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Human Factors in Helicopter Air Ambulance Operations Annotated Bibliography (2014 – 2022)

Hannah M. Baumgartner[1]
Rebecca DiDomenica[2]
Justin Durham[2]
Peter T. Hu[2]

[1]Civil Aerospace Medical Institute
Federal Aviation Administration
Oklahoma City, OK 73125

[2]Cherokee Nation Support, Services, & Solutions
Oklahoma City, OK 73125

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<tr><td colspan="4">16. Abstract
Helicopter air ambulance (HAA) operations involve particularly challenging conditions, including landing at unfamiliar, remote, or unimproved sites with terrain and obstacle hazards, and involve urgent or time-sensitive situations. Associated human factors (HF) issues including fatigue, stress, human error, and perceived pressure to fly compound the challenging nature of HAA operations. This report aims to inform the current understanding of HF risks and considerations within HAA operations spanning 2014 – 2022 through a focused review of flightcrew fatigue considerations, environmental conditions, areas for increased training opportunities, and other operational risk factors.</td></tr>
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The opinions expressed are those of the authors alone, and do not necessarily reflect those of the Federal Aviation Administration, the Department of Transportation, or the Federal government of the United States.

Correspondence concerning this report should be addressed to Hannah Baumgartner, Aerospace Human Factors Research Division (AAM-500), 6500 S. MacArthur Blvd. Oklahoma City, OK, 73125. Email: hannah.m.baumgartner@faa.gov

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List of Abbreviations

AC	Advisory Circular
ACTA	Applied Cognitive Task Analysis
ATS	Accumulated Time with Sleepiness
BMI	Body Mass Index
BOS	Beginning of a Shift
CFIT	Controlled Flight into Terrain
CFR	Code of Federal Regulations
CFV	Christophorus Flugrettungsverein (Christophorus Air Rescue Association)
COVID-19	Coronavirus Disease 2019
CRM	Crew Resource Management
DTE	Domain Task Experience
DTIC	Defense Technical Information Center
ECG	Electrocardiography
EDS	Excessive Daytime Sleepiness
EMS	Emergency Medical Services
EMT	Emergency Medical Technician
ESS	Epworth Sleepiness Scale
FAA	Federal Aviation Administration
FRAT	Flight Risk Assessment Tool
GA	General Aviation
GCS	Glasgow Coma Scale
HAA	Helicopter Air Ambulance
HCM	HEMS Crewmember
HEMES	Helicopter Hospital Emergency Medical Evacuation Service
HEMS	Helicopter Emergency Medical Service
HF	Human Factors

HFACS	Human Factors Analysis and Classification System
HHO	Helicopter Hoist Operation
HR	Heart Rate
HTAWS	Helicopter Terrain Awareness and Warning System
ICU	Intensive Care Unit
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
ISS	Injury Severity Score
KSS	Karolinska Sleepiness Scale
LD	Liability Damage
LOC	Loss of Control
LOS	Length of Stay
NAA	Norwegian Air Ambulance
NASA	National Aeronautics and Space Administration
NTRS	NASA Technical Reports Server
NTS	Non-technical Skills
NTSB	National Transportation Safety Board
NVG	Night Vision Goggles
PEARLS	Promoting Excellence and Reflective Learning in Simulation
PVT	Psychomotor Vigilance Test
QTc	Q-wave to T-wave (Interval)
RNoAF	Royal Norwegian Air Force
SAR	Search and Rescue
SBP	Systolic Blood Pressure
SCORE	Systematic Coronary Risk Evaluation
SCWT	Stroop Color and Word Test
SMS	Safety Management System

SOP	Standard Operating Procedures
TDPS	Temperature Dew Point Spread
TFA	Transport Fatigue Assessment
UWES-9	Utrecht Work Engagement Scale
VFR	Visual Flight Rules
WHO-5	World Health Organization 5-item
WHOQOL-100	WHO Quality of Life

Background

Following a high number of accidents and ongoing safety issues associated with Helicopter Air Ambulance (HAA)[1] operations, the Federal Aviation Administration (FAA) received Congressional direction in the "FAA Modernization and Reform Act of 2012" (P.L. 112-095), as well as in National Transportation Safety Board recommendations, to improve the safety of HAA operations. In response, the FAA instituted operating requirements for HAA operations by publishing the final rule "Helicopter Air Ambulance, Commercial Helicopter, and Part 91 Helicopter Operations" (79 F.R. 9931, 2014), and its subsequent revision "IFR Operations at Locations Without Weather Reporting" [2] (84 F.R. 35820, 2019). Careful consideration of the human factors (HF) issues associated with HAA operations is necessary to support safe HAA operations and ensure that potential new risks are identified and addressed. This report aims to inform the current understanding of HF risks and considerations within HAA operations by assessing and summarizing the related scientific literature. Findings will be used to inform future research and analysis regarding HF-related incidents and accidents in HAA operations.[3]

The HAA primarily functions to transport patients from the scene of an accident to a medical facility for treatment or to transport patients between different medical facilities. Flight and medical crewmembers staff HAA operations. Often pilots are the only flightcrew onboard because of the limited space available in helicopters.[4] In addition to operating the aircraft, HAA pilots are responsible for pre-flight planning, analyzing potential risks and hazards, and executive decision-making (i.e., declining, canceling, diverting, or terminating a flight; see 14 CFR § 135 Subpart L and 14 CFR § 91). HAA pilots fly under strict flight-time limitations and rest requirements to ensure safety in these conditions to help offset the risks (see Table 1). Teams of highly trained medical staff including medical doctors, paramedics, emergency medical technicians (EMTs), and nurses accompany the flightcrew/HAA.[5] HAA operations are conducted around the clock and occur at low altitudes during various weather conditions. They often involve landing

[1] The term Helicopter Air Ambulance replaced Helicopter Emergency Medical Service (HEMS), which was made obsolete in 2015 by FAA Advisory Circular (AC) 135-14B. The change recognizes not all air ambulance flights operated involve an emergency. References to HEMS in this report reflect the original language of the authors.
[2] Instrument Flight Rules.
[3] Incidents and accidents are defined in 49 CFR § 830.
[4] Patients are configured in the aircraft in such a way that they generally block the co-pilot seat in rotorcraft (Ruskin, 2019).
[5] These roles include medical training as EMT, paramedics, or nurses, and assist the pilot as needed (Rasmussen & Sollid, 2015).

at unfamiliar, remote, or unimproved sites with terrain and obstacle hazards, and typically involve urgent or time-sensitive situations.

Between 1999 and 2019, the proportion of fatal helicopter accidents was higher for emergency medical service (EMS) accidents than for non-EMS helicopter operations (Greenhaw & Venesco, 2021). Between 2007 and 2019, 35% of accidents (or 28 of 80 total accidents) involving Part 135 air medical flight operations[6] resulted in a fatality (National Transportation Safety Board [NTSB], 2019). It should be noted, however, that these data do not reflect how the role of exposure (e.g., flight hours) across helicopter operations may interact with these fatality statistics, nor the fact that HAA operations account for between 2 to 4 times the number of flight hours in comparison to other types of helicopter operations in the United States (FAA, 2020). Further, trends indicate that the fatality risk associated with HAA operations may be declining in recent years (FAA, 2020; FAA, 2022). Still, the risks associated with these operations contributed to the FAA implementing the Helicopter Terrain Awareness and Warning System (HTAWS)[7] in addition to stricter weather implementations for flying under visual flight rules (VFR; 14 CFR § 135.605; 14 CFR § 91; see NTSB, 2006).

The challenging nature of HAA operations raises a number of relatively unique HF issues. Such operational conditions can elevate mental and physical fatigue, stress, and human error, and make flightcrew communication and decision-making difficult. Special considerations of HF and safety culture are needed to combat any perceived pressure on pilots to perform these operations given the critical medical condition of onboard patients.

Purpose

This report summarizes current scientific literature on HF risks and considerations within HAA operations spanning 2014 – 2022, focusing on HAA research that has taken place since the 2014 published rule (79 F.R. 9931). It will inform upcoming research to analyze HF within serious incidents and accidents in HAA operations. The report includes a review and an annotated bibliography of HF scientific literature focusing on four main topics:

1. Flightcrew fatigue, duty and schedule limitations, and risk factors for increased sleepiness in HAA operations.

[6] HAA operations are conducted under 14 CFR § 135 and 14 CFR § 91, depending on who or what is transported. 14 CFR § 91 is an umbrella term for any operation that is not regulated by 14 CFR § 121, 135 or 129 and is excluded from the statistic. 14 CFR § 135 includes commuter services and on-demand passenger or cargo services (i.e., non-HAA-specific operations).

[7] The HTAWS mandate became effective as of April 2017.

2. Environmental conditions that pose risk, such as adverse weather conditions and nighttime flying.
3. Areas for increased training opportunities.
4. Other operational risk factors within HAA operations.

Methodology

Articles for this annotated bibliography were collected from the Defense Technical Information Center (DTIC), Google Scholar, the National Aeronautics and Space Administration (NASA)[8] Technical Reports Server (NTRS), ProQuest, and FAA Library databases between April and June 2022 using the following keywords/phrases:

- Air ambulance
- Air medical services helicopter
- Helicopter "air ambulance" crewing
- Helicopter "air ambulance" fatigue
- Helicopter HAA
- Helicopter HEMS
- Helicopter HEMS crewing
- Helicopter HEMS crewing fatigue
- Helicopter HEMS crewing training

The research principal investigator screened the collected articles using inclusion criteria that included (a) relevance to air ambulance operations, (b) rotorcraft operations, and (c) content related to HF and/or accident and serious incident analyses resulting in 91 sources. The principal investigator further screened the sources to exclude secondary sources and articles that only referenced HAA medical crews or HAA patients, resulting in the 42 primary research articles reviewed in this annotated bibliography.

Findings

Flightcrew Fatigue

Fatigue-related considerations are particularly important for the on-call nature of HAA operations, where idleness, shiftwork schedule, workload, and potential circadian disruptions associated with nighttime flying may influence a pilot's fatigue level for any given call. Fatigue can elevate the risk of pilot error that could lead or contribute to a potential aviation incident or accident (Caldwell, 1997; Gurubhagavatula et al., 2021). Nonetheless, a recent survey found high levels of daytime sleepiness in U.S. HAA pilots (Haber Kamine et al., 2022). Research from international HAA operators offers insight into effective shift work scheduling to minimize fatigue in these operations such as 7-day-on, 14-day-off scheduling practices (Flaa et al., 2019, 2021, 2022). However, many international operators are part of state-run healthcare programs and operate under

[8] National Aeronautics and Space Administration.

different civil aviation authority requirements, making comparisons with private operator practices in the U.S. difficult. Overall, the annotated literature highlights the need for more fatigue-related research in U.S. HAA operations. For reference, the current FAA crew duty time (i.e., a scheduled shift that includes duties that are not flight-related) and flight time (i.e., the portion of the duty time spent flying) limitations are included in Table 1.

Table 1
Flight Time Limitations and Rest Requirements per 24 Consecutive Hours: Unscheduled One- and Two-Pilot Crews (14 CFR § 135.267)

	One-Pilot Crew	Two-Pilot Crew
Maximum Duty Period	14 hours	14 hours
Maximum Total Flight Time	8 hours	10 hours
Required Rest	10 hours	10 hours

Note. These requirements summarize those found in 14 CFR § 135.267. Operations that meet additional criteria may instead follow schedule restrictions detailed in 14 CFR § 135.271, "Helicopter Hospital Emergency Medical Evacuation Service (HEMES)."

