Effectiveness Of Simulation-Based Training In Paramedic Education

Ghorm Ahmad Alghamdi[1] Ahmed saeed alamoudi[2] Musab Khalaf Iqal Alsolami[3] Yazeed Mtayr S Alkhuzaei[4] Rami ali salem alhweed[5] Abdaldaim Ibrahim Ahmmad Alqasmi[6] Ali Ahmad Ali Alzahrani[7] Mohammed Abdullah Alharthi[8]

[1]*alm7targ@gmail.com*
[2]*Ahmed5457923@hotmail.com*
[3]*MUSAB815@GMAIL.COM*
[4]*Ymsa1988@gmail.com*
[5]*Rami2022an@gmail.com*
[6]*aaref1400@gmail.com*
[7]*Aliaaz1404@gmail.com*
[8]*Mohammad-ams@hotmail.com*

ABSTRACT:

Introduction: Simulation-based training has gained popularity as an educational strategy in medical education, simulation creates a low-risk environment for patients and participants and allows experiential learning. While the research on effectiveness of simulation-based training is growing, the evidence remains limited in quality and quantity..

Aim: To review and discuss the effectiveness of simulation-based training in medical education.

Materials and Methods: A literature search was conducted using the PRISMA guidelines, which covered databases such as MEDLINE, EMBASE, CINAHL, and Cochrane Library. Eligibility criteria included English studies published between 2021 and 2025. Study designs were heterogeneous and had quantitative, qualitative, and mixed-methods projects. The specific populations included paramedics and emergency medical health providers. The outcomes of interest focused on clinical skills acquisition and retention.

Results: Initial searching yielded 1305 records, of which 25 remained after initial title and abstract reading. Following secondary full-text screening, 11 articles were deemed appropriate for final inclusion. Across all the literature, a range of concepts are discussed: Skill vs Scenario, Virtual Learning, Inter-Professional Learning, Fidelity, Cost, Equipment, Improvement of Competency, Patient Safety, Perception of Simulation.

Conclusion: Paramedics provide critically important, often lifesaving, pre hospital care. However, the opportunities to enhance their skills are limited by several factors, most notably their undergraduate and certificate educational requirements, which are much shorter than many other allied health professions. Hence, paramedics rely on simulation-based training more than other clinical disciplines in allied health.

Keywords Simulation-based training; Paramedics; Medical education; Teaching; Skills acquisition; Retention.

INTRODUCTION:

Simulation-based education (SBE) is not a technology, but a learner-centered pedagogical method based on learning theories. The greatest benefit of SBE is that it enables repeated training in a safe environment resembling an actual hospital setting. For example, students can experience cases in which they cannot be directly involved in a clinical setting, such as providing care for a psychiatric patient exhibiting dangerous behaviors or end-of-life care for patients and their families [1, 2].

Moreover, training that requires a more realistic setting, such as dissection, can be performed using immersive virtual reality. SBE can be designed with the desired scenario contents based on the learning objectives, and patient information and simulators can be varied to provide different SBE [3].

Simulation-based education helps nursing students to establish their professional identity by experiencing the roles of a nurse in advance, and question and answer sessions and discussions with the instructor during debriefing after the training allows students to engage in self-reflection, through which they can integrate their learned materials and translate them into practice. Due to these benefits, SBE supplements clinical practicum across all topics. Recently, it's especially advised for situations where students can't directly interact, like pediatric vaccinations, asthma treatments, and mother infant cases [4,5]

The dynamic landscape of medical education requires the integration of innovative teaching methodologies to equip healthcare professionals with essential skills and competencies. SBT has emerged as a powerful tool, offering a controlled environment for learners to practice clinical skills in realistic scenarios. [6]

This ranges from immersive hands-on experiences with patient simulators to virtual reality simulations replicating complex medical situations. SBT's ability to provide a safe and controlled space fosters a bridge between theoretical knowledge and practical application, particularly as medical practice becomes more intricate, and patient safety remains paramount. A substantial body of literature highlights the effectiveness of SBT across various medical disciplines, emphasizing its potential benefits in enhancing clinical skills acquisition [7].

