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Emergency medical transport and critical interventions in aviation medicine: A systematic review

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ABSTRACT

Background: In flight medical events (IMEs) and aircrew health issues pose distinctive challenges in commercial aviation. We aimed to synthesize contemporary evidence on IME epidemiology, onboard interventions and outcomes, and aircrew physiology and fitness with implications for safety policy. Methods: PRISMA aligned review of MEDLINE, Embase, Web of Science, Scopus, and CENTRAL plus regulator sources to 2025. Two reviewers screened and extracted data. SWiM guided structured narrative synthesis reporting. Results: Fifteen studies met criteria: IMEs, onboard interventions (n 6) and aircrew physiology, performance (n 9). IME incidence ranged from one per 604 flights to 16 per million passengers; syncope predominated. Diversion occurred in 7%, admission in 9%, and death in 0.3%. Automated external defibrillators enabled accurate rhythm decisions and 40% survival for ventricular fibrillation. First aid kits were opened in 15% of events; oxygen and telemedical support were common. Among pilots, annual medical incapacitation was 0.25%, increasing with age; psychiatric diagnoses had the longest suspensions. Fatigue exposure covered 10% of flying hours at elevated modeled risk, and about one quarter of duties followed less than 6 hours of sleep. Hypoxia experiments showed delayed symptom recognition and identified EEG, oxygen saturation, and heart rate markers linked to performance. Conclusions: Most IMEs are nonfatal and manageable on board with trained crews, standardized kits, AEDs, and telemedicine. Critical arrests benefit from rapid defibrillation. Aircrew safety improves with fatigue mitigation, hypoxia focused training, physiologic monitoring, and age aware fitness oversight.

Keywords: In flight medical events; aviation medicine; aircrew health; pilot incapacitation; hypoxia; telemedicine; PRISMA; systematic review.

1. INTRODUCTION

Commercial aviation transports billions of passengers, which create a unique clinical setting where in flight medical events (IMEs) should be managed with constrained resources and delayed access to definitive care (Alves et al., 2025). Multinational evidence from a ground-based support network suggests IMEs occur more than earlier estimates and that neurologic and cardiovascular presentations drive a minority of events but a majority of diversions, underscoring both clinical and operational implications (Alves et al., 2025). A recent systematic review and meta analysis synthesized data from 1.5 billion passengers and estimated a low overall IME incidence with very low in-flight mortality, but highlighted wide heterogeneity in reporting and denominators, limiting precise benchmarking in carriers and regions (Borges do et al., 2021).

History shows that structured in flight medical support influence outcomes. A late 1990s FAA evaluation in multiple U.S. carriers documented more than 1,100 incidents with good concordance between in flight and post flight diagnoses and frequent clinical improvement, informing recommendations on kit contents and care pathways (DeJohn et al., 2000). For the rare time critical cardiac arrests, airline wide deployment of automated external defibrillators (AEDs) achieved 100% rhythm decision accuracy and 40% survival to hospital discharge for ventricular fibrillation, demonstrating feasibility and lifesaving potential in the cabin environment (Page et al., 2000).

A meta review of systematic reviews found growing attention to pilots and cabin crew, with prominent themes of mental health, fatigue, and job risks, and advocates stronger integration of human factors into systems level safety frameworks (Papavasileiou et al., 2025). Within aeromedical fitness, in flight medical incapacitation of professional pilots is very rare, on the order of 0.19 to 0.45 per million flight hours, but several studies show age associated increases in broader (not only in flight) medical incapacitation, informing balanced, evidence-based licensing and surveillance policies (Huster et al., 2014).

In this study we aimed to provide an updated, practice-oriented synthesis of IME epidemiology, on board resource utilization (FAK, EMK, oxygen, AED), diversion patterns, and outcomes within contemporary commercial operations; to contextualize these findings within evolving airline telemedical models and human operator factors; and to identify opportunities for standardized reporting and policy that can strengthen preparedness and safety in the global aviation system.

2. REVIEW METHODS

Protocol and reporting

We developed an a priori protocol aligned with PRISMA 2020 guidance for systematic reviews and followed the PRISMA 27 item checklist and flow diagram for reporting. We planned a narrative synthesis and adhered to SWiM (Synthesis without Meta-analysis) recommendations for transparent, structured reporting of non-meta-analytic syntheses.

Eligibility criteria

Population and Setting: Passengers on commercial airline flights experiencing in flight medical events (IMEs); aircrew (pilots and flight crew) in operational, training, or simulated aviation contexts.