Environmental Conditions

Environmental conditions (including adverse weather, unfamiliar terrain, and nighttime flying) can increase pilot task demand, make in-flight decision-making more challenging, and are known risk factors for fatal HAA accidents and serious incidents (Aherne et al., 2018, 2021; Ramee et al., 2021). Poor weather conditions and flying at night also increase susceptibility of *inadvertent flight* into Instrument Meteorological Conditions (IMC) or other conditions that require pilots to fly under Instrument Flight Rules (IFR), which require additional pilot certification and training and additional approval for the aircraft. Poor visual cues associated with adverse weather events are also risk factors for spatial disorientation, which can lead to loss of control and impact into terrain accidents (Aherne et al., 2019). The annotated literature demonstrates the risks associated with different environmental conditions for HAA flying, and details how these adverse conditions may influence pilot decision-making.

Training

A number of areas for improvement in training have been identified for HAA operations, such as increased access to simulation training and an increased focus on pilot skills related to weather instruments in the cockpit (Abrahamsen et al., 2015; Spiers et al., 2021). In situ simulation-based training is a common practice in the medical field and includes acting out clinically relevant situations to practice crew interactions and communication, which may not involve a flight simulation at all. An increased emphasis on this clinical simulation-based training within HAA operations is supported by the literature, particularly with regard to honing Crew Resource Management (CRM) and team communication skills (Bredmose et al., 2021b; Lunde & Braut, 2019; Rasmussen et al., 2019). Additionally, fatality in HAA accidents that occurred during poor weather conditions has recently been linked to low pilot domain task experience (DTE; Aherne et al., 2018), highlighting the need for increased pilot training under IMC using flight simulators (De Voogt et al., 2020; Spiers et al., 2021).

The annotated literature provides insight into potential training practices that should be considered or enhanced for HAA crewmembers including simulation training, virtual and augmented reality scenarios, CRM training, and training for inadvertent encounters with IMC. These data also provide support for recent operational improvements in training and simulator facilities that have been adopted by some major air ambulance operators (Rosenlof, 2020; Air Methods, 2017). A small but significant focus of the reviewed literature is placed on pilot and crewmember perceptions towards the different modes (e.g., simulator, virtual reality) of training and assessment. These perceptions are typically in the form of self-reported reactions concerning level of engagement, learning, motivation, and satisfaction, and are evaluated to inform future training practices.[9]

Other Operational Risk Factors

A number of additional operational risk factors were identified in the literature with regard to HF considerations in HAA operations. The annotations included in this section highlight important risk factors and considerations inherent to HAA operations that do not fall under the themes of fatigue, environmental conditions, or training. For example, a positive safety culture is particularly important in HAA operations where pilots face unique pressures to fly related to patients' medical status (Aalberg et al., 2020; Chesters et al., 2016; Gardner et al., 2017; Lunde & Braut, 2019). Safety culture refers to a collective set of views surrounding an organization's approach to work values, beliefs, and safety practices (Reason, 1997; see Key et al., Under Review, for a review of the literature), which can influence a pilot's perceived pressure to accept an HAA flight (Aalberg et al., 2020; Lunde & Braut, 2019). Additionally, stressful aspects of HAA operations such as rescue missions can contribute to an increased risk of serious incidents

[9] See Bredmose et al. (2020); Bredmose, Østergaard, & Sollid (2021); Bredmose, Røislien, Østergaard, & Sollid (2021); Bredmose, Hagemo, Østergaard, & Sollid (2021).

or accidents, and have chronic physiological effects on pilots' health and wellbeing (Bauer et al., 2018, 2019, 2020; Strauss et al., 2021).

Annotated Bibliography

Flightcrew Fatigue

Akter, R., Larose, T. L., Sandvik, J., Fonne, V., Meland, A., & Wagstaff, A. S. (2021). Excessive daytime sleepiness and associated factors in military search and rescue personnel. *Aerospace Medicine and Human Performance*, *92*(12), 975–979. https://doi.org/10.3357/AMHP.5946.2021

Introduction. The purpose of this study was to determine the prevalence of abnormal excessive daytime sleepiness (EDS) and contributing factors among Royal Norwegian Air Force (RNoAF) Search and Rescue (SAR) helicopter personnel. **Methods.** Two hundred and fifty SAR helicopter personnel in the RNoAF including flight commanders, co-pilots, flight engineers, system operators, rescuers, medical doctors, and technicians were invited to participate in the study. Crews not involved in on-call duties were excluded. A total of 175 RNoAF SAR personnel completed a survey of (a) socio-demographic items including age, marriage status, personnel category, number of children, special family care responsibility, and second job information; and (b) lifestyle-related factors including smoking status, tobacco use, caffeine use off duty, commuting distance, health status, and physical exercise. The Epworth Sleepiness Scale (ESS) was used as both a continuous and categorical outcome variable to evaluate EDS. On the ESS, participants rated the likelihood of dozing off or falling asleep when engaging in eight different activities. Higher scores on the ESS indicated greater severity of EDS. **Results.** Abnormal EDS was prevalent among 41% of the RNoAF personnel. No relationship was found between socio-demographic and lifestyle factors on excessive EDS. **Conclusion.** Results found that abnormal EDS was common among an RNoAF SAR sample population. This survey reached a large and diverse sample that represents a diverse range of occupations and operations within the RNoAF, including a subset that work with HAA operations. Further research is needed to assess any occupational or operational differences in daytime sleepiness within this population.

Bushmaker, R., Corey, K., Dunn, J., Lalonde, T., & Estrada, S. (2019). Evaluation of a new helicopter crew transport fatigue assessment. *Air Medical Journal, 38*(3), 198-201. https://doi.org/10.1016/j.amj.2018.11.006

Introduction. Factors associated with HAA operations such as shift work, transport times, and night vision goggles (NVG) may uniquely influence fatigue. This study aimed to create and validate a tool to assess fatigue levels in air ambulance crews. **Methods.** Universal and air ambulance-specific factors that contribute to fatigue, including questions about the number of transports per shift and night vision goggle use, were included in a new Transport Fatigue Assessment (TFA) tool. In Phase 1, crews (n = 95 shifts) from two HAA operations completed the TFA and the ESS at the beginning of each shift and after each transport within a shift. Internal consistency between pre- and post-flight assessments was assessed, as was concurrent validity between TFA and ESS scores. Seven confusing and/or irrelevant questions were removed from the TFA tool or reworded based on the exploratory factor analysis. Phase 2 evaluated TFA scores and self-reported levels of fatigue using a 5-point Likert scale in a new population of HAA crewmembers at the beginning of a shift (BOS) and following transports. **Results.** In Phase 1, ESS scores were found to be internally consistent ($\alpha = .72$) between BOS (n = 95) and post-transport (n = 63) administrations, while TFA score internal did not reach significance ($\alpha = .48$). Phase 1 BOS TFA and BOS ESS scores were positively correlated ($\hat{b} = 0.503$) as were post flight TFA and ESS scores ($\hat{b} = 0.167$). In Phase 2, BOS TFA scores (n = 923) and post flight TFA scores (n = 745) were found to be internally consistent (Cronbach $\alpha = .753$), and TFA scores were positively associated with concurrently reported fatigue levels ($\hat{b} = 0.479$ and $\hat{b} = 0.189$ for BOS and post flight scores, respectively). **Conclusion.** These findings suggest that the TFA may be a useful tool in evaluating flightcrew fatigue that is specific to air ambulance operations. The study found that TFA scores were positively associated with both freely self-reported fatigue levels and associated with scores on a validated daytime sleepiness scale, the ESS.

Flaa, T. A., Bjorvatn, B., Pallesen, S., Røislien, J., Zakariassen, E., Harris, A., & Waage, S. (2021). Subjective and objective sleep among air ambulance personnel. *Chronobiology International*, *38*(1), 129-139. https://doi.org/10.1080/07420528.2020.1802288

Introduction. The purpose of this study was to assess how shift work affects sleep quality and quantity in Norwegian HEMS workers. **Methods.** Sixty-one pilots and HEMs crewmembers (HCMs) from Norwegian Air Ambulance (NAA) participated in this study for 3 weeks during the fall/winter of 2014, and a subset of this population (n = 50) also participated in a second data collection for 3 weeks during summer 2015. The studied shift schedules included a 7-day on-duty workweek, a 14-day off-duty period, a 7-day on-duty workweek, and a 21-day off-duty period. All shifts started and ended at 10 am on Monday morning. Work conditions followed typical NAA procedures, including communal housing and maximum flight times (7 hours in a consecutive 24-hour period, 12 hours in a 48-hour period, and 30 hours in a 7-day period) and maximum active work times (14 hours during a consecutive 24-hour period, 30 hours during a 72-hour period) approved by the Civil Aviation Authority of Norway. The present study analyzed data from sleep diaries completed daily in the morning and from wrist actigraphy worn throughout the six test weeks. **Results.** Actigraphy and sleep diary data showed bedtimes were later during the workweek in the summer than in the winter, and sleep diary data showed that workers spent less time in bed during the summer versus winter workweeks. Summer and winter workweeks did not differ in terms of wake-up time, wake after sleep onset, sleep efficiency, or total sleep time. During the winter, actigraphy and sleep diary data showed that bedtime and wake time were later, time in bed was longer, and wake after sleep onset was higher during the workweek compared to the weeks before and after. Additionally, actigraphy data showed that sleep efficiency was lower, and sleep diary data showed that total sleep time was longer during the winter workweek. During the summer, actigraphy and sleep diary data showed later bedtimes and wake-up times, longer times in bed, and wake after sleep onset was higher during the workweek in comparison to the weeks before and after work. Finally, actigraphy data also showed that sleep efficiency was lower during the workweek. **Conclusion.** Actigraphy and sleep diary data were largely similar between HEMS workweeks during the winter and summer seasons in NAA, and the observed slight changes in bedtime and time in bed could be due to seasonal workload and circadian differences. Altogether, workers experienced delayed sleep onsets, more time awake after sleep onset, and lower sleep efficiency scores during the workweek in comparison to non-working weeks, which relate to being on-call for night HEMS trips. However, total sleep times were higher during the workweek, at least during the winter season, and more time was spent in bed during the workweek across seasons. Overall, these findings suggest that HEMS workers are relatively well adjusted to sleep schedules during the workweek, though attention to actigraphy data is important to assess objective measures of sleep quality and disruption due to shift work.

Flaa, T. A., Bjorvatn, B., Pallesen, S., Zakariassen, E., Harris, A., Gatterbauer-Trischler, P., & Waage, S. (2022). Sleep and sleepiness measured by diaries and actigraphy among Norwegian and Austrian helicopter emergency medical service (HEMS) pilots. *International Journal of Environmental Research and Public Health*, *19*(7), 4311. https://doi.org/10.3390/ijerph19074311

Introduction. HEMS pilots in the NAA and the Christophorus Flugrettungverein (Christophorus air rescue association, CFV) in Austria work a seven consecutive 24-hour shift schedule. The fatigue and sleepiness experienced by these pilots can be detrimental to HEMS operations. This study examined the sleep and sleepiness of NAA and CFV pilots in HEMS using sleep diaries and wrist actigraphy data. **Methods.** Twenty-five NAA (1 female, 24 male; M_{Age} = 43.6 years; *SD* = 5.2) and 22 CFV pilots (0 female, 22 male; M_{Age} = 42.8 years, *SD* = 6.1) working seven consecutive 24-hour shifts participated in this study. A questionnaire was administered on the first workday regarding sex, age, years in the position, and caffeine intake at work (number of cups), sleep needs, and sleep problems related to the work schedule. NAA and CFV staff recorded the time spent during training sessions, time spent on missions, and the total number of missions in a Mission Log. Sleep was recorded upon awakening each morning in a sleep diary and continuously throughout the week by wrist actigraphy. Sleep variables (i.e., bedtime, wake-up time, wake after sleep onset, time in bed, total sleep time, and sleep efficiency[10]) were calculated based on the diary entries. The Karolinska Sleepiness Scale (KSS) measured sleepiness[11] every other hour throughout the workweek. **Results.** The NAA pilots had later bedtime and wake-up time, spent more time awake after sleep onset, spent more time in bed, slept longer, reported more disturbed sleep, and had lower sleep efficiency compared with the CFV pilots. All differences were significant ($p < .01$). Sleep and sleepiness parameters did not change throughout the workweek; however, both crews reported later bedtime and wake-up times towards the end of the workweek (Days 6 and 7). KSS scores significantly differed by the time of day and day of the week, but did not differ between crews. NAA pilots completed upwards of 30 missions per week whereas CFV pilots completed upwards of 51 missions per week. However, the number of missions did not influence sleep variables significantly. **Conclusion.** Differences between NAA and CFV pilots were indicated by diary entries and actigraphy. NAA pilots had later bedtime and wake-up times and spent more time awake after sleep onset and had lower sleep efficiency compared with the CFV pilots. This could be due to the NAA pilots taking on more missions after dark. There were no differences in the bedtime and wake-up time throughout the workweek for both crews. However, both crews revealed convergence on the following result: bedtime and wake-up times were delayed by the end of the workweek.

