Air Medical Journal 000 (2026) 1–6

Contents lists available at ScienceDirect

Air Medical Journal

journal homepage: http://www.airmedicaljournal.com/

Original Research

Enhancing High-Fidelity Simulation Flight–Based Training for Critical Care Paramedics in EMS Aviation: A Systematic Review

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A B S T R A C T

Objective: High-fidelity simulation (HFS) is used with critical care paramedics (CCPs) to enhance preparedness in high-stake scenarios. This systematic review aims to assess the evidence on the role and effectiveness of HFS flight-based training, evaluating its application in education for CCPs operating within emergency medical services aviation settings.
Methods: A systematic literature search was performed using a set of inclusion and exclusion criteria, resulting in 8 articles which were appraised using the Critical Appraisal Skills Programme tool.
Results: HFS training equips learners with skills relevant to their practice. CCPs register improved expertise, engagement and motivation, responsiveness, and general mood. There was insufficient evidence on whether this modality enhances self-awareness.
Conclusion: HFS learning is feasible in training CCPs in emergency medical services aviation. However, there is limited evidence on the performance of CCPs trained using HFS learning in the prehospital setting. The findings suggest that standardizing training and assessment methods is recommended to optimize skill acquisition, improve team performance, and enhance patient safety in high-acuity emergencies.

Within air medicine, critical care paramedics (CCPs) are a unique member of the helicopter emergency medical service (HEMS). They operate in high-risk environments, with an extended scope of practice and autonomy; this makes them an integral member of the HEMS team. Simulation is an integral part of the learning and updating of staff. This can help assist learners to acquire and master skills in an environment that does not expose them or patients to undue risks.[1] Simulation-based learning (SBL) facilitates learners development of new skills through repetition and reflection. It also allows them to engage with clinical processes and follow them through to their natural conclusion.[2] Another advantage of SBL is that it exposes learners to the relevant situations for their practice, thereby gaining relevant experience and fostering deliberate practice when conducted in their own teams.[3]

SBL has therefore become an important teaching method across all health care professionals, but it is particularly important in those situations that are highly time/skill intensive and infrequent. This is particularly important for air medical helicopters, where the reason for its use is less the severity of the injury but rather the geographical location that necessitates its use.[4]

High-fidelity simulation (HFS)-based training refers to an educational approach that combines realistic aviation environments with advanced simulation technology to prepare CCPs for emergency aviation situations.[2] HFS flight-based training is necessary to ensure EMS aviation CCPs are well trained to deliver enhanced clinical practice in

The first author wishes to dedicate this article to his father, Gordon McCormick (Gordy), who passed in October 2024 after a long illness. Gordy was his best friend, mentor, and an exceptional paramedic and educator. Gordy, known for his integrity, kindness, and dedication, left a lasting impact on the ambulance service and wider health care community. Admired by all who worked with him, his calm presence and wisdom touched many lives. He served with compassion and selflessness and is missed by all who knew him.

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1067-991X/$36.00

https://doi.org/10.1016/j.amj.2026.08.004

Table 1
PICO Framework Used

POPULATION	INTERVENTION	COMPARISON	OUTCOME
Critical Care Paramedics working in Emergency Medical Services (EMS) aviation settings	AND High-fidelity, flight-based simulation training aimed at enhancing clinical performance, decision-making, and preparedness in pre-hospital critical care environments	AND Traditional training methods, low- or medium-fidelity simulation, or no simulation-based training	AND Improved clinical competence, performance, confidence, decision-making, teamwork, and patient outcomes in aeromedical critical care scenarios

critical care, working at a high level of expertise to manage complex patient needs. Patient safety through enhanced communication and timely decision-making is critical in any health care environment. Experiential learning using approaches such as HFS education has proven particularly effective in enhancing aspiring health care providers' decision-making and clinical skills.[5] More specifically, CCP programs rely heavily on such experiential learning modalities to build health care providers' technical proficiency and adaptive judgment for unpredictable prehospital environments.[6]

SBL involves structured activities that replicate clinical or operational scenarios mirroring authentic challenges encountered in professional practice.[7] By exposing learners to life-like emergencies, SBL encourages the development of cognitive, psychomotor, and affective competencies in a controlled setting. For CCPs, SBL education provides invaluable experience in managing complex scenarios and integrating teamwork, communication, and situational awareness—skills central to competent prehospital care.[7] Notably, simulation technology has evolved from low-fidelity simulation (LFS) classroom exercises to sophisticated HFS with the help of computer-based systems, advanced manikins, and virtual or augmented reality environments.[8]