Interventions: For IMEs: onboard assessment including first aid kits, emergency medical kits, oxygen, automated external defibrillators (AEDs), tele medical consultation, and diversion decisions. For aircrew: exposures relevant to flight safety and performance (hypoxia awareness training, high-G centrifuge profiles, fatigue and scheduling, aeromedical fitness, grounding, and incapacitation).

Outcomes: For IMEs: event types and frequencies; use of resources (oxygen, EMK, and AED); diversion; post-flight transport, admission; survival, ROSC, and mortality. For aircrew: incapacitation and grounding rates and causes; fatigue metrics; physiologic performance markers (SpO_2 dynamics, EEG indices, AGSM effectiveness, heart rate responses); qualification and mission performance outcomes.

Study designs: Observational cohorts, case series more than 5 participants, cross sectional studies, and controlled human experiments and simulator studies. We excluded single case reports, editorials, narrative reviews, letters without primary data, animal studies, and non-aviation contexts. Preprints regulatory and technical reports with extractable data were eligible with sensitivity analyses planned to assess their influence.

Time frame & language: From database inception to the 2025. No language restrictions; non-English articles were screened with translation as needed.

Information sources

We searched multidisciplinary and biomedical databases (MEDLINE, Embase, Web of Science Core Collection, Scopus, and Cochrane CENTRAL) and grey literature sources relevant to aviation medicine (regulator and industry sites such as FAA, EASA, ICAO, and telemedical providers), plus reference lists and forward citations of included studies. We also screened relevant conference proceedings and abstract books where available. We include 15 articles (Fig 1).