[10] Total sleep time/time in bed X 100.

[11] Sleepiness is measured on a scale of 1 (very alert) to 9 (very sleepy, great effort to stay awake, fighting sleep). Excessive sleepiness is indicated by a score of 7 or greater.

Flaa, T. A., Harris, A., Bjorvatn, B., Gundersen, H., Zakariassen, E., Pallesen, S., & Waage, S. (2019). Sleepiness among personnel in the Norwegian air ambulance service. *International Archives of Occupational and Environmental Health*, *92*(8), 1121-1130. https://doi.org/10.1007/s00420-019-01449-w

Introduction. Shift work conditions and extended work hours in Norwegian HEMS operations put crews at risk for increased sleepiness and fatigue. This field study assessed sleepiness in Norwegian HEMS flightcrews before, during, and after a 7-day workweek and across various operations, schedules, and conditions. **Methods.** Fifty pilots and HCMs (1 female, 49 male) from NAA that had previously participated in an initial shift-work study, took part in a 3-week second study in the spring/summer of 2015. Schedule information for these participants mimicked the conditions described above (see Flaa et al., 2021). Crews completed a questionnaire and the ESS on their first duty day, completed the KSS every other hour while awake during the workweek, completed a reaction-time test at different points throughout the workweek, and completed the Accumulated Time with Sleepiness (ATS) scale nightly before bed for the 3-consecutive study weeks. **Results.** Participants reported lower sleepiness scores during the workweek versus off-weeks for all six measures of ATS (i.e., heavy eyelids, feeling gravel-eyed, difficulty focusing your eyes, irresistible sleepiness, reduced performance, periods of fighting sleep). ATS scores remained consistent within the 7-day workweek. During the workweek, time of day significantly increased KSS scores (highest at 2400h). Additionally, having a higher workload was associated with lower KSS scores, and participants reported higher KSS scores on day 1 of the workweek in comparison to the remaining six workdays of the study. Reaction times did not significantly change throughout the workweek. **Conclusion.** Overall, the participants reported less sleepiness and associated factors during the 7-day workweek in comparison to off-duty weeks. Home-life factors including child rearing, second jobs, and personal responsibilities may explain this reported effect, in combination with the structured living environment available while on duty. Additionally, the activeness associated with a higher workload may explain the decrease in associated sleepiness scores during the workweek. Overall, these results suggest that the work conditions and structured living environment may be effective in mitigating risks of elevated sleepiness associated with shift work and long work hours in NAA crews.

Fletcher, A., Stewart, S., Heathcote, K., Page, P., & Dorrian, J. (2022). Work schedule and seasonal influences on sleep and fatigue in helicopter and fixed-wing aircraft operations in extreme environments. *Scientific Reports, 12*(1), 1-13. https://doi.org/10.1038/s41598-022-08996-2

Introduction. The purpose of this research was to measure sleep, work, alertness, mental performance, and other fatigue-related factors within several aviation emergency medical, firefighting, SAR, offshore transport, and other mission-critical contexts. **Methods.** Two hundred and ten employees at a company providing EMS, SAR, and oil and gas services participated in this study. Participants included pilots, other crew, and technicians across seven countries. Data were collected between November 2014 and December 2018 over 21 days for each study in which participants continued their duties while they completed study questionnaires and performance tasks. Experimenters visited each operating company to provide equipment and training where participants were on-duty at the base, working either continuously (not including breaks) or as needed (i.e., on-call). Participants wore activity monitors, completed electronic tablet-based work, and sleep diaries. Participants completed the Psychomotor Vigilance Test (PVT) on tablets during breaks in duty periods and on days off. **Results.** Work occurred primarily during daytime hours while most sleep occurred during the night for both daytime operations and 24-hour operations. The proportion of sleep occurring during duty time fluctuated between 0% and 30% across countries. However, there were extended sleep and nap times in the afternoons and during days off. Overall, PVT response times were significantly longer on duty days compared to non-duty days. **Conclusion.** The results indicate that some extended sleep and napping occur during duty time in the examined aviation operations, which should be taken into account when assessing fatigue risk management. Most sleep occurred at night for both daytime operations and 24-hour operations, suggesting that the availability of rest places for on-call 24-hour operations is critical. This study provides insight into typical resting patterns of a large range of aviation personnel across seven countries involved in extreme environments, which could inform future fatigue mitigation plans for similar high-stress aviation operations.

Haber Kamine, T., Dhanani, H., Wilcox, S., Kelly, E., Alouidor, R., Kramer, K., Carey, Y., Ryb, G., Putnam, A.T., Winston, E., & Cohen, J. (2022). American helicopter emergency medical service pilots report to work despite high rates of sleepiness. *Air Medical Journal, 41*(5), 432-434. https://doi.org/10.1016/j.amj.2022.07.005

Introduction. The purpose of this study was to assess sleepiness in HEMS pilots in the United States. **Methods.** Thirty-one HEMS pilots (0 female, 31 male; $M_{Age} = 48$ years, $SD = 12$) completed the ESS and answered demographic questions. **Results.** Twelve of the 31 pilots completed the ESS while on duty ($n = 9$ on the day shift, $n = 3$ on the night shift). Twenty or 65% of pilots reported ESS scores >10, indicating EDS. There were no differences found between ESS scores of on-duty versus off-duty pilots. Fourteen pilots (45%) reported that they have previously turned down a flight due to fatigue, while 20 pilots (65%) reported that they should have previously turned down a flight due to fatigue. Pilots reported that fatigue degraded alertness during flight (77.6%), degraded performance during flight (51.6%), and that it affected their ability to concentrate during flight (29%). When fatigue affected performance in flight, 74% of pilots reported that it largely occurred during the route to the destination as opposed to takeoff or landing. **Conclusion.** These findings demonstrate the high prevalence of daytime sleepiness among HEMS pilots whether on- or off-duty and show that the effects of this sleepiness on flight performance are noticeable to pilots. Further, these results imply that while some pilots are turning down flights due to fatigue, several pilots that report that they should have previously turned down flights due to fatigue but did not. Further research should investigate differences in daytime sleepiness and fatigue while on- and off-duty in HEMS pilots with a larger sample to better assess differences between day and night shiftwork.

Radstaak, M., Geurts, S. A. E., Beckers, D. G. J., Brosschot, J. F., & Kompier, M. A. J. (2014). Work stressors, perseverative cognition and objective sleep quality: A longitudinal study among Dutch helicopter emergency medical service (HEMS) pilots. *Journal of Occupational Health*, *56*(6), 469-477. https://doi.org/10.1539/joh.14-0118-OA

Introduction. In general, individuals with poor sleep quality do not completely recover from the cognitive and emotional demands of work and consequently, put their health and well-being at risk. A longitudinal study was conducted to examine the associations between work stressors (e.g., workload and distressing shifts), preservative cognition (prolonged activation of the cognitive representation of stressors), and objective and subjective sleep quality (i.e., sleep onset latency). **Methods.** Twenty-four pilots (1 female, 23 male; M_{Age} = 44.1 years, *SD* = 5.97) working for the Dutch HEMS participated in this study. Each participant was administered six questionnaires addressing work stressors, sleep quality, and perseverative cognition. Questionnaires were administered at the end of three consecutive day shifts and each morning following the shifts. An activity monitor was worn for three consecutive days during testing to measure sleep quality (i.e., onset latency, total sleep time, and the number of awakenings). **Results.** Work stressors were positively associated with poor sleep quality; more distressing shifts further delayed the onset of sleep ($r = 0.5$) and higher workloads further impaired subjective sleep quality ($r = -0.42$). Work stressors were positively associated with perseverative cognition; higher workload and distressing shifts led to higher levels of perseverative cognition ($r = 0.19$, $r = 0.62$, respectively). Perseverative cognition was positively associated with delayed sleep onset ($r = 0.74$). Perseverative cognition mediated the association between work stressors and sleep onset latency (95% CI [0.02, 5.99]). **Conclusion.** This study examined the association between work stress and sleep quality. Distressing shifts delayed the onset of sleep and negatively impacted subjective sleep quality, even more so than perseverative cognition. This suggests that distressing shifts take the most time to recover from, perhaps because they are more emotionally charged. Most notably, preservative cognition acted as an explanatory mechanism in the association between work stressors and sleep onset, supporting the preservative cognition hypothesis' which asserts that thinking about stressful events can impede stress recovery.[12]

Zakariassen, E., Waage, S., Harris, A., Gatterbauer-Trischler, P., Lang, B., Voelckel, W., Pallesen, S., & Bjorvatn, B. (2019). Causes and management of sleepiness among pilots in a Norwegian and an Austrian air ambulance service—A comparative study. *Air Medical Journal*, *38*(1), 25-29. https://doi.org/10.1016/j.amj.2018.11.002

Introduction. HEMS pilots work for extended hours, during different times of day, and on different shift schedules. This can disrupt natural sleeping patterns and be hazardous for the job. As an attempt to combat sleepiness in HEMS pilots, subjectively reported sleepiness and fatigue levels, as well as strategies for managing sleepiness and fatigue, were evaluated. **Methods.** NAA and CFV pilots in Austria participated in this study. Thirty NAA pilots completed a work schedule that sequentially consisted of 7 days on-duty, 14 days off-duty, 7 days on-duty, and 21 days off-duty. Twenty-four CFV pilots completed the same work schedule, but instead with seven days on-duty, followed by seven days off-duty. While on duty, the pilots completed a questionnaire addressing sleep, work-related sleepiness and fatigue, and management of sleepiness. Pilots rated situations for their fatigue-triggering potential (does not cause fatigue, low fatigue, moderate fatigue, and high fatigue). The ESS and KSS were used to evaluate sleepiness. **Results.** NAA and CFV pilots had normal ESS and KSS scores (within acceptable range) and reported getting sufficient sleep on- and off-duty. Both groups used napping and coffee to combat sleepiness and fatigue. However, a significantly larger proportion of NAA pilots than CFV pilots slept more and did physical exercise to combat sleepiness and fatigue. CFV pilots reported administrative duties, phone calls, and environment as factors preventing them from napping while on duty; NAA pilots reported HEMS missions as a factor preventing them from napping. **Conclusion.** Strategies for managing sleepiness and fatigue were assessed between two groups of HEMS pilots. Napping and

[12] See Brosschot et al. (2006) for a discussion of the perseverative cognition hypothesis.

coffee-drinking were prevalent strategies for preventing sleepiness and fatigue for both groups. Neither group suffered from sleep deprivation; ESS and KSS scores were normal and pilots reported "sufficient sleep" while on and off duty. Overall, results validated that NAA and CFV pilots perceive low levels of sleepiness.