In recent years, HFS flight-based training has emerged as an extension of this pedagogy, replicating the unique challenges of aviation-based EMS. For example, simulation scenarios may place CCPs in a mock helicopter cabin with active rotor noise, vibration, and limited lighting while they manage a deteriorating trauma patient during a simulated in-flight emergency or weather diversion. These simulations incorporate realistic aircraft environments, sound, vibration, and operational stressors, preparing CCPs for critical decision-making in confined and dynamic in-flight conditions. Although HFS flight-based training can be used to teach CCPs at any stage, it is most vital at the intermediate and advanced stages of CCP education.[9] As such, CCPs stand to benefit the most from HFS flight-based training when they are exposed to this learning modality before clinical placement and high-acuity practice, to enhance their independent decision-making responsibilities. Although there are a number of primary studies on this topic, there has been no systematic review of this literature. This systematic review seeks to fill the critical literature gap while synthesizing diverse evidence that could inform future practice.

Methods

Aim

This systematic review aims to assess and synthesize evidence on the role and effectiveness of HFS flight-based training, evaluating its application in education for CCPs operating within EMS aviation settings.

Objectives

The review seeks to achieve the following objectives:

- To assess the impact of HFS flight-based training on CCPs.
- To assess the self-perceived changes in learning from CCP engaging in HFS flight-based training.
- To establish the impact of HFS flight-based training on the CCP's technical skill proficiency.

A Population, Intervention, Comparison, and Outcome (PICO) framework[10] was used to formulate the literature search strategy outlined in Table 1. This systematic literature search was conducted using appropriate keywords within the following databases:

Table 2
Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
- Studies published in peer-reviewed journals - Primary research studies (quantitative, qualitative, or mixed-methods) - Published from 2015 onward to ensure contemporary relevance - Published in the English language - Available as full-text journal articles - Focus on optimizing or enhancing high-fidelity flight-based simulation training for prehospital critical care paramedics in EMS aviation settings	- Secondary research such as literature reviews, systematic reviews, discussion papers, or editorials - Conference abstracts, posters, or unpublished theses - Studies published before 2015 - Publications in languages other than English - Incomplete or missing data, such as missing pages or inaccessible full text - Excludes student paramedics, paramedics not specialising in pre-hospital critical care, and paramedics working in EMS aviation settings - Studies focusing on in-hospital simulations, non-EMS, or non-aviation settings - Inappropriate study designs that do not contribute primary empirical data (eg, reviews, commentaries, or expert opinions)

EMS = emergency medical services.

Table 3
Literature Search Terms

Databases	Search Strategy Terms
MEDLINE (MeSH + free text)	1. exp Simulation Training/ 2. exp Education, Scenario-Based/ 3. ("high-fidelity simulation" OR "scenario-based learning" OR "simulation training" OR "flight simulation").ti,ab. 4. 1 OR 2 OR 3 5. exp Paramedics/ OR exp Emergency Medical Technicians/ OR exp Critical Care/ OR exp Helicopter Ambulances/ 6. (paramedic* OR "flight paramedic" OR "critical care paramedic" OR HEMS OR "air ambulance" OR "aeromedical" OR "EMS aviation").ti,ab. 7. 5 OR 6 8. 4 AND 7 9. limit 8 to (english language and yr="1975 -Current")
CINAHL (EBSCO syntax, subject headings + free text)	(MH "Simulation Training+" OR "high-fidelity simulation" OR "scenario-based learning") AND (MH "Emergency Medical Technicians+" OR paramedic* OR "flight paramedic" OR "air ambulance" OR HEMS OR aeromedical OR "air medical")
CENTRAL (EBSCO syntax, subject headings + free text)	("high-fidelity simulation" OR "scenario-based learning" OR "simulation training" OR "flight simulation") AND ("flight paramedic" OR "critical care paramedic" OR paramedic* OR HEMS OR "air ambulance" OR aeromedical)
PubMed (EBSCO syntax, subject headings + free text)	("high-fidelity simulation"[tiab] OR "simulation training"[tiab]) AND (paramedic*[tiab] OR "critical care paramedic"[tiab] OR "flight paramedic"[tiab] OR EMS[tiab])
Embase (Ovid syntax, Emtree + free text)	"simulation training" OR "simulation education" OR "simulation learning"AND"paramedic" OR "ambulance" OR " pre-hospital" AND "fidelity"
Web of Science (MeSH + free text)	("high-fidelity simulation" OR "scenario-based learning" OR "simulation training") AND ("critical care paramedic" OR "flight paramedic" OR HEMS OR paramedic* OR "air ambulance")
Google Scholar and Citation searching (EBSCO syntax, subject headings + free text)	"simulation training" OR "simulation education" OR "simulation learning" AND "paramedic" OR "ambulance" OR "pre-hospital" AND "fidelity"