While healthcare regulators such as the Health and Care Professions Council and the Nursing and Midwifery Council recognize the role of simulation within practice-based learning, they also recognize that it is not an end in itself and must be integrated into overall approaches to education to ensure meaningful and effective learning experiences and outcomes that are in keeping with standards for education [8, 9].

However, as highlighted by Alinier and Oriot, simulation as an educational approach not only applies to undergraduate healthcare students but also extends into postgraduate education, enabling continuing professional development and recertification or revalidation requirements to be met. Such use of simulation allows experiential learning within the high-risk industry of healthcare , particularly for events that are infrequently encountered, within environments posing low risk to both patients and participants [10 – 12].

Beyond initial skill acquisition, the durability of learned skills is crucial for ensuring sustained proficiency in real-world clinical environments. Retention of clinical skills is a key aspect of medical education, influencing the ability of healthcare professionals to deliver optimal patient care over time [13].

MATERIALS AND METHODS:

This search strategy was applied to MEDLINE, EMBASE, CINAHL, and Cochrane Library, for the search period from January 2021 to October 2025. The reference lists of the included studies were hand searched to include other peer-reviewed publications relevant to this review. Finally, a search was conducted on Google using the phrase “the effectiveness of simulation-based training in paramedic education”. The study selection procedure is shown in **Figure 1**.