Environmental Conditions

Aherne, B., Newman, D., & Chen, W. S. (2021). Acute risk in helicopter emergency medical service transport operations. *Health Science Journal, 15*(1), 0-0.

Introduction. The purpose of this study was to objectively measure the difference in acute risk between day and night HEMS transport relative to aviation and medical procedure risks. **Methods.** U.S. HEMS fatal accident data between 1995 and 2015 – including accidents involving any flights to pick up a patient, transport a patient, or return to base after delivering a patient to the destination were identified from previous research and used in this study. The frequency of fatal HEMS accidents by day and night missions, fatal patient injuries, and patients transported by day and night were quantitatively classified. Acute risk was quantified in micromorts, a unit of risk representing a one-in-a-million chance of death, to estimate the probability of a fatal HEMS accident by day and night, fatal patient injury in a HEMS accident during the day, fatal spatial disorientation HEMS accident during the night, fatal patient injury in a spatial disorientation HEMS during the night, and fatal HEMS accident at night from other causes. Acute risk for medical procedures including fatal injury in road ambulance accidents, anesthesia-related mortality, skiing fatalities, diving fatalities, parachuting fatalities, and rock climbing fatalities were also used to make comparisons. **Results.** There was an overall acute risk of 15 micromorts for fatal HEMS accidents per mission. Acute risk was lower for daytime accidents (7.55 micromorts) relative to nighttime accidents (27.33 micromorts). For nighttime accident acute risk, the majority of operational accident risk was made up of spatial disorientation (18.75 micromorts, 69%). Patient risk during nighttime spatial disorientation (6.43 micromorts) was greater than double the patient risk during the daytime (2.95 micromorts). Importantly, acute risk to HEMS flightcrew was double relative to a patient's risk during daytime HEMS missions (7.55 micromorts vs 2.95 micromorts) and more than quadruple for nighttime HEMS missions (27.33 micromorts vs 6.43 micromorts). **Conclusion.** In general, this study found that nighttime HEMS missions increase acute risk to HEMS flightcrews and patients compared to daytime HEMS missions for accidents that occurred from 1995-2015. This work provides one metric to compare differences in risk between daytime and nighttime HEMS missions, though other factors besides fatality (e.g., accident rates, injuries) are also important considerations for overall safety comparisons.

Aherne, B. B., Zhang, C., Chen, W. S., & Newman, D. G. (2018). Pilot decision making in weather-related night fatal helicopter emergency medical service accidents. *Aerospace Medicine and Human Performance*, *89*(9), 830-836. https://doi.org/10.3357/AMHP.4991.2018

Introduction. Nighttime flights in fog or cloud are particularly dangerous for HEMS flights operating under VFR. The purpose of this study was to investigate the relationship between Temperature Dew Point Spread (TDPS) and pilot years of experience during these situations. It was hypothesized that HEMS pilots with less experience were associated with increased fatal outcomes when TDPS was low. **Methods.** Thirty-two NTSB-reported fatal accidents between 1994 and 2013 were selected; these accidents were single-pilot, at night, under VFR, and involved a loss of control (LOC) or controlled flight into terrain (CFIT). Relative risk and odds ratios were calculated for the likelihood of nonvisual meteorological conditions (non-VMC) and the likelihood of a fatal accident when TDPS is in the 0°-to-4°C range (i.e., cloud-ceiling conditions) versus TDPS ≥5°C. Relative risk and odds ratio was also calculated for fatal accidents during 0°-to-4°C TDPS when pilots have low or high experience. **Results.** Among the 32 fatal accidents examined, pilot experience was found to be a significant predictor in estimating the 0°-to-4°C TDPS range. The 0°-to-4°C TDPS range was also significantly associated with fatal outcomes, and low-experience pilots were significantly associated with fatal outcomes in the 0°-to-4°C TDPS range when compared to high-experience pilots. **Conclusion.** The finding that experience predicting TDPS indicates that high-experience pilots flew significantly more in non-VMC conditions with lower cloud ceiling than low-experience pilots. However, accidents during 0°-to-4°C TDPS conditions were over nine times more fatal when flown by a pilot with low experience (≤2 years of HEMS experience) than when flown by a pilot with ≥6 years of HEMS experience. Therefore, increased experience may inform better risk assessments in these conditions. However, increased experience may also lead such pilots to demonstrate overconfidence when assessing risk. Further research is needed to understand how other factors, such as experience with weather cues, work pressure, and cognitive demand may affect outcomes.

Aherne, B. B., Zhang, C., Chen, W. S., & Newman, D. G. (2019). Systems safety risk analysis of fatal night helicopter emergency medical service accidents. *Aerospace Medicine and Human Performance*, *90*(4), 396-404. https://doi.org/10.3357/AMHP.5180.2019

Introduction. Nighttime conditions are a common risk factor for accidents in HEMS operations. Other risk factors for accidents include pilots with less than 6 years of HEMS DTE, pilots lacking instrument flying capabilities, and adverse weather conditions. This study conducted a system safety risk analysis to (a) determine whether fatal night accident rates differ in the day and night; (b) identify other risk factors driving fatal accident rates; and (c) identify measures to reduce the likelihood of fatal accidents occurring during the nighttime. **Methods.** Findings from 32 night VFR fatal HEMS accidents between 1995 and 2013 were obtained. Accidents were stratified by LOC, night operational accident sequence, and the following design options: pilot DTE (i.e., low, high), and flight rule capability. The probability of fatal accidents occurring under different DTE, VFR, and IFR conditions was calculated as a measure of the overall effectiveness of these design options as a high-risk system.[13] Effectiveness results were used to estimate residual risk for the overall system. **Results.** Fatal accident rates were significantly different between daytime and nighttime operations. The fatal accident rate was over three times greater for low-DTE than high-DTE pilots, and over six times greater for pilots without IFR-capabilities (VFR-only) than for pilots with IFR capabilities. Low-DTE pilots with VFR-only capabilities were the least effective combination, as they had the highest probability of sustained spatial disorientation and were significantly associated with night operational nonsurvivable accidents. VFR-only capability had a higher probability of spatial disorientation than IFR capability. **Conclusion.** This study used a system safety approach to determine the factors that could reduce the likelihood of fatal accidents in HEMS, with the larger goal of preventing future accidents. Night operations, DTE, and instrument flying capabilities influenced the severity of HEMS accidents and contributed to the different rates of fatal accidents observed during the day versus the night. Visual orientation cues are lost during the nighttime and often result in spatial disorientation. This study showed that low-DTE pilots with VFR-only capabilities were less likely to maintain spatial orientation, were less familiar with the aircraft instruments, and thus were at a much greater risk for fatal night accidents.

[13] The system safety risk analysis technique used also assesses the stability of the design options, identifies issues that may increase risk over time, and determines how rapidly effectiveness of the system declines over time.

Aherne, B. B., Zhang, C., & Newman, D. G. (2016). Pilot domain task experience in night fatal helicopter emergency medical service accidents. *Aerospace Medicine and Human Performance*, *87*(6), 550-556. http://doi.org/10.3357/AMHP.4454.2016

Introduction. This study examines the relationship between pilot experience with HEMS (i.e., DTE) and accidents during night HEMS operations. **Methods.** Thirty-two fatal single-pilot nighttime HEMS accidents between 1994 and 2013 were identified in the NTSB database. Years of HEMS experience, age, sex, and total flight hours were identified against an EMS pilot industry demographic. **Results.** All 32 pilots were male, M_{Age} = 47.6 years (*SD* = 9.23). Total flight hours varied between 1,902 and 20,537 hours (M_{Flight} = 5,283 hours, *SD* = 3,893). Average HEMS experience was *M* = 4.10 years (*SD* = 6.23); 14 pilots had less than one year of HEMS experience. Five pilots (16%) had an instrument proficiency check within the preceding six months. Pilots with less than 4 years of HEMS experience had a statistically significant increase in accident rate; pilots with more than 10 years of HEMS experience had a statistically significant decrease in the accident rate. **Conclusion.** The study found a relationship between HEMS experience and the likelihood of a nighttime accident. The majority of pilots (56%) in the identified accidents had less than two years of HEMS experience. The lack of experience may be in part due to the on-demand nature of HEMS operations. Although increased (>10 years) experience may be effective at reducing risk, years of experience do not directly explain the decision-making that leads pilots to operate in risky, hazardous conditions. Although cognitive and decision-making mechanisms are proposed, more research is needed to better understand and prevent future HEMS accidents.

De Voogt, A., Kalagher, H., & Diamond, A. (2020). Helicopter pilots encountering fog: An analysis of 109 accidents from 1992 to 2016. *Atmosphere*, *11*(9), 994. https://doi.org/10.3390/atmos11090994

Introduction. The FAA increased weather minimums for helicopter operations in 2014 as a precaution against fatal accidents during IMC. Prior to this change, most helicopters could operate in Class G airspace under IFR and VFR with low and potentially unsafe minimum visibility. Accident reports were evaluated for fog, specifically to understand its occurrence in helicopter operations in IMC. **Methods.** One hundred and nine helicopter accident reports between 1992 and 2016 were acquired from the NTSB online database. Only accidents that mentioned fog around the area of and during the accident were selected. NTSB investigator impressions (i.e., narrative statements) of whether or not the pilot faced external or self-induced pressures to maneuver the helicopter to or away from IMC conditions (i.e., fog) were also obtained. **Results.** Seventy-three (67%) incidents evaluated in this study were fatal, with a total of 163 fatalities. Instrument rating was not a significant factor in fatal accidents. Fatal accidents occurred more often when the pilot flew into IMC intentionally as opposed to unintentionally. Accidents occurred significantly more frequently when the pilot was under pressure compared to when the pilot was not under pressure, even after excluding HEMS pilots from the analysis. **Conclusion.** Fog poses a significant risk to helicopter operations. Pilots who were reportedly under pressure when encountering fog were more likely to be in an accident, as were pilots who reportedly flew into IMC intentionally. These findings from NTSB investigator impressions suggest that flight accidents under fog conditions are mainly due to decision-making under pressure. Therefore, helicopter pilots should be trained on how to respond to IMC to mitigate the risks involved.

Ramee, C., Speirs, A., Payan, A. P., & Mavris, D. (2021). Analysis of weather-related helicopter accidents and incidents in the United States. *In AIAA Aviation 2021 Forum* (p. 2954). https://doi.org/10.2514/6.2021-2954

Introduction. The purpose of this study was to determine what types of weather cause helicopter incidents. **Methods.** Two hundred and fifty-four weather-related helicopter events between 2008 and 2018 were analyzed from the NTSB aviation database. FAA GA and Part 135 Activity Surveys administered between 2008 and 2018 were used to estimate the number of flight hours by helicopter type and industry (data was not available for 2011). Geographical analysis of event location was also performed. **Results.** Overall, weather was a factor in 28% of fatal helicopter accidents. Weather-related factors (i.e., wind, ceiling visibility, precipitation, light conditions) were more often associated with accidents and incidents that also cited issues with aircraft operations performance and capabilities (68%), task performance (57%), and action/decision (45%). Wind was the most common weather type among incidents but had a low fatality rate (7%). However, the next most common weather types – ceiling/visibility/precipitation and light conditions – had very high fatality rates (62% and 57% respectively). Furthermore, turbulence and convective weather had low frequencies but also high fatality rates (33% and 67% respectively). Incidents and accidents involving wind-related weather involved flights close to the ground and often were related to LOC. The majority of weather conditions that affected flight visibility had a fatality rate greater than 70%. Additional analyses found that weather-related events occurred more frequently in the summer. Moreover, pilots with lower total flight hours had higher counts of weather-related events. Air ambulance operations accounted for the highest proportion of weather events related to visibility conditions (29%) across types of operations. **Conclusion.**

These findings describe general trends in the relationship between weather and helicopter accidents and incidents. While it provides some information about different types of operations, including HAA, most of the findings relate to non-operationally specific trends in helicopter events. Future research should improve awareness of weather conditions and training to maintain control of the aircraft in windy conditions or poor visibility conditions.