EMS = emergency medical services; HEMS = helicopter emergency medical services; MeSH = Medical Subject Headings; MH = subject heading.

MEDLINE, CINAHL, PubMed, EMBASE, Cochrane Library, and Web of Science platforms. Google Scholar and snowball searching were used to retrieve more articles from other open-access databases. The inclusion and exclusion criteria are identified in Table 2 and were applied at each stage of the process. The search strings and combinations that were used for each database are outlined in Table 3.

Following best practice for evidence-based research, the snowballing technique was applied to identify further studies from the reference lists of relevant papers.[11] The first author independently screened titles and abstracts, followed by a full-text review according to predefined and agreed eligibility criteria, which were verified by the additional authors. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement of 2020 was used to guide reporting in this systematic review.[12] Figure 1 summarizes the selection process and application of criteria following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. This review has been registered with PROSPERO (No. 1176262).

Screening and Quality Appraisal Checks

The included studies were assessed for methodological quality using the Critical Appraisal Skills Programme (CASP). The tools assess the methodological choices in journal articles to ascertain their effectiveness in addressing the research question.[13] Disagreements were resolved by consensus between authors. The checklists enable the interrogation of the methodological choices in journal articles and ascertain their effectiveness in addressing the research question.[14] The completed CASP tables are attached in Appendix A.

Data Extraction and Synthesis

A data extraction table was used to help summarize the research articles by highlighting key information such as the author, year, setting, participants, design, intervention, and outcomes[15] (Table 4). Data synthesis was used to answer the research question. Given the heterogeneity of the study designs, a narrative synthesis approach was adopted.[16] Themes were organized around the applicability to practice of HFS in CCP education, factors affecting implementation, and future recommendations for research.

Table 4 is a data-extraction table with study characteristics and key findings from the selected articles.

Results

The findings have been organized into groups relating to the overall methodologies used within the studies found and the application of their findings to the population under consideration (ie, CCPs).

All papers included met the predefined inclusion criteria; however, when appraised critically, they did not collectively provide a clear or robust answer to the research question concerning the effectiveness of HFS flight-based training within EMS aviation. Most studies included were evaluations of HFS-based education (n = 5; Table 4). The stated aims of the included studies aligned broadly with SBL education, with only 2 not explicitly evaluating training[17,18]

Study Designs

The appropriateness of study design varied considerably. Most studies identified were evaluations of educational interventions. For example, some used pre-/post-test designs[19,20]; however, all study designs[17-23] had some element of self-report questionnaires which related to either their (the participants) perceptions of the course and their own perceptions of what they had learned during the program (Table 4). Different scales were used to do this, with a focus on self-assessment of their (ie, education participants) competence and evaluation of training, normally focused on satisfaction with the program.

Although such designs are suitable for exploring the trainee's experiences and perceived gains during the training, they are inherently limited in their ability to determine the effectiveness of said training or causality, as their focus is on perceptions. This is particularly important in terms of identifying the effect of an educational intervention, as previous research has revealed that self-reports of competence are not accurate.[24] The predominance of non-experimental designs therefore constrains conclusions regarding whether HFS flight-based training produces meaningful improvements in HEMS performance, limiting the strength of evidence available to support practice change. This is also true of the follow-up periods identified within the papers. This limits the evidence to the immediate self-reported benefits of simulation.