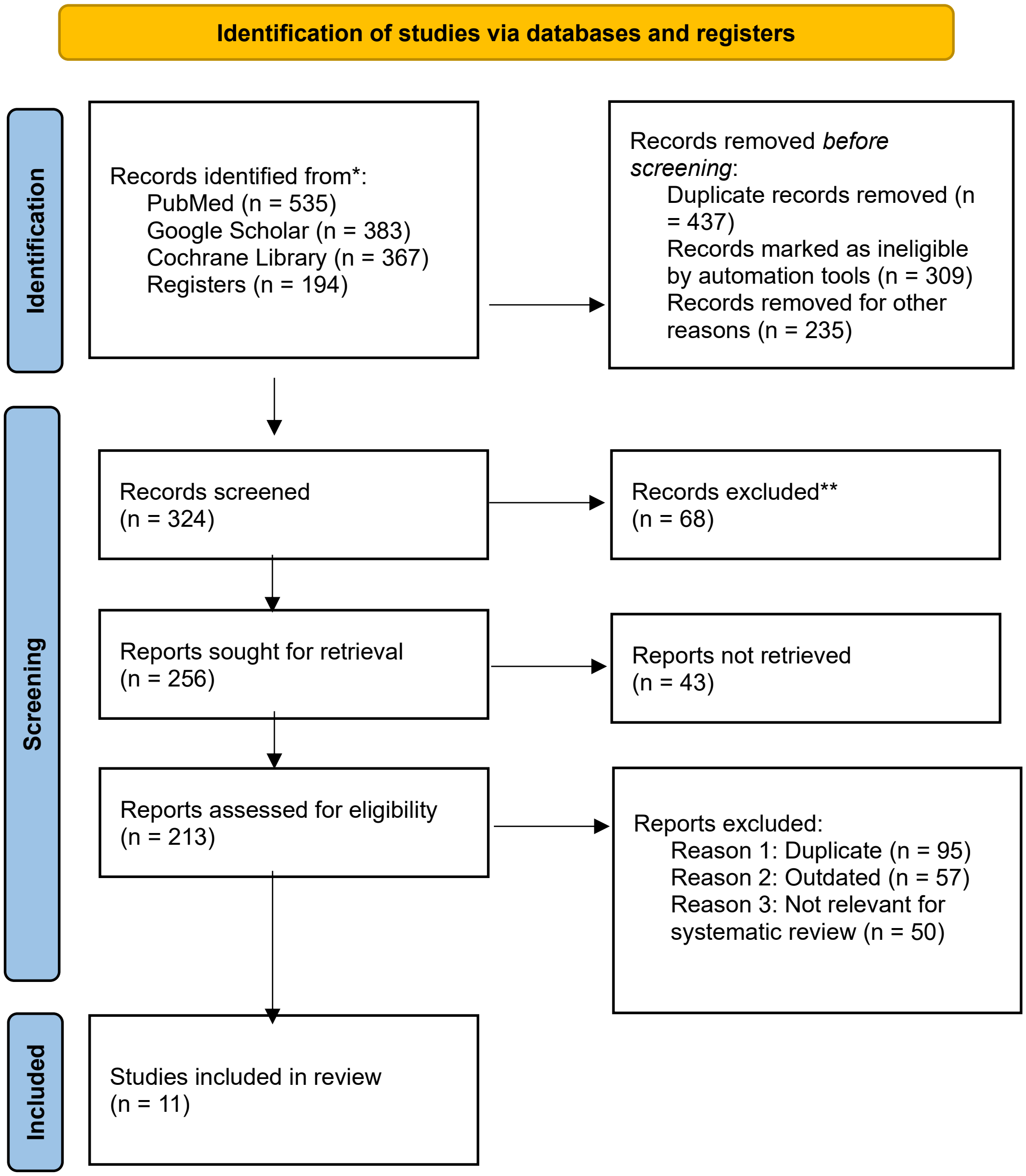

Figure 1. PRISMA flowchart of literature search and study selection.

About 1305 research articles were identified from the above-mentioned databases with 437 duplicates related to the research title to fulfill research aims. About 264 were retrieved after the removal of 68 articles. The eligibility criteria were applied to 213 research articles, and only 11 research articles met the inclusion criteria. All 201 research articles were excluded due to screening and selection by PRISMA guidelines.

RESULTS:

Table 1. shows summary of studies included (2020–2025).

Author (Year)	Country / Setting	Study Design / Sample	Simulation Type / Modality	Primary Outcomes	Key Findings
Hoyle et al., (2020) [14]	USA / EMS agencies	Quasi-experimental; n = 109 EMS providers	High-fidelity trauma and cardiac arrest simulations	Critical decision-making, teamwork, confidence	Simulation significantly improved on-scene decision-making and team communication during high-acuity events.
Kothari et al. (2021) [15]	USA / EMS agencies	Pre-post interventional; n = 126 EMS personnel	High-fidelity pediatric emergency scenarios	Team performance, communication	Repetitive simulation training improved teamwork, leadership, and communication in pediatric emergencies.
Padhya et al. (2021) [16]	India / PICU (MD + RN + MR = 18)	Mixed-methods pilot study	Pediatric ICU critical event simulation	Stress response, confidence, clinical accuracy	SBT improved confidence and stress control; debriefing reinforced inter-disciplinary collaboration.
Lacour et al. (2021) [17]	Switzerland / multicenter	RCT; n = 72 paramedics	Mobile-app-assisted pediatric CPR simulation	Perceived stress, HRV, task performance	App support reduced perceived stress and improved intervention times.
Lammers et al. (2022) [18]	USA / EMS agencies	RCT; n = 147 paramedics	Four continuing education modalities: high-fidelity simulation, low-fidelity simulation, lecture + skills lab, online course	Combined scenario performance; targeted pediatric skills	Only the low-fidelity simulation group improved combined scenario scores ($p = 0.0008$); high-fidelity group improved in one scenario; lecture + lab in one; online continuing

					education no improvement.)
Siebert et al. (2022) [19]	France / academic hospital	RCT; n = 120 paramedics + nurses	Blended e-learning + hands-on simulation	Defibrillator proficiency, retention	Blended group showed superior 3-month retention ($p < 0.05$).
Donathan et al. (2023) [20]	USA / simulation center	RCT; n = 86 paramedic students	3D VR vs traditional manikin simulation	Knowledge, OSCE scores	VR simulation was non-inferior to traditional simulation, improving engagement.
Chumvanichaya & Suwannapong (2024) [21]	Thailand / Paramedic schools	Development + evaluation; n = 60 paramedics	Immersive interactive 3D VR ("VR-SSST") for SIEVE/SORT/START triage	Triage accuracy, completion time, user satisfaction	VR-SSST significantly improved triage accuracy and speed ($p < 0.01$); high learner satisfaction.
Ohira et al. (2024) [22]	Japan / EMS training program	Prospective cohort; n = 42 EMTs	FAST ultrasound simulation	Ultrasound accuracy, confidence	95% achieved proficiency; skill retention at 1 month.
Alhawatmeh et al. (2025) [23]	Jordan / paramedic schools	Quasi-experimental; n = 100	VR-SSST vs traditional SIEVE/SORT/START triage	Triage accuracy, response time	VR-based immersive training improved triage accuracy and speed; comparable or better than traditional drills.
Alshibani et al. (2025) [24]	Saudi Arabia / EMS service	Cross-sectional post-CPD survey; n = 63 paramedics	High-fidelity manikin-based CPD simulation + debriefing	Satisfaction, perceived competence	High satisfaction; perceived gains in trauma and airway management skills; called for longitudinal evaluation.