Speirs, A., Ramée, C., Payan, A. P., Mavris, D., & Feigh, K. M. (2021). Impact of adverse weather on commercial helicopter pilot decision-making and standard operating procedures. In *AIAA Aviation 2021 Forum* (p. 2771). https://doi.org/10.2514/6.2021-2771

Introduction. Weather poses a significant challenge for helicopter pilots. Helicopter pilots receive limited weather data in the cockpit and this can be detrimental to their decision-making, and ultimately, their safety; weather is a factor in 28% of fatal helicopter incidents. This study investigated the weather-related challenges faced by helicopter pilots. **Methods.** Two hundred and sixteen helicopter professionals (22 helicopter pilots; 70% with HAA experience) completed a survey about their respective demographics (i.e., crew experience), flight environment (i.e., weather conditions), and safety operations (i.e., equipment / technologies). Nine of the surveyed pilots (three each from the HAA, air tour / air taxi, and law enforcement industries) were interviewed using the Applied Cognitive Task Analysis (ACTA) that consists of (a) a surface-level interview and task diagram depicting the operation's Standard Operating Procedures (SOP); (b) an overview of weather-related events encountered by the pilot; and (c) a "knowledge audit" reviewing the in-flight competencies of the pilots during adverse weather conditions.[14] Interviews were audio recorded, transcribed, and reviewed for accuracy and common themes of interest. **Results.** The majority of pilots reported using digital tools and graphical displays both before and during the flight, such as the HEMS weather tool[15] and the Flight Risk Assessment Tool (FRAT). HAA pilots reported having access to panel-mounted displays more than other commercial helicopter pilots and were more likely to report using these displays during weather events. Pilots used fewer weather sources while in-flight than during the pre-flight phase. Pilots who did not view the weather tools available to them as sufficient (29%) also frequently reported on the scarcity of weather stations. Pilots most frequently reported on a lack of weather

[14] Also covered the pilot's opinions on their SOP, how the SOP could be improved to enhance safety, and how they recognize when their missions will deviate from their SOP. (Minotra & Feigh, 2017, 2020).
[15] Originally developed for HEMS operations. See https://www.aviationweather.gov/hemst for more information.

information, sparsity of weather sensing, reliance on local weather knowledge or past experience, impact of current technology on safety, external pressures on weather-related decision-making, and distrust of weather information. **Conclusion.** Overall, pilots view the tools at their disposal as sufficient for safe operations. However, many difficult aspects of using and interpreting weather information were identified, suggesting that there is room for improvement.

Training

Abrahamsen, H. B., Sollid, S. J., Öhlund, L. S., Røislien, J., & Bondevik, G. T. (2015). Simulation-based training and assessment of non-technical skills in the Norwegian helicopter emergency medical services: A cross-sectional survey. *Emergency Medicine Journal*, *32*(8), 647-653. http://doi.org/10.1136/emermed-2014-203962

Introduction. Due to the risky nature of HEMS operations, adverse events and injuries while on the job are not uncommon. Non-technical skills (NTS; i.e., cognitive, social, and personal resource skills) may reduce the risk of adverse events and contribute to a safer work environment. The purpose of this study was to assess the level of in-situ stimulation-based training in, and assessment of, NTSs in Norwegian HEMS. **Methods.** Two hundred and seven physicians, non-physician medical HCMs, and pilots working in the civilian Norwegian HEMS completed a questionnaire covering seven NTS categories: situation awareness, decision-making, communication, teamwork, leadership, managing stress, and coping with fatigue. Participants indicated their maximum number of consecutive on-call duty hours. Logistic regression was used to assess differences in simulation-based training and assessment between professions. Fisher's exact test was used to explore the associations among profession, on-call duty hours, and simulation-based training and assessment. **Results.** The majority of HEMS personnel lacked simulation-based training and assessment of their NTSs, with physicians undergoing significantly less training and NTS assessment than pilots and HCMs. HEMS personnel training on how to cope with fatigue was severely limited; 79% of physicians who were on-call for more than 72 consecutive hours did not have training in coping with fatigue and 54% of pilots and HCMs who were on call for more than 3 consecutive days did not have training in coping with fatigue. **Conclusion.** This study compared the frequency of in-situ simulation-based training and assessment in Norwegian HEMS crewmembers by occupation, and suggest that in comparison to pilots and non-physician HCMs, physicians undergo less training and assessment of NTSs. While these results provide information about the number of yearly trainings and assessments of NTSs in this setting, future research is needed to draw conclusions about the quality of the trainings or assessments received.

Bredmose, P. P., Hagemo, J., Østergaard, D., & Sollid, S. (2021a). Combining in-situ simulation and live HEMS mission facilitator observation: A flexible learning concept. *BMC Medical Education*, *21*(1), 1-10. https://doi.org/10.1186/s12909-021-03015-w

Introduction. In-situ simulation training can be useful in HEMS because it fuses together the working environment with simulation technology. However, training sessions are often interrupted by live missions, and this can be detrimental to learning. The purpose of this study was to determine whether observation by the simulation facilitator during live HEMS missions and post-mission debriefing would be a feasible alternative to mission-interrupted simulation training. **Methods.** Three Norwegian HEMS bases with different mission profiles in terms of the number of annual missions, population density, and crew configuration were sampled. Data describing the number and types of interventions (i.e. simulation or live mission observation) were collected over a one-year period beginning in May 2016. Senior HEMS physicians served as the facilitators and developed scenarios depending on each base mission profile. When simulations were interrupted by live missions, facilitators joined the crews on the missions to observe them. Facilitators debriefed crewmembers after both in-situ simulations and live mission observations using the Promoting Excellence and Reflective Learning in Simulation (PEARLS)[16] framework. A questionnaire was administered to facilitators and crewmembers followed by 20-minute interviews performed with physicians, HEMS technical crewmembers and facilitators at the end of the study period to gather more in-depth feedback. **Results.** Of the 78 training sessions attempted, 46 (59%) were conducted as planned, 23 (29%) were not started, and 9 (12%) were converted to observed live missions. The Lørenskog base undertook 43 (55%) attempts to facilitate simulation training. Ål and Ålesund bases undertook 16 (21%) and 19 (24%) attempts to facilitate simulation training, respectively. Both in-situ simulations and live missions received high satisfaction ratings, were seen as having an appropriate duration, and as having included relevant SOPs. Furthermore, crewmembers did not have concerns about exposing skills and competencies after live mission training. However, facilitators considered live mission observation to be more challenging than in-situ observation.

[16] Eppich and Cheng (2015).

Conclusion. This study compared the effectiveness of live-mission observation and debriefing by a simulation facilitator to in-situ simulation training in HEMS. Overall, facilitators and crewmembers perceived the new training concept as valuable and helpful in terms of learning experience and overall satisfaction. Due to the on-call nature of HEMS operations, this study offers a feasible training option for operators that make use of in-situ simulation training. Given the limited scope of this study, research on the long-term learning outcomes that are associated with this type of live training versus in-situ simulation is needed to fully compare the two training types.

Bredmose, P. P., Hagemo, J., Røislien, J., Østergaard, D., & Sollid, S. (2020). In situ simulation training in helicopter emergency medical services: Feasible for on-call crews? *Advances in Simulation*, *5*(1), 1-7. https://doi.org/10.1186/s41077-020-00126-0

Introduction. In-situ simulation-based training can be effective for maintaining the skills and competence of HEMS personnel.[17] The purpose of this study was to explore the particularities of implementing on-site (in-situ) simulation-based training in HEMS. **Methods.** In-situ simulation-based training was conducted at the HEMS base of Oslo University Hospital in Norway over the course of a year (January 2012 to December 2012). Eight patient scenarios were created by the main facilitator in consultation with a physician and based on the mission profile of the base. The training included learning objectives related to technical and NTS. Forty-four individual simulations were carried out by 15 physicians, 12 HCMs, and 15 pilots in total; all but four simulations were conducted by the whole HEMS team (i.e., physician, HCM, and pilot). Training consisted of (a) preparing the scenario for the simulation; (b) scenario completion; (c) clean-up and readying the equipment for the next scenario; and (d) a structured debriefing to highlight any learning points from the simulation. A questionnaire was administered to all team members after the training. They reported on their experience with and attitude towards the training using a 7-point Likert scale (1 = *I strongly agree*, 7 = *I strongly disagree*). The time needed to prepare and carry out the training in each phase[18] was manually recorded by the facilitator. **Results.** The total median time consumption for a simulation training session for the on-call HEMS crew and facilitator was 65 and 75 minutes, respectively. The preparation time for scenarios (facilitator only) was 10 minutes. The time for simulations was 20 minutes, cleaning up after the scenario was 7 minutes, and debriefing was 35 minutes. Crewmembers viewed the training favorably as almost all

[17] Sollid et al. (2019).
[18] This includes the time the facilitator spent preparing the scenario, the time the crew spent performing the actual simulation, time spent cleaning up, and time spent in debrief.

(98.4%) responded with the two most positive categories on the Likert scale. Feedback showed that crews did not see the training as disruptive to on-call work, found it easy to motivate, and found that the organization and time devoted were sufficient. **Conclusion.** This one-year prospective study provides initial support for the feasibility of in-situ simulation-based training at an HEMS base with on-call crews. Crewmembers were positive about their experience with the training. Crewmember involvement in the training was deemed short as did not exceed 65 minutes. However, other factors that influence implementation must be identified before this training concept becomes more widely accepted. While this study provides support for the practical feasibility of in-situ simulation-based training, learning-outcomes and quality of training should be evaluated. See Bredmose et al. (2021b, 2021c) for more information.

Bredmose, P. P., Østergaard, D., & Sollid, S. (2021b). Challenges to the implementation of in situ simulation at HEMS bases: A qualitative study of facilitators' expectations and strategies. *Advances in Simulation*, *6*(1), 1-11. https://doi.org/10.1186/s41077-021-00193-x

Introduction. Simulation-based training is a useful tool for critical care and emergency medicine operations such as HEMS. However, facilitators get little guidance on how to properly implement such training and have low familiarity with their roles. The purpose of this exploratory study was to identify factors that would challenge the implementation of in situ-simulation-based training as well as the solutions to overcome these challenges. **Methods.** In-situ simulation-based training was implemented by physicians acting as facilitators at 11 Norwegian HEMS bases and one SAR base. Facilitators were appointed by the local clinical leads in each base and trained using the EuSim concept.[19] Sixteen HEMS and SAR physicians were recruited for data collection that occurred over three stages. Sixteen facilitators gathered to identify topics that they expected would be challenging and obstructive for the implementation of the training at their HEMS base, as well as their expectations, and use these to create the interview guides (stage 1). Prior to the training, semi-structured group interviews were conducted by senior consultants in anesthesiology with extensive air ambulance experience with these facilitators using an interview guide from stage 1 (stage 2). Seven facilitators partook in these interviews after one year of training (stage 3). Themes were identified from stage 2 and stage 3 interviews separately using Systematic text condensation.[20] **Results.** Seventeen themes were identified in the pre- and post-study-year interviews.

[19] See the EuSim course description for more information (EuSim Group, 2015).
[20] Malterud (2001, 2012).