A major limitation across the studies was the heterogeneity of study populations. Although all participants were emergency personnel, recruitment strategies resulted in samples that included single-discipline clinicians, interdisciplinary teams, and mixed ground and

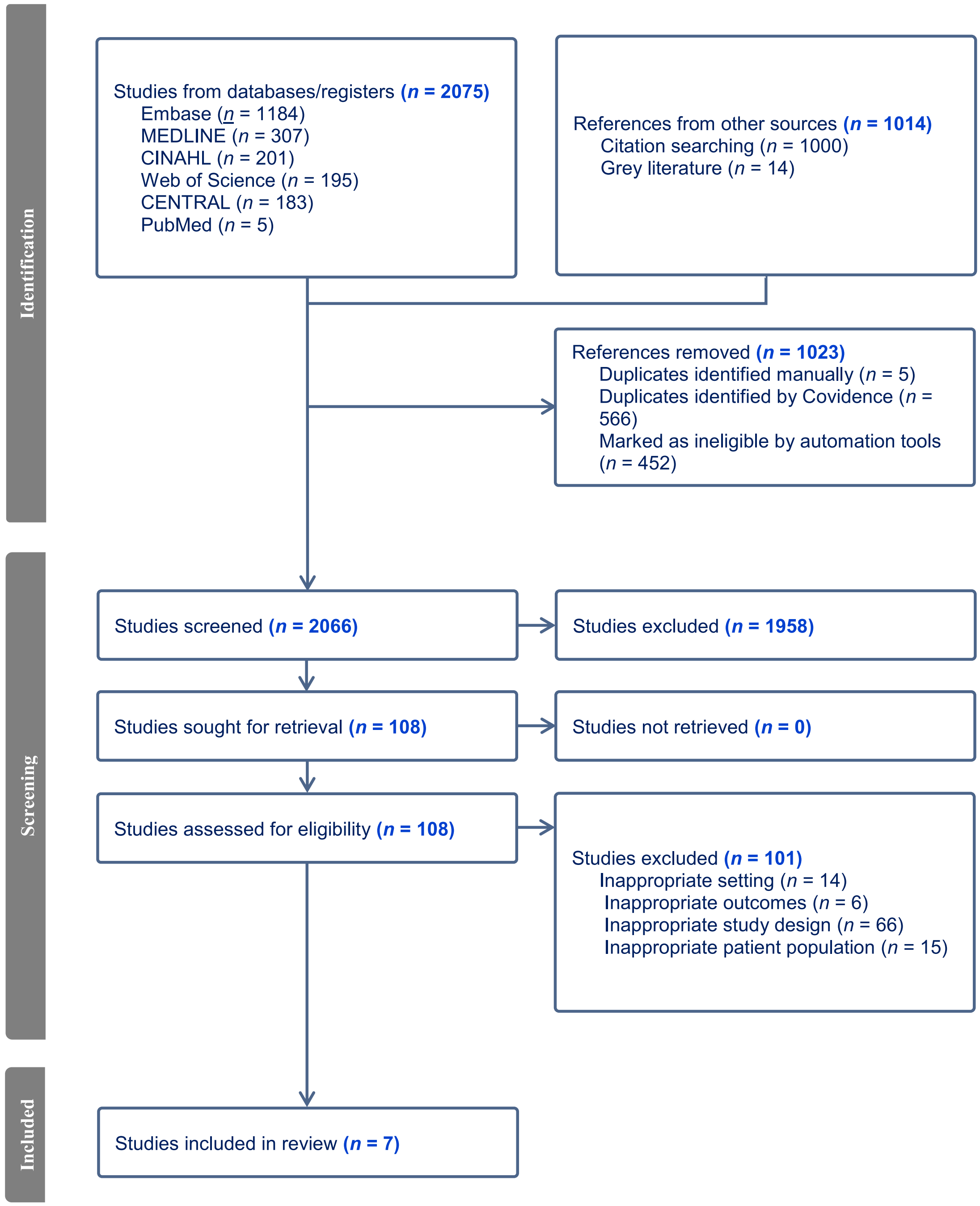

Figure 1. Literature selection procedure (PRISMA diagram). PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

air EMS staff. HEMS flight teams, however, typically consist of experienced clinicians from multiple professional backgrounds, such as CCPs, whose effectiveness depends on advanced team integration rather than individual competence alone. Several studies assessed individual skills or isolated non-technical skills (NTS) competencies, which do not reflect the operational realities of HEMS practice. From a CASP standpoint, this heterogeneity substantially limits external validity and reduces confidence in the transferability of findings to real-world flight-based EMS teams.

Several studies lacked fundamental methodological safeguards, including control groups, randomization, and blinding, increasing susceptibility to selection, performance, and reporting bias; this was not unusual as most studies were evaluations of training. Therefore, the sample sizes were frequently small, further reducing statistical power and increasing the likelihood of type I (false positive) and type II (false negative) errors. Taken together, these factors reduce internal validity and severely limit causal inference.