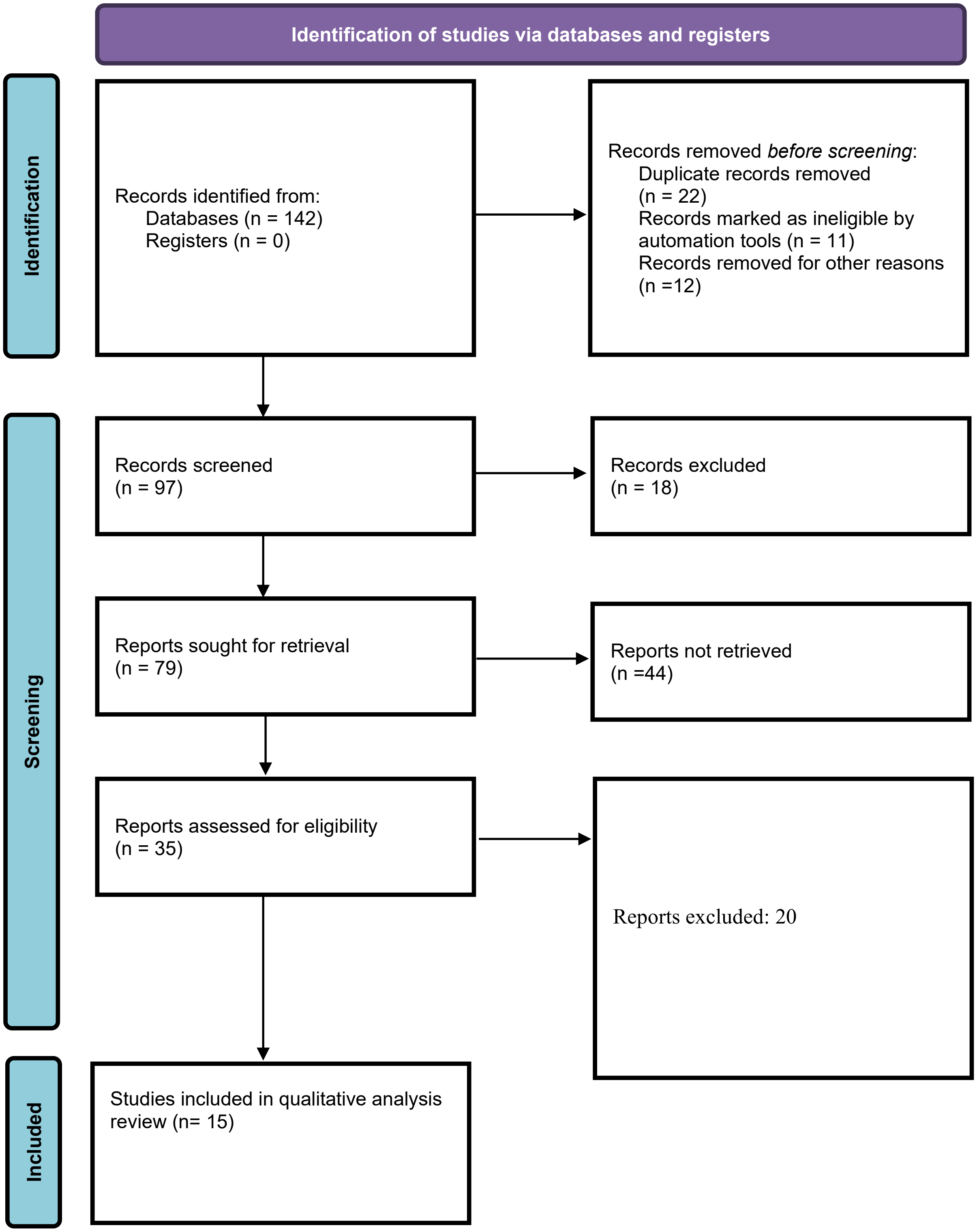

Figure 1. PRISMA consort chart of selected studies

Selection process

Two reviewers screened titles and abstracts, then full texts, against pre-specified criteria. Discrepancies were resolved by consensus or third reviewer adjudication. Reasons for full-text exclusion were recorded to populate the PRISMA flow diagram. When multiple reports described overlapping datasets, we retained the most comprehensive source and cross-checked consistency.

Data collection process

A piloted extraction form was used by two reviewers working independently, with a cross-check to minimize errors. We extracted: bibliographic details; setting (airline, flight vs simulator training); design; time frame; population and sample characteristics; emergency categories; interventions and resources; physiologic and operational measures; definitions and denominators (per passenger, per flight, per flight hour); outcomes (diversion, transport, admission, survival and ROSC, mortality; incapacitation and grounding rates; fatigue exposure; qualification, pass, fail; physiologic thresholds). Study-specific assumptions and unit of analysis decisions were recorded (event-based vs passenger-based denominators).

Ethics

This review synthesizes publicly available, previously published data and did not involve interventions with human participants; institutional ethics approval was not required.

3. RESULTS

Study selection and characteristics

We include 15 studies, two broad domains of aviation medicine: in IMEs and on-board interventions and aircrew physiology, performance, and fitness to fly. Study designs were observational cohorts or case series from airline databases, telemedicine providers, or regulatory records, with controlled simulator experiments. Sample sizes ranged from focused experimental cohorts (n 34 participants) to large operational datasets (11920 IMEs and multi-year regulator, airline registries). Geographic coverage included North America, Europe, the Middle East, Latin America, and East Asia (Page et al., 2000; DeJohn et al., 2000; Brown et al., 2010; Peterson et al., 2013; Evans and Radcliffe, 2012; Simons et al., 2021; Hohmann and Pieterse, 2023; Coombes et al., 2020; Steinman et al., 2021; Borden et al., 2024; Alvear Catalan et al., 2024; Paxinos et al., 2023; Shi et al., 2024; Tu et al., 2020; Alves et al., 2025).

In flight medical events: epidemiology, presentations, and management

In multi airline and single airline datasets, syncope emerged as the most frequent IME, followed by respiratory, gastrointestinal, allergic, neurologic, and cardiac complaints (Peterson et al., 2013; DeJohn et al., 2000; Shi et al., 2024; Alves et al., 2025). In the largest U.S. call center cohort (five airlines, 2008–2010), the IME rate was one event per 604 flights; diversion occurred in 7%, post landing transport in 26%, hospital admission in 9%, and death in 0.3% (Peterson et al., 2013). An airline programmatic evaluation from the late 1990s reported 1,132 incidents with high agreement between in-flight and post-flight diagnoses and clinical improvement during flight in most cases, underscoring the value of structured medical support and standardized kits (DeJohn et al., 2000).

First aid kits (FAK) were opened in one fifth of IMEs on a European regional carrier, with analgesics and burn treatments the most common items, which indicate that many events are minor and manageable without diversion (Paxinos et al., 2023). AEDs were safe and operationally feasible on board; in an airline wide program, shocks were advised for all documented ventricular fibrillation cases with survival to hospital discharge around 40% after defibrillation (Page et al., 2000). A later multi airline analysis of self reported AED uses and ground consult interactions described 169 applications (40 cardiac arrests), mean patient age in the sixth decade, and rapid shock delivery (median first shock after analysis ≈19 s), highlighting both time critical response and the role of remote physician support (Brown et al., 2010). Contemporary global data from a large telemedical database provide updated incidence metrics normalized by passengers and RPKs and describe resource utilization (oxygen, EMK, AED) and outcomes in regions, reflecting current practice heterogeneity (Alves et al., 2025).