Among these, pedagogical issues, timing and planning, crew- and faculty members' expectations, and motivation were the most common (i.e., if the training was voluntary and not mandatory it would boost motivation; having more than one facilitator at the base could improve the motivation of the facilitator). Management support, dedicated time for the facilitators to prepare and lead the training, and ongoing development of the facilitator were also common. The remaining themes included expedient factors, barriers, and suggestions for how to overcome these barriers (i.e., excessive workload was considered a barrier that could be overcome by planning less training in busy periods like mid-summer and holidays). Facilitators described increasing levels of motivation and engagement in the crews over the study period, and this was regarded as a positive development. **Conclusion.** Facilitators commented on the anticipated challenges to the implementation of simulated-based training in HEMS pre- and post-one year of training. Pedagogical, motivational, and logistical issues were the most common themes identified after one year of training. Notably, the crews increased their level of motivation over the study period. As motivational factors are essential for the implementation of such programs,[21] this was taken as evidence that simulation-based training is useful in HEMS. Future research could evaluate other objective metrics of operational success to fully support the adoption of in-situ simulation-based training for HEMS operations.

Bredmose, P. P., Røislien, J., Østergaard, D., & Sollid, S. (2021c). National implementation of in situ simulation-based training in helicopter emergency medical services: A multicenter study. *Air Medical Journal*, *40*(4), 205-210. https://doi.org/10.1016/j.amj.2021.04.006

Introduction. Patients in incidents involving the HEMS are often in need of critical care. HCMs must have the right skills, experience, and training to provide this care. Medical simulation-based training is an opportunity for HCMs to brush up on their caregiving skills, however, implementing the training can be logistically challenging. To better understand these challenges, the degree to which facilitators (HEMS physicians) implemented in situ on-call simulation-based training as well as their perceptions towards the training were evaluated. **Methods.** Facilitators at 11 Norwegian HEMS bases (including one SAR base) implemented the simulations. At each base, 1-2 senior HEMS physicians were selected by the lead physician and trained as simulation facilitators. Simulation-based training was conducted by HEMS crews during the daytime on a convenience basis. The total number of sessions or frequency of sessions to be completed was not specified by the researchers. Standard operational procedures were followed, but

[21] Hosny et al. (2017).

facilitators were encouraged to design novel scenarios involving crewmembers (i.e., pilots, physicians, and paramedics). After each attempted simulation, facilitators noted whether the training was completed successfully (simulation and briefing were completed regardless of any interruptions) and evaluated the degree of satisfaction with the simulation on a visual analog scale ranging between 0 mm (completely unsatisfactory) and 100 mm (maximum satisfaction). **Results.** The number of attempted simulations across bases ranged between 1 and 46 (*median* = 17). Sixty-six percent of the attempted simulations across bases were successfully completed. The number of annual missions at each base did not significantly impact the number of simulation attempts and the number of completed simulations. However, the number of attempted simulations was higher on bases containing two, as opposed to one, facilitators. The number of attempted simulations was not impacted by the facilitator's travel distance to work. Training sessions were interrupted on account of acute missions; fatigue and lack of motivation had very little impact on session completion. **Conclusion.** This study provided a retrospective evaluation of the adoption of in-situ simulation-based training in Norwegian HEMS operators over the course of a one-year prospective study (see Bredmose et al., 2020, 2021b). Overall they found that the adoption of the program and the number of attempted simulations was impacted by the number of facilitators available, suggesting that this is a limiting factor for further adoption of this training style. While these results offer a retrospective evaluation of a prospective roll-out of national in-situ simulation training for Norwegian operations, the roll-out of such training in private sector HEMS operators would likely face distinct challenges.

Rasmussen, K., Langdalen, H., Sollid, S. J., Abrahamsen, E. B., Sørskår, L. I. K., Bondevik, G. T., & Abrahamsen, H. B. (2019). Training and assessment of non-technical skills in Norwegian helicopter emergency services: A cross-sectional and longitudinal study. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, *27*(1), 1-10. https://doi.org/10.1186/s13049-018-0583-1

Introduction. HCMs must have the right technical and NTS, experience, and training to deliver safe care to patients. Simulation-based training is an opportunity for crewmembers to develop their NTS. The purpose of this study was to document the level of simulation-based training and assessment of NTS among Norwegian HMS crewmembers following the onset of new training initiatives by the Norwegian Air Ambulance Foundation.[22] **Methods.** A questionnaire was administered to 214 Norwegian HEMS physicians, pilots, and crewmembers at 12 HEMS bases. All groups reported on

[22] Bredmose and Sollid (2015); Martinsen (2015).

the frequency of simulation-based training and assessment of each of the seven generic categories of NTS (situation awareness, decision-making, communication, teamwork, leadership, stress management, and coping with fatigue) at their local base. Responses from 109 crewmembers were retained for analysis.[23] **Results.** Simulation-based training and assessment increased for all but one NTS category (coping with fatigue) since the onset of the new training initiatives. Physicians were assessed significantly more frequently for all but two NTS (managing stress and coping with fatigue) and reported on the most NTS categories compared to pilots and HCMs. There was no significant difference in the frequency of training and assessment between groups. HCMs increased the frequency of training but not the assessment of NTS. Coping with fatigue did not significantly increase for any group. **Conclusion.** The frequency of simulation-based training and assessment of NTS have increased significantly over time in the examined professional groups. Overall, the frequency of assessment was lower than the frequency of training. Despite a lack of homogeneity in the NTSs reported among groups, NTS training and assessment is likely equally important to all groups and should continue to be promoted in HEMS. Further research should additionally assess the quality of training in achieving desired learning outcomes to better understand the impact of increased frequency of trainings.

Other Operational Risk Factors

Aalberg, A. L., Bye, R. J., Kråkenes, T., & Evjemo, T. E. (2020). Perceived pressure to fly predicts whether inland helicopter pilots have experienced accidents or events with high potential. In P. Baraldi, F. Di Maio, & E. Zio (Eds.), *Proceedings of the 30th European Safety and Reliability Conference and the 15th Probabilistic Safety Assessment and Management Conference*. Research Publishing.

Introduction. Accidents are common in the inland helicopter industry. Accident rates have been found to vary according to the type of operation, phase of operation, helicopter type, fatigue, workload, employment conditions, age of pilot and experience (number of flight hours), competence and training, operational support from the company, and size of the company, among other factors. The purpose of this study was to explore which of the aforementioned factors influence the probability of pilots

[23] 49% (*n* = 53) responses were from physicians, 28% (*n* =31) were from HCM and 23% (*n* = 25) were from pilots.

experiencing a situation that leads to an accident or high-potential event. **Methods.** Questionnaire data was adopted for use in this study from previous research that involved 132 pilots in the domestic inland helicopter industry. Pilots self-reported on the conditions of their work. Based on interviews with industry experts, a statistical model was formulated to include the following variables: employment conditions, company size, pilot age, fatigue, pressure to fly, workload/time pressure, experienced event, and training and competence. **Results.** The statistical model explained 23% of the variance in the likelihood of having experienced an event and demonstrated high goodness-of-fit. Pressure to fly was the only significant predictor for the likelihood of experiencing accidents or events with high potential; higher reported pressure to fly was associated with a higher probability of having experienced an event. Fatigue was a significant predictor before pressure to fly was included in the model, partially supporting the finding that higher reported fatigue was associated with a higher probability of having experienced an event. Age was a significant predictor in the model only when pressure to fly was included. **Conclusion.** Among the factors associated with the probability of critical events occurring in inland helicopter operations, pressure to fly was the strongest predictor; it originates from many sources including low economic margins, motivation for accumulating flight hours, contract issues, and employment conditions. The relationship between pressure to fly, fatigue, and the likelihood of having experienced an event warrants further investigation. Results suggest that fatigue and pressure to fly are correlated, impacting the ability to claim cause and effect of the likelihood of having experienced an event.

Aherne, B. B., Zhang, C., Chen, W. S., & Newman, D. G. (2019). Preflight risk assessment for improved safety in helicopter emergency medical service operations. *Aerospace Medicine and Human Performance, 90*(9), 792-799. https://doi.org/10.3357/AMHP.5330.2019

Introduction. The purpose of this study was to develop predictive risk assessment tools from historical accident data to support decision-making processes. **Methods.** NTSB accident data between 1995 and 2013 were analyzed in this study. The dataset consisted of 189 rotorcraft accident reports; there were 32 single-pilot night VFR fatal HEMS accidents due to LOC or CFIT. Relative risk and odds ratios were calculated for (a) nonsurvivable accidents for routes with positive elevation difference compared to those with the same or lower elevation, for all flights, and those within a TDPS range of 0-4°C; and (b) accidents for flight sectors with patients compared to flights with crew only. Logistic regression analyses were performed to develop predictive models for the probability of accident cause, non-survival outcomes, and nonvisual meteorological conditions (non-VMC). **Results.** Logistic regression analyses accurately predicted the likelihood of entering non-VMC in 75% of cases, accident cause in 81% of cases, and sustaining a nonsurvivable accident in 94% of cases. Twenty-six of the 32 fatal accidents were nonsurvivable and 22 were flown by low-DTE pilots. The non-VMC model found that TDPS significantly explained over 18% of the variance in non-VMC outcomes. In the accident cause model, flight composition sector, TDPS, pilot DTE, flight rule capability, and task type explained 55% of the variance for all flights. LOC significantly predicted a nonsurvivable accident explaining over 19% of the variance between nonsurvivable and survivable accidents. In a separate model, positive elevation difference, HEMS DTE, and LOC explained over 74% of the variance in nonsurvivable accidents. **Conclusion.** Results showed that preflight information can predict the likelihood of adverse safety outcomes in a planned HEMS mission. Findings from this study support the use of preflight analysis in safety decision making broadly, though the small sample size in the current study limits the usability of the specific statistical model. Future research with larger samples would be needed to fully understand how the specific variables and risk factors described may predict adverse safety outcomes.

Bauer, H., & Herbig, B. (2019). Occupational stress in helicopter emergency service pilots from 4 European countries. *Air Medical Journal*, *38*(2), 82-94. https://doi.org/10.1016/j.amj.2018.11.011

Introduction. HEMS pilots often work in conditions of extreme pressure. These stressful work conditions combined with insufficient workplace resources could lead to decreased motivation, skill development, emotional irritability, and in some cases, illness,[24] all of which are potential hazards to flight safety. This study examined the effect of work conditions on work performance, work engagement, worker well-being, energy levels, and motivation in HEMS. **Methods.** Questionnaire data from 72 HEMS pilots (24 Western European, 48 Eastern European; M_{Age}= 51.9 years) employed in 2015/2016 were obtained. The questionnaire covered different aspects of work-related demands, stressors, resources, and symptoms of strain. Work conditions were measured by works stressor (i.e., job insecurity, work hours, work-family conflict) and resource (i.e., social support, role clarity, autonomy) variables. Work motivation was measured by the 9-item version Utrecht Work Engagement Scale (UWES-9). Psychological well-being was measured by the World Health Organization 5-item instrument (WHO-5) and energy levels (i.e., lack of fatigue) were measured by the 4-item "Energy/Fatigue" subscale of the WHO quality of life instrument (WHOQOL-100). Data were stratified by the participant's region of

[24] Bakker and Demerouti (2007); Glaser et al. (2015).

origin (Eastern or Western Europe) and age. **Results.** Work stressors were perceived as medium to low stress whereas work engagement, energy, and subjective well-being were perceived as high stress. Eastern European pilots reported less social support, lower autonomy to use their own ideas in their work, and lower levels of explicit supervisor feedback compared to Western European pilots. Eastern European pilots also reported lower levels of work engagement than Western European pilots. These differences were less pronounced between age groups. Work stressors/ resources did not predict work engagement but did significantly predict subjective well-being and energy; pilots with the least favorable ratings of work stressors/resources were at higher risk for ill-being in the form of disturbed mood. **Conclusion.** Many of the work characteristics were rated favorably; work stressors and resources were characterized by low to medium levels, whereas outcomes (i.e., motivation, well-being, and energy) were characterized by high levels. HEMS pilots strongly identify with their work, even more so than the general workforce and airline pilots. However, resources such as support groups should be available to continue promoting safety in HEMS.