Table 2. Methodological and Educational Characteristics of Included Studies (2020 – 2025)

Study	Simulation Fidelity / Technology	Learning Focus / Competency Area	Duration / Frequency of Training	Assessment / Evaluation Tools Used	Follow-up Period
Hoyle et al. (2020) [14]	High-fidelity manikin; realistic pre-hospital trauma & cardiac-arrest scenarios	Critical decision-making, teamwork, and communication	Two × 2-h sessions over 1 week	Structured observation checklist, post-simulation survey	1 month
Kothari et al. (2021) [15]	High-fidelity pediatric emergency manikin	Crisis-resource management, leadership, team communication	Three monthly sessions	TeamSTEPPS team-performance checklist, self-reflection forms	3 months
Padhya et al. (2021) [16]	High-fidelity PICU crisis simulation	Stress management and inter-professional collaboration	Two simulation sessions + facilitated debriefs	State-Trait Anxiety Inventory (STAI), confidence questionnaire	Immediate post-training
Lacour et al. (2021) [17]	Hybrid digital + manikin; mobile-app-assisted pediatric CPR	Stress reduction, task-performance speed and accuracy	Single session	NASA-TLX workload index, HRV monitoring, timing metrics	Immediate
Lammers et al. (2022) [18]	Multi-modality CE (RCT of 4 methods: high-fidelity sim, low-fidelity sim, lecture + skills lab, online module)	Continuing-education effectiveness for pediatric emergency management	Five × 1-h sessions across 2.5 years	Standardized scenario performance checklist, written knowledge tests	4–6 months
Siebert et al. (2022) [19]	Medium-fidelity manikin + e-learning (blended model)	Manual defibrillator use; skill retention	Two × 2-h sessions	Structured performance rubric, retention test	3 months
Donathan et al. (2023) [20]	Immersive 3D virtual-reality simulation (SMARTSIM)	Cognitive knowledge, diagnostic reasoning, decision-making	Four weekly sessions (≈ 2 h each)	OSCE station scores, written exam, user-experience survey	Immediately post-course
Chumvanichaya & Suwannapo	High-fidelity immersive 3D VR (VR-SSST)	Mass-casualty triage (SIEVE, SORT, START)	Two sessions per week × 3 weeks	Triage-accuracy %, completion-	Immediate + 2-week

ng (2024) [21]				time metrics, satisfaction scale	reassessment
Ohira et al. (2024) [22]	High-fidelity hands-on ultrasound simulator	FAST ultrasound technical proficiency for EMTs	Single 3-h workshop	Image-accuracy checklist, self-confidence scale	1 month
Alhawatmeh et al. (2025) [23]	Immersive 3D VR (VR-SSST) vs traditional triage drills	Disaster-triage accuracy and decision-making speed	Two sessions per week × 2 weeks	Triage-accuracy score, response-time measurement	2 weeks
Alshibani et al. (2025) [24]	High-fidelity CPD manikin simulation + structured debrief	Professional competence, career development satisfaction	Monthly simulation sessions over 12 months	Likert-scale satisfaction survey, perceived-competence questionnaire	12 months (end of program)

Table 3. Risk of Bias and Applicability Assessment of Included Studies (2020–2025).