Aircrew fitness, incapacitation, and operational risk

Population level registry studies quantified rare but safety critical events among pilots. In the U.K., the annual incapacitation rate among Class 1 license holders was 0.25%, with increasing risk at older ages and differing etiologic patterns on duty vs off duty (Evans and Radcliffe, 2012). European regulatory data identified cardiovascular, neurologic, psychiatric, and musculoskeletal conditions as common reasons for grounding, with clear age associations (Simons et al., 2021). A Middle East registry reported an annual incapacitation proportion of 2.8% with a mean suspension duration of 148 days and an 8% rate of permanent license loss, with psychiatric categories carrying the longest suspensions (Hohmann and Pieterse, 2023).

Operational fatigue risk was characterized using field self-reports and biomathematical modeling in 18 U.K. airlines: 7.3 reports of involuntary sleep per 1,000 flight hours were documented, 10% of flying hours occurred at elevated modeled fatigue risk, and about a quarter of duty periods were preceded by <6 hours of main sleep, supporting roster level mitigation (Coombes et al., 2020).

In centrifuge training designed to simulate a "9G for 15 s" profile, low anti G straining maneuver (AGSM) effectiveness and a blunted early heart rate rise independently predicted failure within the first seconds, offering concrete, coachable targets to improve qualification rates (Tu et al., 2020). In a helicopter simulator study, exposure equivalent to 4,572 m (11.4% O_2) increased misses of environment awareness items and many pilots did not recognize hypoxia symptoms, reinforcing the need for monitoring and scenario-based training at altitude (Steinman et al., 2021).

Synthesis of themes

The evidence indicates that most IMEs are non-cardiac and can be managed on board with crew volunteer care, FAK, EMK resources, oxygen, telemedical support, and selective diversion; time-critical cardiac arrests benefit from rapid AED deployment, which is feasible in the cabin environment (Page et al., 2000; Brown et al., 2010; Peterson et al., 2013; Paxinos et al., 2024; Alves et al., 2025). For flight crew, incapacitation is uncommon but non-negligible and increases with age, with cardiovascular and neuropsychiatric etiologies prominent in grounding decisions (Evans and Radcliffe, 2012; Simons et al., 2021; Hohmann and Pieterse, 2023). These findings support a layered safety model that combines robust on-board equipment and remote expertise with targeted aircrew training and regulatory fitness oversight in the aviation system. Table 1 presents the characteristics of the included studies, and Table 2 presents the main findings.

Table 1: Characteristics of the included studies

Citation, year, journal	Study design	Methods	Population characteristics	Study aim
Page et al., 2000	Prospective observational case series (program evaluation)	American Airlines introduced AEDs in 1997, flight attendants trained, ECGs from each use analyzed by two arrhythmia specialists, all 200 AED uses (Jun 1997–Jul 1999) reviewed.	200 AED applications (191 in aircraft, 9 terminal). Shock advised in all 14 VF cases, survival to discharge after AED shock 40%.	Assess AED use aboard aircraft (efficacy, safety as monitor) after airline wide deployment.
Brown et al., 2010	Retrospective case series	Collected self reported in flight AED cases to an airline ground consult service from 3 US airlines (May 2004–Mar 2009), data files, consult forms, and recordings reviewed.	169 AED applications, 40 cardiac arrests, mean age 58 (all uses) & 63 (arrests), 64% male, median time to first shock 19 s.	Describe characteristics, outcomes of AED use during in flight emergencies and patterns of ground medical consultation.
Peterson et al., 2013	Retrospective cohort using call center database	Reviewed in flight medical emergency calls from 5 airlines to a physician directed medical communications center (Jan 2008 to Oct 2010).	11,920 IMEs (1 per 604 flights). Most common: syncope, presyncope 37.4%, respiratory 12.1%, N, V 9.5%. Diversion 7.3%, 25.8% transported, 8.6% admitted, 0.3% died.	Describe IME types, on board assistance, and outcomes (diversion, transport, admission, death).
DeJohn et al., 2000	Retrospective analysis of MedAire supported events, program evaluation	Surveyed 5 US carriers contracting with MedAire, included incidents with air to ground radio patch, standardized forms and CAMI coding.	1,132 in flight medical incidents (Oct 1996–Sep 1997), 22% of US enplanements represented, 70% agreement between in flight and post flight diagnoses, 60% improved in flight.	Evaluate in flight medical care delivery and re evaluate FAA mandated medical kit contents.
Paxinos et al., 2023	Prospective observational study	Collected anonymized Aegean Airlines IME reports (2014–2018), classified IMEs, recorded kit usage and outcomes.	990 IMEs, incidence 16 per million passengers, FAK opened in 18% (used in 15%), common meds: burn hydrogel 4.7%, paracetamol 3.6%.	Evaluate real world use of onboard first aid and emergency medical kits to identify gaps, needs.
Shi et al., 2024	Retrospective study	Analyzed electronic narrative records	Airline with >89 million	Estimate IME incidence,