Bauer, H., Nowak, D., & Herbig, B. (2018). Aging and cardiometabolic risk in European HEMS pilots: An assessment of occupational old-age limits as a regulatory risk management strategy. *Risk Analysis*, *38*(7), 1332-1347. http://doi.org/10.1111/risa.12951

Introduction. A retrospective cohort study was conducted to determine the validity of the "Age 60 Rule" imposed in aviation. Per this rule, older pilots are prohibited from conducting operations, as they are believed to be at higher risk for cardiovascular events.[25] Cardiometabolic risk marker change rates in HEMS pilots near or above age 60 served to measure overall incapacitation risk. **Methods.** The aeromedical examination records from 66 German, Austrian, Polish, and Czech HEMS pilots employed in 2015-2016 were obtained from the 10-year period prior to their study participation (14.8 average number of examinations per pilot). The following risk markers were assessed: systolic blood pressure (SBP), serum total cholesterol, serum high-density lipoprotein cholesterol, fasting glucose, body mass index (BMI), and Q-wave to T-wave interval (QTc interval). A cardiovascular risk score was computed using the Systematic Coronary Risk Evaluation (SCORE) method to determine the absolute risk of a fatal cardiovascular event in between examinations. Changes in risk marker rates

[25] Note, in the United States, 14 CFR § 121.383 was revised in 2007 to allow for some operations by pilots up to age 65. See the Fair Treatment for Experienced Pilots Act, P.L. 110-135 (Dec. 13, 2007).

were assessed over time.[26] The relationship between age and the risk of fatal cardiovascular events was also assessed. **Results.** SBP did not change significantly over time in younger pilots but increased faster in older pilots. QTc increased with aging and well into the 60s age range. BMI and fasting glucose in older pilots changed at a slower rate than in younger pilots. The lipid profile improved in older pilots but was unchanged in younger pilots. SCORE risk was estimated between 0% and 0.3%;[27] the absolute SCORE risk increased in the older, compared to the younger, HEMS pilots. **Conclusion.** Age-related changes in cardiovascular risk between HEMS pilots and younger pilots were observed, however, these results were estimated with uncertainty. Further, individual differences explained between 41% and 95% of risk marker variability rather than the outcome measures. Overall, the cardiometabolic risk marker profile is not likely worse in older than in younger HEMS pilots. Incapacitation risk should be evaluated on an individual basis, and a one-size-fits-all solution such as the "Age 60 Rule" is likely insufficient.

Bauer, H., Nowak, D., & Herbig, B. (2020). Age, aging and physiological dysregulation in safety–critical work: A retrospective longitudinal study of helicopter emergency medical services pilots. *International Archives of Occupational and Environmental Health*, *93*(3), 301-314. https://doi.org/10.1007/s00420-019-01482-9

Introduction. Mental and physical health is known to decline with age.[28] The purpose of this study was to assess the effect of age on the functional decline of multiple organ systems (i.e., psychological dysregulation) in an occupational context. Professional pilots are thought to maintain better health than age-similar workers and should therefore demonstrate lower rates of psychological dysregulation over time compared to the overall working population. **Methods.** Aeromedical examination records from 41 male German, Austrian, Polish, and Czech Republican HEMS pilots employed in 2015-2016 were obtained from the 10-year period prior to their study participation. The average age ranged from 27.9 to 60.6 years. From these records, 18 biomarkers were identified and served as an index for overall health. The aggregated estimated probabilities for lying outside a predetermined "healthy" or "normal" biomarker range (psychological dysregulation state), as well as the average biomarker change over time (pace of change),

[26] Models were separately fitted for East (Czech Republic, Poland) and West (Austria, Germany) European pilots.
[27] SCORE risk estimates are higher for Eastern European pilots, as they hail from "high-risk" countries.
[28] Farrow and Reynolds (2012); Salthouse (2012).

and were calculated for each participant.[29] The state of psychological dysregulation was evaluated cross-sectionally and pace of change was evaluated longitudinally. **Results.** According to the cross-sectional analysis, psychological dysregulation first increased, then decreased with age. Maximum dysregulation occurred between ages 45 and 50 years. This same negative quadratic effect of age on dysregulation state was observed in the longitudinal analysis. Physiological dysregulation significantly increased over time, however, the pace of change did not differ between participants with a different "average baseline age" (the age at the first available measurement of each biomarker). **Conclusion.** This study analyzed the change rates of health biomarkers over time. Dysregulation first increased with age up until 45-50 years - after which it started to decrease, demonstrating a curvilinear pattern. Also, the pace of change did not depend on the average baseline age. These results are consistent with the "healthy worker survivor" effect[30] and suggest that the particularities of the work (e.g., requiring regular health examinations) influence the health of the workers.

Bryan, C. G. (2014). *An analysis of helicopter EMS accidents using HFACS: 2000-2012* [Master's Thesis, Embry-Riddle Aeronautical University]. https://commons.erau.edu/edt/31/

Introduction. This study examined archival data on HEMS accidents between 2000 and 2012 using the Human Factors Analysis and Classification System (HFACS) taxonomy to inform human error mitigation strategies. The purpose of this study was to associate categories of human error with physical and temporal characteristics present in HEMS accidents. **Methods.** Multiple keyword searches for all helicopter accidents and a list of accident file numbers for the total helicopter air medical accidents in the NTSB database during the time period were merged into a single dataset. Accidents that occurred outside of the United States and those that did not result from a patient needing to or potentially needing to be moved were excluded resulting in a total of 147 accidents to be analyzed. Three graduate-level HF students coded the data and achieved 80% of agreement after two rounds of coding. HEMS accident phase of flight was coded by considering the phase of flight (i.e., Takeoff, Transit, Landing), destination at the time of the accident (i.e., Patient Pick-up, Patient Drop-off, Base of Operations), and type of patient movement (i.e., Retrieval from Accident Site, Inter-hospital Transfer). Accidents were divided into four categories: Investigation Incomplete, Unforeseeable/Unknown, Foreseeable Mechanical Failure, or Human Error. **Results.** Human error underlaid over

[29] Only data from participants who had measurements for at least 15 biomarkers was analyzed. Data was stratified by participant's region of origin (East and West Europe).
[30] Arrighi and Hertz-Picciotto (1994).

two-thirds of the accidents analyzed in this study (101/147, 69%). HEMS accidents occurred more frequently during landing at patient site, transit to a patient, and transit to home base. The most frequently identified HFACS error categories were for unsafe acts (i.e., decision errors, perceptual errors, and skill-based errors) and preconditions in the physical environment. Rotary wing flying hours for pilots involved in human error-related accidents was available for 89 of 101 cases. In 70% of these accidents, pilots had between 2,000 and 6,000 hours of flying experience. Over 60% of accidents that included natural light conditions at the time of the human error accident occurred at night. No significant correlations between HEMS missions and accident density were found. **Conclusion.** Human error is prevalent in HEMS accidents. Training and testing the feasibility of the technology to assist pilots in detecting obstacles during degraded vision conditions are possible strategies to mitigate accidents due to human error.

Chesters, A., Grieve, P. H., & Hodgetts, T. J. (2016). Perceptions and culture of safety among helicopter emergency medical service personnel in the UK. *Emergency Medicine Journal, 33*(11), 801-806. http://dx.doi.org/10.1136/emermed-2015-204959

Introduction. This study assessed HEMS crewmember attitudes and perceptions towards risks involving HEMS operations. **Methods.** One hundred current HEMS crewmembers (*n* = 11 pilots, *n* = 45 doctors, *n* = 43 paramedics, and *n* = 1 other) in the United Kingdom completed a survey by email on risk and safety culture in HEMS operations. **Results.** Overall, 34% of respondents responded "No" to the primary research questions: are "HEMS operations inherently safe?" Respondents with previous experience of a helicopter crash were more likely to respond "No" to that question. Out of a list of factors that could potentially contribute to a crash, participants attributed the most risk to night HEMS operations without the use of NVG, commercial pressure, and mechanical aircraft failure. Participants also rated factors such as the use of single-engine aircraft, IMC, limited pilot experience, human error, and pilots not holding a current instrument rating as factors that were "likely to contribute to a crash." Respondents rated landing at the scene and departing the scene as the riskiest stages of flight. The majority (>70%) of respondents reported regular participation in risk reduction discussions, regular discussion about risks particular to their own base, review and action of internal incident reports, and in-flight emergency rehearsals either in flight or on base. Sixteen respondents said that practices at their base do not fully comply with operational policies and procedures, and seven reported that not all aviation near-misses or minor incidents are reported for further action. Only 27% of respondents had undertaken a dedicated CRM course, and clinical crews overall reported a lack of training in weather minimums for HEMS operations (15%), HEMS aviation exemptions (14%), national aviation regulations (21%), and HEMS landing procedures (8%). **Conclusion.** The results provided insight into perceptions of safety culture and risk among HEMS crewmembers in the United Kingdom. Crewmembers largely perceive HEMS operations as inherently safe and largely report positive aspects of safety culture related to organizational policy and practices. However, a number of operational risk factors were identified by crewmembers that enhance the likelihood of an accident. Additionally, areas for growth related to clinical crew training and overall operator practices were noted and provided.

Cline, P. E. (2018). Human error analysis of helicopter emergency medical services (HEMS) accidents using the human factors analysis and classification system (HFACS). *Journal of Aviation/Aerospace Education & Research, 28*(1). https://doi.org/10.15394/jaaer.2018.1758

Introduction. The purpose of this study was to understand the factors that contribute to HEMS accidents using HFACS. **Methods.** Forty-four HEMS accidents from the NTSB's Aviation Accident Database between 2000 and 2016 were analyzed in this study. Only data from operations within the United States that were conducting HEMS at the time of the accident were used. Of the 44 accidents, 107 independent causal factors were evaluated. HFACS framework was used to classify causal factors of each accident. Each HFACS error or violation category was used only once per accident. **Results.** The majority of the 44 accidents examined were made up of some kind of skill-based error (80%), followed by perceptual errors (52%), supervisory errors (52%), decisional errors (41%), and exceptional violations (16%). Of the 36 skill-based error accidents, 56% resulted in fatalities, and all fatal accidents in this study involved skill-based error. Failure to maintain control (50%) and failure to maintain clearance (33%) made up the majority of causal factors due to skill-based errors. Accidents due to perceptual errors were primarily caused by IMC (30%) and occurred at night (30%). Accidents due to supervisory errors were primarily caused by inadequate operational supervision (57%). Accidents due to decision errors were primarily due to aeronautical decision-making (56%). **Conclusion.** Results suggest that the majority of HEMS accidents were due to skill-based errors and that skill-based errors were associated with fatal accidents.

De Voogt, A., Hohl, C. H., & Kalagher, H. (2021). Fatality and operational specificity of helicopter accidents on the ground. *Aerospace Medicine and Human Performance*, *92*(7), 593-596. https://doi.org/10.3357/AMHP.5801.2021

Introduction. The purpose of this study was to investigate the characteristics of helicopter accidents when they are standing on the ground. **Methods.** One hundred and fifteen helicopter accidents from the NTSB online database that occurred during the 'standing' or grounded phase of flight between 1998 and 2018 were analyzed in this study. **Results.** Standing helicopter accidents made up 115 of 3,291 helicopter accidents identified between 1998 and 2018. Chi-square tests were performed to determine differences between expected and observed frequencies of accident factors. Most helicopter accidents occurred in Alaska ($N = 15$), California ($N = 10$), and Florida ($N = 10$). Accidents in Alaska were off-airport in 13 of 15 cases and were significantly more frequent than in other states combined. However, accidents in Alaska did not include any fatalities. Fatal accidents or serious injuries were less frequent when the aircraft was substantially damaged or destroyed, which may be explained by the occurrence of roll-over accidents where damage to the aircraft is often substantial while serious injury is rare. For all 10 fatal accidents in the dataset, a rotor strike was the cause and 8 of these cases were causally attributed to the victim's actions. High winds and gusts were also causal factors in accidents. **Conclusion.** Results suggest that pilots, passengers, and crewmembers are at risk when they are outside near a standing helicopter while the rotors are still moving. Helicopter manuals should highlight the dangers of wind and gusts specifically when standing, loading/unloading passengers, and during start-up and shut-down procedures.