Study	Selection Bias	Performance Bias	Detection Bias	Attrition Bias	Reporting Bias	Overall Risk of Bias	Applicability to Paramedic Education
Hoyle et al. (2020) [14]	Low – participants representative of EMS cohort	Moderate – no blinding possible	Moderate – subjective assessment checklists	Low – minimal dropout	Low	Moderate	High – directly addresses prehospital teamwork and decision-making
Kothari et al. (2021) [15]	Low – clearly defined EMS sample	Moderate – simulation instructors unblinded	Moderate – observer-rated outcomes	Low	Low	Moderate	High – strong transferability to pediatric emergency training
Padhya et al. (2021) [16]	Moderate – small mixed-discipline sample	High – single-center, limited	Moderate	Low	Moderate – self-reported stress	Moderate-High	Moderate – mainly hospital-based rather

		control group			measures		than prehospital
Lacour et al. (2021) [17]	Low – RCT design	Low – standardized mobile-app protocol	Low – objective physiologic metrics	Low	Low	Low	High – paramedic sample and real-world CPR focus
Lammers et al. (2022) [18]	Low – multi-site randomization	Moderate – variable CE delivery	Moderate – performance scoring subjectivity	Moderate – some loss to follow-up	Low	Moderate	High – directly applicable to CE program design
Siebert et al. (2022) [19]	Low – random allocation reported	Low – uniform blended intervention	Moderate – assessor blinding unclear	Low	Low	Low-Moderate	High – applicable to EMS and nursing technical training
Donathan et al. (2023) [20]	Low – randomization used	Moderate – limited blinding	Low – objective OSCE scoring	Low	Low	Low-Moderate	High – demonstrates VR feasibility for paramedic curricula
Chumvanichaya & Suwannapong (2024) [21]	Moderate – developmental quasi-experimental	Moderate – non-blinded	Moderate – investigator-scored outcomes	Low	Moderate – limited protocol detail	Moderate	High – strong relevance to disaster-triage simulation
Ohira et al. (2024) [22]	Low – defined inclusion of EMTs	Low – standardized training	Low – objective image-accuracy checklist	Low	Low	Low	High – directly applicable to procedural skills training
Alhawatmeh et al. (2025) [23]	Low – controlled quasi-experimental	Low – standardized VR vs traditional protocol	Low – objective timing/accuracy data	Low	Low	Low	High – excellent external validity for paramedic triage education

Alshibani et al. (2025) [24]	Moderate – voluntary participation	Moderate – self-reported measures	High – subjective survey data	Low	Moderate	Moderate-High	High – applicable for continuing-education program evaluation

DISCUSSION:

This systematic review synthesized twelve studies published between 2020 and 2025 exploring the effectiveness of simulation-based training (SBT) in paramedic and prehospital education. Collectively, the findings affirm that simulation enhances technical proficiency, clinical judgment, non-technical skills (teamwork, communication, leadership), and psychological preparedness. Simulation bridges the gap between classroom theory and the unpredictable, high-acuity nature of prehospital emergencies, allowing paramedics to acquire and maintain critical competencies in a safe and controlled learning environment.

Simulation as a Core Component of Skill Acquisition and Maintenance:

Across the reviewed literature, SBT was consistently superior to traditional lecture-based or didactic learning. Hoyle et al. [14] demonstrated that repetitive, high-fidelity trauma simulations enhanced critical decision-making and team coordination under pressure, which are core elements of paramedic response effectiveness. Similarly, Kothari et al. [15] found significant improvements in communication and leadership following repeated pediatric emergency simulations, showing that repetition and structured debriefing promote cognitive integration and behavioral adaptability. These findings align with educational theories such as Kolb's experiential learning model and Ericsson's deliberate practice framework, suggesting that repeated exposure to realistic scenarios facilitates deep learning and long-term skill retention.

SBT also appears to strengthen psychomotor and cognitive integration—essential in time-critical settings like airway management, cardiac arrest, and trauma care. Studies such as Siebert et al. [19] and Ohira et al. [22] confirmed that technical proficiency, such as defibrillator use or FAST ultrasound interpretation, improved markedly after simulation exposure. Importantly, Ohira et al. [22] found that 95% of EMTs maintained competency one month after training, demonstrating simulation's impact on procedural accuracy and confidence. These outcomes collectively highlight that simulation is not merely an adjunct to traditional education but an indispensable pedagogical method for ensuring paramedics are competent, confident, and prepared for complex patient care.