	(single large airline)	of IMEs from a major Chinese carrier (2018–2022), included events pre takeoff, taxi and post landing, two physician classification and consensus.	annual passengers, outcomes included diversion, hospital transport, deaths, incidence and mortality rates calculated vs passengers, flights.	characterize patterns, severity, assess risk factors for deaths and diversions, provide management suggestions.
Alves et al., 2025	Observational cohort (multinational)	Queried MedAire clinical database for IMEs worldwide (Jan 2022–Dec 2023), covered >100 airlines in 5 continents (31% of global traffic), STROBE guided, IRB exempt de identified data, exclusions: crew, ground returns.	Rates reported per 1M passengers and per billion RPKs, subanalysis for 9 US carriers for flight denominator incidence.	Provide a comprehensive global characterization of IMEs: epidemiology, resource use, and outcomes.
Evans & Radcliffe, 2012	Population based cohort (registry synthesis)	All UK, JAR Class 1 licensed pilots in 2004, three sources: statutory illness notifications, Mandatory Occurrence Reports (in flight events), death certificates.	16,145 pilots, 40 incapacitations (0.25% per year). Half cardiac or cerebrovascular, in flight incapacitations predominantly psychiatric, risk increased with age (60s vs 40s).	Derive a baseline annual incapacitation rate in UK commercial pilots (on and off duty).
Simons et al., 2021	Cross sectional analysis of pooled regulatory data	Requested anonymized aeromedical exam outcomes from 18 European NAAs, diagnoses classified per EASA Part MED, analyzed Class 1 vs Class 2 and age associations.	Large European cohort of CAT pilots, frequent grounding causes: cardiovascular, neurologic, psychiatric, musculoskeletal, assessed age related risk.	Analyze aeromedical fitness and causes of grounding in Europe and discuss prevention to improve safety.
Hohmann & Pieterse, 2023	Retrospective registry analysis	Searched UAE General Civil Aviation Authority database for temporary suspensions (2018 to 2021), extracted ICD 10 codes.	n 1233 incapacitations, mean suspension 148.4±276.8 days, permanent suspension 8.1% overall, highest mean duration in psychiatry, annual temporary incapacitation 2.8%.	Report rates, durations, and specialty specific patterns of pilot incapacitation and permanent suspensions in the UAE.
Borden et al., 2024	Single blind, repeated measures (counterbalanced) within subjects experiment	Normobaric mask on hypoxia via aviation survival trainer (ODHT, FBAT) with gradual ascent 10k to 25k ft for 20 min after 10 min baseline, cognitive battery during exposure, continuous EEG (auditory oddball), symptom self reports, SpO2 & HR monitoring	N 34 healthy adults (mean age 29, 22 males, 12 females), delayed symptom reporting (8 min average) and physiological responses observed	Bring hypoxia research closer to training conditions, quantify physiological, cognitive, and EEG markers sensitive to acute hypoxia
Alvear Catalán et al., (2024)	Retrospective observational analysis of hypoxia awareness training (HAT) records in a hypobaric chamber	Analyzed pulse oximetry SatO2 time series during mask disconnection, reconnection at simulated 7,620 m, computed parameters (D97, D90, R97, R90, TUC D97, D90, L97, L90, SDSAT97, SDSAT90, SRSAT97), correlations vs. time of useful consciousness (TUC)	2,298 HAT records from 1,526 military men (mean age 30.48±6.47 years), roles: pilots, aircrew, paratroopers (Chile, 2010–2018)	Provide reference values for HAT and identify SatO2 curve parameters that estimate TUC for monitoring, protection of aircrew
Tu et al., (2020)	Retrospective cohort, registry analysis of 9G profile training attempts	Human centrifuge ‘9G for 15 s’ very high onset rate runs, quantified anti G straining manoeuvre (AGSM) effectiveness and early HR increase (first 5 s), multivariable logistic regression for qualification, failure	530 attempts, failure associated with AGSM effectiveness <2.5G and <20% early HR rise, most failures occurred within 1–5 s	Assess combined impact of AGSM technique and HR response on high G tolerance, identify predictors of disqualification

