespi, R., Hill, Y., Gyllencreutz, L., Sauter, T. C., Saveman, B. I., Mohr, S., Regal, G., Wrzus, C., & Frenkel, M. O. (2022). Preparing medical first responders for crises: A systematic literature review of disaster training programs and their effectiveness. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, *30*(1), 2-23.

Cmorej, P. C., Hrach, K., Argayova, I., Peran, D., Pekara, J., Jarabicova, O., Kelbich, P., Spicka, J., & Ralbovska, D. R. (2023). Impact of personal protective equipment on the quality of chest compressions in prehospital care: A prospective randomized crossover study. *Prehospital and Disaster Medicine*, *38*(1), 103–110.

Corrigan, S. L., Roberts, S., Warmington, S., Drain, J., & Main, L. C. (2021). Monitoring stress and allostatic load in first responders and tactical operators using heart rate variability: A systematic review. *BMC Public Health*, *21*(1).

Darling-Hammond, L., & Snyder, J. (2015). Meaningful learning in a new paradigm for educational accountability: An introduction. *Education Policy Analysis Archives*, *23*(7).

Dixon, M., Keane, F., & Taylor, A. (2016). Paramedic education–Is dynamic problem-based learning the way forward? *Irish Journal of Paramedicine*, *1*(2).

Duschek, S., Bair, A., Haux, S., Garrido, A., & Janka, A. (2020). Stress in paramedics: Relationships with coping strategies and personality traits. *International Journal of Emergency Services*, *9*(2), 203-216.

Givati, A., Street, K. I., & Markham, C. (2016). On the road again? Training paramedics in higher education in the UK [Abstract]. In *ISA Forum of Sociology*. Vienna, Austria.

Hayes, C. (2018). Building psychological resilience in the paramedic. *Journal of Paramedic Practice*, *10*(4), 147-152.

Hill, Y., Kiefer, A. W., Silva, P. L., Van Yperen, N. W., Meijer, R. R., Fischer, N., et al. (2020). Antifragility in climbing: Determining optimal stress loads for athletic performance training. *Frontiers in Psychology*, *11*, Article 10. *https://doi.org/10.3389/fpsyg.2020.00272*

Hill, Y., Van Yperen, N. W., & Den Hartigh, R. J. (2021). Facing repeated stressors in a motor task: Does it enhance or diminish resilience? *Journal of Motor Behavior*, *53*(6), 717–726. *https://doi.org/10.1080/00222895.2020.1852155*

LeBlanc, V. R., Regehr, C., Tavares, W., Scott, A. K., MacDonald, R., & King, K. (2012). The impact of stress on paramedic performance during simulated critical events. *Prehospital and Disaster Medicine*, *27*(4), 369-374.

Naushad, V. A., Bierens, J. J. L. M., Nishan, K. P., Firjeeth, C. P., Mohammad, O. H., Maliyakkal, A. M., ChaliHadan, S., & Schreiber, M. D. (2019). A systematic review of the impact of disaster on the mental health of medical responders. *Prehospital and Disaster Medicine*, *34*(6), 632–643.

Schulz, F. K., Altman D.G., & Moher D. (2010). CONSORT 2010 Statem (ent: updated guidelines for reporting parallel group randomised trials. *BMC Medicine,* 8(18).

Zeuger, R., Annen, H., & Ehlert, U. (2023). Testosterone and cortisol responses to acute and prolonged stress during officer training school. *The International Journal on the Biology of Stress*, *26*(1).