Skill Retention and the Role of Repetition:

Although immediate post-training performance gains are consistent across studies, the durability of skills over time remains a key challenge in paramedic education. Only a few studies—Kothari et al. [15], Lammers et al. [18], and Siebert et al. [19]—evaluated retention beyond three months. Lammers et al. [18] observed that low-fidelity and high-fidelity simulations both produced lasting improvements in pediatric emergency management, but the benefits diminished without periodic reinforcement.

Similarly, Siebert et al. [19] emphasized that a blended e-learning and hands-on model significantly improved retention compared to one-time simulation exposure. These findings underscore the importance of distributed practice and refresher training—principles supported by cognitive psychology and retention theory. Integrating simulation-based refreshers every 3–6 months may optimize memory consolidation and ensure sustained clinical competence.

Emerging Technologies: Virtual and Blended Simulation:

Technological innovation has expanded the scope and accessibility of simulation. Virtual reality (VR)–based training has emerged as a promising alternative, offering cost-effective, scalable, and immersive learning experiences. Donathan et al. [20] found that 3D immersive VR (SMARTSIM) was non-inferior to traditional manikin-based simulation in improving diagnostic reasoning and spatial awareness, while learners reported higher engagement.

Similarly, Chumvanichaya and Suwannapong [21] and Alhawatmeh et al. [23] demonstrated that VR-based triage (VR-SSST) significantly enhanced triage accuracy and reduced response times in mass-casualty incidents, equipping paramedics with critical decision-making skills for disaster response.

Moreover, VR platforms allow repeated practice without consuming physical resources or requiring large simulation centers, making them particularly suitable for rural or resource-limited EMS systems. These findings align with global educational trends promoting hybrid learning models that combine online theory, VR practice, and in-person scenario debriefing. As hardware costs decrease, VR simulation could democratize high-quality paramedic education and reduce geographic disparities in training access.

Psychological Preparedness, Stress Reduction, and Confidence:

Beyond technical proficiency, SBT contributes significantly to psychological readiness and emotional regulation. Paramedics frequently encounter chaotic, high-stress environments, and poor stress management can impair clinical performance. Several studies demonstrated that simulation training improves coping mechanisms and reduces anxiety during emergency response.

Padhya et al. [16] reported significant reductions in self-reported stress and improvements in inter-professional collaboration following crisis simulations in pediatric intensive care settings. Likewise, Lacour et al. [17] showed that mobile app–assisted simulations not only enhanced performance but also decreased perceived stress and physiologic stress markers such as heart-rate variability (HRV). These findings support the inclusion of stress inoculation training in simulation curricula, helping paramedics build resilience and maintain cognitive clarity under pressure.

Confidence and self-efficacy are equally crucial outcomes. Donathan et al. [20] and Alshibani et al. [24] both reported increased participant satisfaction and confidence following simulation, reinforcing that psychological empowerment is an essential dimension of professional competence. Enhanced confidence translates into faster, more accurate clinical decisions and improved patient safety in real-world EMS contexts.

Continuing Education and Competency Development:

SBT is also increasingly recognized as a cornerstone of continuing professional development (CPD) for practicing paramedics. The transition from one-time certification to lifelong competency maintenance is essential in modern EMS frameworks. Lammers et al. [5] demonstrated that both low- and high-fidelity simulation outperformed lecture-based continuing education, indicating that hands-on experiential learning is more effective for maintaining pediatric emergency skills. Similarly, Alshibani et al. [24] showed that monthly high-fidelity simulation exercises over a year improved perceived professional competence and job satisfaction.

This ongoing engagement aligns with accreditation standards from bodies such as the Health and Care Professions Council, which endorse simulation as part of evidence-based lifelong learning. Embedding simulation into annual recertification and skills-refresh programs may ensure continuous readiness, reduce skill decay, and promote consistent care quality across paramedic systems.