Coombes et al., (2020)	Observational field study with biomathematical fatigue modelling	Mobile app self reports of sleepiness, alertness from pilots in 18 UK airlines (Aug 2017), roster based fatigue risk modelling to estimate sleep opportunity and on duty risk	Per flight hour metrics: 7.3 reports of involuntary sleep per 1,000 flying hours, 25% of duty periods preceded by main sleep <6 h, 10% of flying hours at elevated fatigue risk	Quantify in service sleepiness and predicted fatigue exposure, compare against medical incapacitation risk benchmarks
Steinman et al., 2021	Single blind, counterbalanced repeated measures simulator study	Apache helicopter crews flew two simulator sorties breathing 20.9% O2 (0 m) vs 11.4% O2 (4,572 m), introduced environment items (AoE) to detect, respond, Stanford Sleepiness Scale, SpO2, HR tracking	8 crews (16 pilots, mean age 30, 1,216 flight hours), more AoE misses at 4,572 m (28 vs 12), many pilots did not recognise hypoxia symptoms	Determine hypoxia's impact on non technical skills (awareness of environment) and alertness, inform training, monitoring and altitude policy

Table 2: Demographics, Emergencies, Interventions, Main Findings, Outcomes

Citation	**Demographic characteristics**	**Emergency medical situations**	**Interventions**	**Main findings**	**Outcomes**
Page et al., 2000	Passengers experiencing in flight medical events, age, sex variably reported in cases	Cardiac arrest (ventricular fibrillation), syncope, chest pain, and monitoring of symptomatic passengers	On board AED deployment by trained flight attendants, rhythm analysis, shocks for VF , monitoring via AED ECG, ground medical advice as needed	AEDs were feasible and frequently useful for both monitoring and defibrillation, shock advised in all VF cases	Survival to hospital discharge 40% after AED shocks for VF, no device related safety signals noted
Brown et al., 2010	N 169 AED applications, mean age 58 (all uses) & 63 (cardiac arrests), 64% male	Cardiac arrest (n 40), presyncope, syncope, chest pain, tachyarrhythmia, bradyarrhythmia assessment	AED assessment, shock, ground physician consultation, crew first aid, oxygen	Rapid shock delivery (median first shock 19 s from analysis), substantial role for ground consult in decision making	Return of spontaneous circulation in a subset of arrests, diversions occurred selectively (proportions reported)
Peterson et al., 2013	Passengers from 5 large airlines, demographics variably recorded	Syncope, presyncope (37%), respiratory (12%), nausea, vomiting (10%), cardiac, neurologic, allergic reactions	On board care by crew, clinician volunteers, medical kit, AED, oxygen use, real time ground medical consultation, flight diversion when indicated	IME incidence 1 per 604 flights, most events managed on board without diversion	Diversion 7%, post landing transport 26%, hospital admission 9%, death 0.3%
DeJohn et al., 2000	Passengers in 5 US carriers using a medical patch service, limited age, sex data	Wide spectrum: syncope, gastrointestinal, respiratory, neurologic, cardiovascular symptoms	Crew, volunteer care with FAA medical kit contents, air to ground physician patch, oxygen, AED when indicated	High concordance between in flight and post flight diagnoses, majority improved in flight	1,132 incidents assessed, recommendations informed updates to kit contents and procedures
Paxinos et al., 2023	Passengers on a European regional carrier, age, sex often not recorded in kit forms	Minor trauma, burns, headache, fever, motion sickness, GI upset, occasional respiratory, cardiovascular symptoms	First aid kit items (burn gel, paracetamol, dressings), oxygen, and EMK, AED if required	FAK opened in 18% of IMEs, analgesics and burn treatments most used, actionable data for kit inventory planning	Most cases managed on board without diversion, few escalations to EMK, AED