There was marked inconsistency in how HFS was defined and implemented across studies. Interventions ranged from in situ simulations to structured training programs delivered in mock or purpose-built environments, with wide variation in frequency, duration, and fidelity. Few studies provided justification for simulation design choices or demonstrated that selected outcome measures were sensitive to performance changes relevant to HEMS contexts. Although this heterogeneity limits comparability across studies and weakens the synthesis of findings, reducing the overall coherence of the evidence base, it should also be noted that there is an element of specificity within simulation training. There is evidence in other acute

Table 4
Overview of Study and Data Collection

Author (Year)	Aim	Data Collection Method	Participants	Data Collection Instrument	Results
Bredmose et al (2020)	Feasibility of in situ HEMS training	SRQ (post)	44	14 Questions to evaluate training. 7-Point Likert scales used (1 = strongly agree).	Median scores 1-2 across all attendees.
Imbriaco et al (2021)	Evaluate HEMS simulation training	SRQ (post and 3 mo)	16	4 Questions on a 5-point Likert scale regarding usefulness of training (5 = strongly agree).	Mean scores 4-5. CI (2-3) across the 4 questions at 3-mo post-training.
Langdalen et al (2018)	Compare frequency of training	SRQ (cross-section).	GEMS (*n* = 998) HEMS (*n*= 109)	14 Questions based on NNSOPSC survey regarding training for NTS. Each question had 4-point Likert scale.	Significant differences between GEMS < HEMS in frequency of training.
Nabecker et al (2021)	Simulation education program	SRQ (post only)	329	16 Question evaluation of course. Likert scale 5 = total agreement.	Course evaluation was rated positively.
Omori et al (2025)	Effectiveness of sim program	SRQ (pre-post)	208	21 Questions across 4 areas. 5 = satisfied/ complete agreement depending on question.	Increase in satisfaction of training.
Pietsch et al (2016)	Simulation education program	SRQ (pre-post)	40	9 Question on 6-point Likert scale (1 = best).	Increase in self-assessed competence.
Pietsch et al (2020)	Comparison of indoor and outdoor simulations.	SRQ (pre-post)	22	Unclear as to number of questions but 5 self-reported evaluation of session. 6-Point Likert scale. 1 = most positive.	Indoors/Outdoors similar in terms perceived improvement.

Cross-sectional = a cross-sectional study; GEMS = ground emergency medical services; HEMS = helicopter emergency medical services; post = after training; pre = before training; SRQ = self-reported questionnaire.

areas to suggest that scenarios should be tailored to the workforce undertaking the simulation,[25,26] which is reflected in current professional guidance.[27]

Applicability to Practice

Team performance and crew integration, key determinants of safety and effectiveness in HEMS, were insufficiently addressed, mainly due to the overall study designs. Only a few studies attempted to evaluate higher order team functioning, including communication, leadership, shared situational awareness, and decision-making under flight-specific constraints, encompassing NTS and team trauma non-technical training (TNTS); however, this was done again via self-report questionnaires rather than by assessment. This is a critical omission, as contemporary simulation practice in other high-risk domains, such as Advanced Life Support (ALS) training, has shifted decisively toward team-based effectiveness rather than individual performance. The failure to evaluate the “whole team” significantly limits the applicability of findings to HEMS operations and weakens the evidence base from a CASP contextual relevance perspective. Furthermore, as discussed previously, these were self-reported evaluations rather than objective measures of individual ability.

This fidelity and linking to deliberate practice therefore link explicitly with applicability. Although several studies reported perceived benefits of SBL, including improvements in technical skills, communication, and confidence, these findings must be interpreted cautiously. The studies by Pietsch et al[23] and Langdalen et al[18] demonstrate positive self-reported outcomes in realistic or in situ environments; however, these outcomes cannot be assumed to directly translate into objectively measured operational or patient-centered improvements. The absence of clinically meaningful end points prevents firm conclusions regarding the effectiveness of HFS flight-based training in routine HEMS practice.