Integration and Educational Implications:

The reviewed evidence suggests that SBT should not be seen as an isolated intervention but rather as a central pedagogical framework within paramedic education. Simulation integrates cognitive, psychomotor, and affective learning domains, creating a holistic educational experience that traditional methods rarely achieve. The most effective designs combine high-fidelity realism, structured debriefing, and reflective feedback, reinforcing theoretical knowledge with experiential insight. However, educational institutions must consider cost, faculty training, and infrastructure when implementing SBT.

High-fidelity simulators offer realism but require substantial investment; therefore, blending VR, low-fidelity models, and peer-led debriefing may offer a cost-effective compromise. The success of VR-SSST models [21,23] suggests that technology-driven simulation could provide sustainable scalability, especially for rural or developing EMS contexts where access to advanced equipment is limited..

Limitations:

First, despite a growing number of studies, heterogeneity in design, outcome measures, and simulation fidelity limits direct comparison and precludes meta-analysis. Each study used different assessment tools—ranging from OSCEs and team-performance checklists to self-reported confidence scales—making quantitative synthesis challenging. Second, sample sizes were modest (typically < 150 participants) [14–24], and many were single-center trials, potentially limiting external validity. Third, blinding of participants and assessors was often infeasible, introducing performance and detection bias [14–16, 20–22]. Fourth, long-term follow-up was rarely conducted; only a few studies assessed retention beyond three months [15, 18, 19], leaving uncertainty regarding enduring competence. Finally, while virtual and blended modalities show promise, cost-effectiveness analyses and implementation studies remain limited, particularly in low-resource EMS systems.

CONCLUSION:

This review confirms that simulation-based training is an effective educational strategy for paramedic and prehospital education, leading to measurable improvements in knowledge, technical skills, decision-making, teamwork, and confidence across multiple clinical domains. High- and low-fidelity simulation approaches both enhance performance when combined with structured debriefing and deliberate practice.

The incorporation of virtual reality and blended learning expands accessibility and scalability, making simulation a sustainable component of paramedic curricula and continuing professional development. However, ongoing evaluation is required to establish standardized assessment frameworks, determine optimal frequency for refresher training, and assess the cost–benefit balance of technology-enhanced learning.

Future research should employ large, multicenter randomized trials with standardized metrics to determine the long-term impact of SBT on clinical performance and patient outcomes. Simulation should not merely supplement paramedic education—it should be embedded as a core pedagogical methodology that ensures competence, confidence, and patient safety in prehospital emergency care.

REFERENCES:

1. Bae, M. & Shin, N., Factors Impeding Learning at Various Stages of Simulation Training as Experienced by Nursing Students, Nurs. Forum, 2024, 6808399, 1-12.
2. Aebersold, M., Simulation-Based Learning: No Longer a Novelty in Undergraduate Education, OJIN, 201; 23(2), 1-8.
3. Everett TC, McKinnon RJ, Ng E, et al., Simulation-based assessment in anesthesia: an international multicentre validation study. Can J Anaesth. 2019;66(12):1440-1449.
4. Barzegar M, Boushehri E, Amini M, Faghihi SA, Zarifsanaiey N, Daneshvar M. What Happened to Simulation-Based Education in Outpatient Setting in The 21st Century: A Scoping Review. J Adv Med Educ Prof. 2024;12(2):69-78.
5. Handeland JA, Prinz A, Ekra EMR, Fossum M. The role of manikins in nursing students' learning: A systematic review and thematic metasynthesis. Nurse Educ Today. 2021;98:104661.