Shi et al., 2024	Passengers from a major Chinese airline (2018–2022), demographics variably recorded	Syncope, presyncope, cardiovascular and respiratory complaints, GI symptoms, pre and post flight phases included	Crew, volunteer treatment, oxygen, medical kit, AED use, ground medical support, diversion when warranted	Provided airline specific incidence rates and patterns, identified factors linked to diversion, death	Reported diversion and mortality rates with denominators by passengers, flights (airline level)
Alves et al., 2025	Global passenger cohort in >100 airlines (2022–2023)	Syncope, presyncope, cardiovascular, respiratory, neurologic, GI, allergic, trauma	Standardized telemedical consultation, onboard oxygen, EMK, AED, crew, volunteer care, diversion policy per carrier	Contemporary global characterization of IMEs and resource utilization, regional comparisons	Incidence per passenger and per RPK, diversion, transport, admission, death proportions summarized
Evans & Radcliffe, 2012	16,145 UK Class 1 licensed pilots (mix of ages, registry based)	In flight pilot incapacitation (psychiatric, cardiovascular, neuro) , rare events	Operational response, relief procedures, aeromedical oversight, subsequent licensing decisions	Baseline annual incapacitation 0.25%, risk rises with age, causes differ on duty vs off duty	Quantified event rates to inform risk models and policy
Simons et al., 2021	European commercial pilots (Class 1) in 18 NAAs, age and license class distribution reported	Not applicable (regulatory fitness outcomes rather than acute in flight events)	Aeromedical examinations, temporary, permanent grounding, remediation, return to fly pathways	Common grounding causes: cardiovascular, neurologic, psychiatric, musculoskeletal, age related patterns	Grounding rates and diagnostic distributions, implications for preventive strategies
Hohmann & Pieterse, 2023	UAE commercial pilots with temporary suspensions (2018–2021), n 1,233, duration mean 148 days	Temporary incapacitation categories (psychiatric, cardiovascular) impacting fitness to fly	Regulatory suspension, evaluation, and potential permanent license loss	Highest suspension durations in psychiatric categories, permanent suspension 8% overall	Annual temporary incapacitation 2.8%, durations and specialty specific patterns quantified
Borden et al., 2024	N 34 healthy adults (22 males, 12 females, mean age 29)	Not applicable (controlled hypoxia exposure in training device)	Mask on normobaric hypoxia ascent to 25,000 ft, cognitive tasks, EEG, physiologic monitoring	Cognitive, EEG markers and symptoms emerge with delay, physiological changes precede symptom awareness	Identified sensitive markers to inform training detection, mitigation protocols
Alvear Catalán et al., (2024)	2,298 HAT tests from 1,526 Chilean military men (mean age 30.5±6.5)	Not applicable (simulated hypoxia exposure)	Mask disconnection at simulated 7,620 m, pulse oximetry curve analysis, mask reconnection	Derived $SatO_2$ curve metrics correlate with time of useful consciousness (TUC) and can benchmark training	Reference values for D97, D90, R97, R90, TUC related metrics, proposes monitoring thresholds
Tu et al., (2020)	530 training attempts, fighter aircrew candidates, age, sex not consistently reported	Not applicable (high G training failures rather than in flight emergencies)	AGSM coaching, high onset rate 9G runs, HR monitoring	Low AGSM effectiveness and blunted early HR rise predict failure within 1–5 s	Predictive model for qualification, disqualification, targets for training interventions
Coombes et	Pilots from 18	Operational	Roster design and	7.3 involuntary sleep	Benchmarking of fatigue

al., (2020)	UK airlines, broad age, experience range	sleepiness, involuntary sleep episodes during duty (self reported)	biomathematical fatigue risk modelling (no clinical intervention)	reports, 1,000 flight hours, 10% flying hours at elevated fatigue risk	exposure vs safety, incapacitation risk thresholds
Steinman et al., 2021	16 military helicopter pilots in 8 crews, mean age 30, 1,200 flight hours	Not applicable (simulated flights at normoxia vs 4,572 m hypoxia)	Controlled oxygen fraction during simulator sorties, AoE detection tasks, physiologic, subjective measures	More missed environment awareness items at hypoxia, many did not recognise symptoms	Supports monitoring, training updates and altitude policy adjustments

4. DISCUSSION

This study adds a global perspective on in flight medical events (IMEs) and operational responses, and it situates our findings alongside recent syntheses of aviation safety, human performance, and hypoxia research. Large scale meta-analytic evidence indicates that IMEs is relatively infrequent on a per passenger basis and fatal outcomes are rare, though reporting heterogeneity complicates precise benchmarking (Borges do et al., 2021). Our results are consistent with those estimates and reinforce calls for standardized case definitions and data capture to improve comparability and guide resource allocation.