Although the included studies suggest that HFS flight-based training is feasible and well accepted by EMS aviation personnel, a critical appraisal using CASP highlights substantial methodological limitations. These include heterogeneous populations, an insufficient focus on team-level performance, weak study designs, a reliance on self-reported outcomes, and a lack of objective, educationally and clinically relevant effectiveness measures. Collectively, these issues prevent robust conclusions regarding the role and effectiveness of HFS in EMS aviation. The current evidence supports HFS as a promising educational modality, given the educational research in other areas. However, as this review has revealed, this is not a proven intervention with definitive evidence for increasing operational performance or positive patient outcomes in HEMS. Future research must prioritize experimental studies that link HFS training to validated operational, safety, and patient-centered outcomes to address these critical gaps. It should be recognized that this is a similar finding across the simulation education literature and is comparable with the systematic review of Hegland et al[28] within pre-registration nursing education in terms of the wider patient impact of simulation.

Factors Affecting Implementation

Several studies have highlighted resource and contextual barriers that limit the widespread adoption of SBL. HFS is a more resource-intensive version of SBL. Operating real aircraft for in situ SBL or full-scale mock-ups, as demonstrated in Pietsch et al[23] requires significant investment in maintenance, scheduling, and crew time. Despite these challenges, their educational value, particularly in enhancing teamwork and risk management, is often cited as justifying the expense for high-acuity EMS organizations[17,21]; however, this is not necessarily borne out explicitly in the empirical evidence within the papers.

The connection between the training and the improvement in patient-related outcomes is missing from the evidence base. There are, of course, significant challenges in linking any specific simulation training/scenario and patient outcomes from the field. Myes et al[29] for example, although not focused on HEMS, undertook a retrospective evaluation of a simulation educational intervention for airway management and found no statistically significant link between training and success. Furthermore, although there were shortcomings within the design (it was a feasibility study), it does demonstrate the importance of objective patient-related outcomes, rather than self-report questionnaires.

This review raises 2 major points within the evidence base for the implementation of HFS. The first is the link between the use of HFS and the improvement of patient-related outcomes. All studies included in this review focused primarily on learner experience or their perception of what they had learned during the session. This can be found as being problematic, as simulation training is labor intensive and often expensive to run, with some of the evidence base often being contested over whether the educational gains are superior. For example, Wu et al[30] used a quasi-experimental study to investigate 2 educational interventions (HFS and video-based discussion), revealing that although skills-based scores were higher in the high-fidelity group, both groups saw significant improvements across skills and attitude-based measures (both of which were objective, rather than self-reported). None of the papers that focused on HEMS teams used such objective measures of learning, relying on self-reported measures, usually of satisfaction.

Future Initiatives and Recommendations

Based on the study outcomes, this review recommends that future initiatives advance HFS education for EMS aviation CCPs through coordinated, longitudinal, targeted training in tandem with effective measures for learning gain and patient outcomes. Health sciences education policymakers should focus on creating comprehensive frameworks that define learning objectives, scenario fidelity, and standardized assessment tools to ensure consistent skill acquisition and performance evaluation.

International registries linking simulation outcomes with operational mission data should enhance training relevance, identify performance gaps, and support collaborative research. Training programs should be optimized through systematic cost-effectiveness analyses, the strategic integration of virtual and augmented reality technologies, and structured refresher modules to mitigate skill decay in high-risk, low-frequency procedures. There is a need for the development and dissemination of evidence-based guidelines by professional associations to promote uniformity, quality, and continual improvement across aviation EMS.

Conclusion

This systematic review aimed to investigate the effectiveness of HFS training for CCPs in EMS aviation. The review has established that HFS education in EMS aviation enables CCPs to acquire TNTS in a safe, controlled environment that does not expose them, staff, or patients to any risk. There was insufficient evidence on whether such a teaching modality enhances self-awareness among CCPs.

Overall, the articles reviewed in this study conclude that perceptions of training and self-perceived learning improve in the short term after simulation-based interventions. However, there is a need to expand the body of literature to explore the evidence linking these improvements to operational performance and patient safety outcomes. Conducting more longitudinal research studies with the help of standardized frameworks and cross-institutional collaboration could help address these gaps.

Declaration of competing interest

The authors have no relevant disclosures. There was no grant funding or financial support for this manuscript.

CRediT authorship contribution statement

Matthew Hilditch: Writing − original draft, Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization. **Chris Sharpe:** Writing − review & editing, Methodology, Validation. **Kim Litwack:** Writing − review & editing, Methodology, Validation. **Mark Widdowfield:** Writing − review & editing.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amj.2026.08.004.

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