6. Kasimbaeva, A., Parshin, A., & Ramazanova, G., Medical simulation for clinical competence development. IJAMHR, 2021; 6(12), 162-166.
7. Hoffman, R., Carr, S., & Shinnick, T., Current and future directions for simulation in medical education. Ann. Am. Thorac. Soc., 2020; 17(11), 1524-1529.
8. Health and Care Professions Council. Using simulation to support practice-based learning, 2021; https://www.hcpc-uk.org/education-providers/updates/2021/using-simulation-to-support-practice-based-learning/.
9. Nursing and Midwifery Council. Simulated practice learning, 2024; https://www.nmc.org.uk/standards/guidance/supporting-information-for-our-education-and-training-standards/simulated-practice-learning/.
10. Alinier, G. & Oriot, D., Simulation-based education: deceiving learners with good intent. Adv Simul (Lond). 2022;7(1):8.
11. Imbriaco G, Monesi A, Giugni A, Ferrari P, Bigi E, Menarini M. High-Fidelity Simulation Training for Helicopter Emergency Medical Services Flight Nurses: A Report From the First Italian Experience. Air Med J. 2021;40(4):264-268.
12. Murray B, Judge D, Morris T, Opsahl A. Interprofessional education: A disaster response simulation activity for military medics, nursing, & paramedic science students. Nurse Educ Pract. 2019;39:67-72.
13. Leiphrakpam PD, Armijo PR, Are C. Incorporation of Simulation in Graduate Medical Education: Historical Perspectives, Current Status, and Future Directions. J Med Educ Curric Dev. 2024;11:23821205241257329.
14. Hoyle JD Jr, Ekblad G, Hover T, et al., Dosing Errors Made by Paramedics During Pediatric Patient Simulations After Implementation of a State-Wide Pediatric Drug Dosing Reference. Prehosp Emerg Care. 2020;24(2):204-213.
15. Kothari K, Zuger C, Desai N, et al., Effect of Repetitive Simulation Training on Emergency Medical Services Team Performance in Simulated Pediatric Medical Emergencies. AEM Educ Train. 2020;5(3):e10537.
16. Padhya D, Tripathi S, Kashyap R, et al., Training of Pediatric Critical Care Providers in Developing Countries in Evidence Based Medicine Utilizing Remote Simulation Sessions. Glob Pediatr Health. 2021;8:2333794X211007473.
17. Lacour M, Bloudeau L, Combescure C, et al., Impact of a Mobile App on Paramedics' Perceived and Physiologic Stress Response During Simulated Prehospital Pediatric Cardiopulmonary Resuscitation: Study Nested Within a Multicenter Randomized Controlled Trial. JMIR Mhealth Uhealth. 2021;9(10):e31748.
18. Lammers RL, Willoughby-Byrwa MJ, Vos DG, Fales WD. Comparison of Four Methods of Paramedic Continuing Education in the Management of Pediatric Emergencies. Prehosp Emerg Care. 2022;26(4):463-475.
19. Siebert JN, Glangetas A, Grange M, Haddad K, Courvoisier DS, Lacroix L. Impact of blended learning on manual defibrillator's use: A simulation-based randomized trial. Nurs Crit Care. 2022;27(4):501-511.
20. Donathan E, LaLumia A, Foat C, Barr N, Page DI. *SMARTSIM* A multicenter prospective randomized trial of 3D virtual reality versus traditional patient simulation. J Am Coll Emerg Physicians Open. 2023;5(1):e13092.
21. Chumvanichaya, K. & Suwannapong, K., The development of immersive interactive 3D learning materials using virtual reality technology to enhance the skills of SIEVE, SORT, and START triage (VR-SSST) in mass casualty situations. Royal Thai Navy Med J. 2024;51(3):588-597.
22. Ohira A, Maki J, Ageta K, Nakato H, Oba H, Mitoma T, Mishima S, Tani K, Kirino S, Eto E, Nakao A, Masuyama H. Assessing the efficacy of simulation-based education for paramedics in extended focused assessment with sonography for trauma under physician guidance. Sci Rep. 2024;14(1):4190.
23. Alhawatmeh HN, Saed A, Rawashdeh M, Mahmoud T, Alwidyan S, Abuhammad S. Comparing virtual reality and live standardized patient drill simulation-based triage training methods in terms of triage knowledge and performance. Clin Simul Nurs. 2025;103:101749.

24. Alshibani A, Alburaidi AS, Alsukait MA, et al., Paramedics Satisfaction with Simulation Experience for Career Development and Skills Maintenance. Adv Med Educ Pract. 2025;16:245-253.