Diversion is an uncommon but consequential management decision. Pooled analyses suggest 11 diversions per 100,000 flights, with highly variable cost per event depending on geography and scenario. Our dataset reflects the same reality that decisions to divert are multifactorial and often supported by ad hoc onboard expertise and remote medical consultation. Notably, AED deployment appears rare, and when used, shockable rhythms are infrequently detected; nevertheless, AED availability and training are essential safeguards for the small subset of time critical cardiovascular emergencies (Borges do et al., 2021).

The system level response to IMEs continues to evolve. A focused review of airline practices highlights three levers that consistently improve outcomes: robust crew training in first aid and kit use aligned with IATA, ICAO guidance, well-standardized, well-maintained onboard medical kits, and reliable telemedical consultation pathways (Battineni et al., 2024). Our findings indicate all three telemedicine augments non clinician crews with expert decision support, helps triage diversion, and facilitates post landing handoff. The industry would further benefit from centralized, de identified IME registries to close knowledge gaps and enable continuous quality improvement (Battineni et al., 2024; Borges do et al., 2021).

A recent synthesis of general aviation accidents emphasizes persistent human factor contributors (adverse weather decision making, VFR into IMC, and training gaps) and calls for targeted recurrent training and scenario-based simulation to address them (Sheffield et al., 2025). While our cohort centers on commercial operations, these insights generalize: high-reliability teams benefit from recurrent, scenario-rich training that anticipates cognitive stressors and rare events.

A systematic review of incapacitation shows that true in-flight medical incapacitation among professional pilots is very rare, 0.19–0.45 per million flight hours, yet several studies indicate an age-associated increase in overall (not solely in-flight) medical incapacitation (Huster et al., 2014). These data inform balanced policy discussions (age thresholds vs experience benefits) and reinforce the value of proactive health surveillance and well-designed crew pairing policies for resilience.

A separate but related axis is the impact of hypoxia on cognition, critical both in cabin, flight deck contexts (pressurization anomalies) and during training. Meta analytic study from simulated altitude experiments shows small to moderate decrements in reaction time and response accuracy and a larger decrement in memory, with attention largely unaffected on average (Ramírez delaCruz et al., 2024). These findings motivate practical emphases in recurrent training on early symptom recognition and on procedures that minimize cognitive load during suspected hypoxia.

A systematic review describes a (hypoxia hangover) wherein simple physiological indices (SpO_2, heart rate) normalize within minutes, but cognitive performance, blood pressure, cerebral oxygenation, ventilation, and EEG markers are perturbed for minutes to hours; in at least one study, regional cerebral tissue oxygenation took up to 24 hours to normalize (Shaw et al., 2023). For civil aviation, these data argue for clear, evidence-based guidance after any hypoxic incident or training exposure, tailored to exposure dose and upcoming duty demands.

Scenario based training that rehearses decision making under stress, rare cardiopulmonary events, and suspected hypoxia aligns with evidence on error prone conditions and sensitive cognitive domains (Sheffield et al., 2025; Post et al., 2023; Ramírez delaCruz et al., 2024). Build policies for hypoxia recovery and crew health. Short, conservative stand downs after hypoxic exposures (with attention to exposure dose and upcoming safety critical tasks) are justified by the "hangover" literature; age-aware health surveillance can optimize safety without overstating very rare in-flight incapacitation risks (Shaw et al., 2023; Huster et al., 2014).

5. CONCLUSION

This systematic review show that in flight medical events are rare but significant occurrences in commercial aviation. Most emergencies are non cardiac and can be managed on board using first aid kits, oxygen, and telemedical support, and rapid AED use is critical for cardiac arrests. Pilot incapacitation is rare but increases with age, indicate the need for continuous health surveillance.

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Informed consent

Not applicable.

Ethical approval

Not applicable. This article does not contain any studies with human participants or animals performed by any of the authors.

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Conflict of interest

The authors declare that they have no conflicts of interests, competing financial interests or personal relationships that could have influenced the work reported in this paper.

Data and materials availability

All data associated with this study will be available based on reasonable request to the Corresponding Author.

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