Gardner, R. W. (2017). *The effects of SMS implementation on safety culture within helicopter emergency medical services* [Master's Thesis, University of North Dakota]. https://commons.und.edu/theses/369/

Introduction. The purpose of this study was to determine whether safety management systems (SMSs), safety culture, or a lack thereof influence the perceptions of HAA operators and crewmembers. **Methods.** Twenty-nine participants completed the survey. Part 135 HAA pilots ($N = 16$), paramedics ($N = 5$), and flight nurses ($N = 8$) responded to questions about their perceived ability to communicate freely, belief that their organization's culture was a Just culture, and the effectiveness of hazard mitigation protocols used in the industry. **Results.** Participants were divided into three groups based on job roles (pilots, paramedics, flight nurses). The only statistical difference between the three groups was in the perception that "crews' decision making is more important to management than the use of technological upgrades." Further comparisons indicated that paramedics more strongly agreed with this statement than flight nurses, but pilots did not differ from either group. Participant's perceptions of their respective operation having a "Just Culture" was compared based on years of experience. Participant's perceptions that their operation has a "Just Culture" were significantly greater for participants with 20 years or more of experience compared to participants with 1-5 and 15-19 years of experience. **Conclusion.** Overall, SMS has been received fairly well among personnel in these HAA operations and there are likely minimal differences in perceptions of safety culture across different HAA job roles.

Gaździńska, A., Jagielski, P., & Gałązowski, R. (2020). Assessment of physical activity of members of the helicopter emergency medical service (HEMS). *Emergency Medical Service*, *6*(2). http://doi.org/10.36740/EmeMS202002103

Introduction. The physical activity of HEMS team members (e.g., paramedics and pilots) was assessed alongside factors responsible for motivating participation in physical activity. **Methods.** One hundred and thirty one HEMS team members (65 paramedics, 66 pilots; age range 27-59 years) from all rescue helicopter bases in Poland participated in this study. A proprietary questionnaire was administered to participants. The questionnaire covered different aspects of physical activity such as the frequency of the activity, the choice of forms of physical activity, motivation for undertaking physical activity, as well as barriers preventing regular activities. Other health factors, such as BMI were measured. **Results.** Body weight did not significantly differ between pilots and paramedics. However, pilots had poorer nutritional health than paramedics. BMI did not significantly differ with age but did differ with the amount of physical activity reported by paramedics; paramedics who exercised three or more times per week were more frequently within normal BMI ranges compared to pilots. Paramedics rated physical exercise more favorably than pilots; pilots held the opinion that physical activity was more for maintaining or improving health than for leisure. **Conclusion.** Physical activity differed between pilots and paramedics, both in terms of perceptions towards physical activity and the amount of physical activity partaken in a given week. The main motive for engaging in physical exercise for pilots was maintaining and improving health (47%), whereas the main motive for paramedics was well-being (63%). Physical activity is not simply limited to improving physical health; it can also improve mental health through reduced stress, both of which are important for HEMS operations.

Greenhaw, R., & Jamali, M. (2021). *Medical helicopter accident review: Causes and contributing factors* (Report No. DOT/FAA/AM-21/19). Federal Aviation Administration, Office of Aerospace Medicine. https://rosap.ntl.bts.gov/view/dot/57283

Introduction. The purpose of this study was to examine differences in EMS and non-EMS helicopter accident rates and trends from fatal and non-fatal accidents and identify contributing factors that result in helicopter accidents. **Methods.** Data were retrieved from the NTSB aviation accident database between 1999 and 2018, including event time, date, location, aircraft type, pilot and crewmembers, light and weather conditions, inspection records, and other parameters. Data were screened for only those cases that occurred in the United States and did not include homemade or military helicopters. The remaining cases were split by EMS helicopters (n = 206 accidents) and non-EMS helicopters (n = 2,832 accidents). The NSTB database includes causal and contributing factors only for events after 2007 involving: (a) Aircraft/Mechanical; (b) Visibility/Darkness; (c) Other Weather; (d) Object/Terrain Encounter; (e) Organizational Compliance; (f) Pilot Decision Making/Judgment; (g) Pilot Experience; (h) Pilot Incapacitation; (i) Pilot Attention/Orientation Issues; and (j) Pilot Flight Preparation. Multivariate logistic regression analyses were performed to evaluate the relationship between outcomes in group membership (EMS helicopters/non-EMS helicopters and fatal/non-fatal EMS helicopter accidents) and predictor variables. **Results.** Overall, EMS and non-EMS helicopter accidents decreased between 1999 and 2018 and fatal accident rates did not differ between EMS and non-EMS helicopter flights. However, the EMS accident percentage was greater than the non-EMS percentage for Pilot Attention/Orientation Issues, Pilot Decision Making/Judgment, and Visibility/Darkness contributing factors. **Conclusion.** Results found that accident and fatal accident rates for both EMS and non-EMS helicopter missions have decreased over time but fatal accidents are higher for EMS helicopter events than for non-EMS helicopter events. In addition, causal and contributing factors were identified. Future research should further examine differences in fatal and non-fatal EMS accidents.

Hinkelbein, J., Schwalbe, M., & Genzwuerker, H. V. (2010). Helicopter emergency medical services accident rates in different international air rescue systems. *Open Access Emergency Medicine*, *2*, 45. https://doi.org/10.2147%2Foaem.s9120

Introduction. Approximately two to four crashes occur each year in Germany's civilian HEMS. Some result in fatal outcomes. HEMS crash rates and fatal crash rates in Germany were compared to the United States and Australia using a time-based approach to determine the safety of the HEMS. **Methods.** Accident rate data between 1970 and 2009 were obtained from a MEDLINE search. Reviews, letters to the editor, case reports, case series, and meta-analyses were reviewed in addition to published studies. Data were reviewed by two specialists in anesthesiology with expertise in air rescue; data rated eligible were binned into 5-year increments for analysis. One-thousand and fifty-three studies were identified in this 40 year span, however, only eleven studies dealt with HEMS accidents on the basis of 10,000 missions or 100,000 flying hours. These eleven studies (seven from the United States, five from Germany, and two from Australia) were retained for analysis. **Results.** In Germany, the crash rate per 10,000 missions was 0.4 and the fatal crash rate per 10,000 missions was 0.04. In the United States, the crash rate per 10,000 missions was 3.05 and the fatal crash rate per 10,000 missions was 2.12. In Australia, the crash rate per 10,000 missions was 0.6 and the fatal crash rate per 10,000 missions was 0.2. There was a fivefold increase in the accident rate in the United States compared to that of Germany and Australia. In Germany, the crash rate per 100,000 flying hours was 10.9 and the fatal crash rate per 100,000 flying hours was between 0.91 and 4.1. In the United States, the crash rate per 100,000 flying hours was between 1.7 and 13.4 and the fatal crash rate per 100,000 flying hours was between 1.61 and 4.7. In Australia, the crash rate per 100,000 flying hours was 4.38 and the fatal crash rate per 100,000 flying hours was 1.46. **Conclusion.** Overall, results found that the United States had higher accident and fatal accident rates in HEMS operations in comparison to German and Australian operations. However, differences/omissions in published data, use of different time frames of HEMS missions, and differences in HEMS systems make direct comparisons between these HEMS systems difficult.

Lunde, A., & Braut, G. S. (2019). Overcommitment: Management in helicopter emergency medical services in Norway. *Air Medical Journal, 38*(3), 168-173. https://doi.org/10.1016/j.amj.2019.03.003

Introduction. The high-risk scenarios that lead to requests for HEMS put responders at risk of overcommitment due to individual and professional drives to save lives. This qualitative focus group study aimed to investigate individual and organizational strategies aimed at preventing overcommitment and associated risks. **Methods.** Nine crews made up of 30 total crewmembers (10 pilots) participated in focus groups that included a short background presentation followed by a moderated discussion that thematically covered (a) associations with the concept of overcommitment; (b) recognition and sharing of operational cues; (c) causal factors in overcommitment; (d) preventative factors in overcommitment; and (e) overcommitment and learning. **Results**. Analysis of focus group data identified keywords associated with the prevention of overcommitment in hazardous situations including *Anticipation, Contingency Planning, Communication, Cue Recognition, Equipment & Sensors, Experience, Risk & Vulnerability Awareness, Quality & Flow of Information, Training & Preparedness, Standard Procedures, and Teamwork Behavior.* Crewmembers noted that early phases of start-up operations may be at risk for overcommitment due to highly motivated but less-trained rescue workers, and they emphasized how experience, teamwork, and communication are key to combatting this behavior. **Conclusion.** This exploratory focus group study identifies a number of tactics identified by HEMS crews to counteract overcommitment. Overall, this study supports an increased focus on inter-organizational CRM-like training to provide a foundation for a team-based approach to adjust the level of commitment in high-stakes HEMS missions. However, the conclusions should be interpreted with the caveat that the ultimate responsibility in accepting or rejecting a flight may differ across international standards, and therefore tactics to prevent overcommitment may need to be adjusted for American HAA settings.

Müller, A., Prohn, M. J., Huster, K. M., Nowak, D., Angerer, P., & Herbig, B. (2014). Pilots' age and incidents in helicopter emergency medical services: a 5-year observational study. *Aviation, Space, and Environmental Medicine*, *85*(5), 522-528. http://doi.org/10.3357/ASEM.3861.2014

Introduction. The purpose of this study was to identify the factors that jeopardize safety in HEMS operations that are so critical to patient care. Age may be one such risk factor; older pilots are believed to be at higher risk than younger pilots for being involved in an incident due to the known decrease of cognitive abilities over time.[31] In particular, this study assessed the association between the age of pilots and incidents in HEMS involving at least one Liability Damage (LD) over a five year period. **Methods.** Incident and person-related data from 257 Austrian and German HEMS pilots (3 female, 254 male; M_{Age} = 44.52 years [2007] and 46.57 years [2011]) active between 2007 and 2011 was obtained. Incidents were operationalized as the number of claims made on an LD for an individual over this five year period. Data was supplemented in each incomplete year by multiplying the average number of LD by the number of months where the data was not obtained. Missing LD data was imputed via multiple imputation[32]. **Results.** One-thousand seven-hundred and seventy LDs were observed that involved property damage or person-related injuries. There were approximately 4 LDs per 1,000 operations making the overall risk of being involved in one LD during an operation low. The number of LD increased over time; this general trend was observed within age groups. There was no significant effect of age on LD; however, there was a significant effect of age on the change patterns of LD over time. Older and younger pilots displayed different growth curves on LD over time, with younger pilots showing greater increases in LDs over time. **Conclusion.** Results do not support the assumption that the number of incidents increases

[31] Hardy and Parasuraman (1997); Stone (1993).

[32] Pilots with missing LD data were significantly younger and had less flight experience than pilots with complete data. Therefore, the data was not missing at random and was supplemented using 20 different simulated data sets. Multiple imputation has been shown to produce unbiased parameter estimates for missing data (Schafer & Graham, 2002).

with age. Rather, the results support the hypothesis that the development of LD patterns changes with age; there were age-differences in the change rate of LD over time. Instead, LD increased at a faster rate in younger rather than older pilots, suggesting that over time older pilots were involved in less errors than younger pilots.

Rikken, Q. G., Mikdad, S., Mota, M. T. C., De Leeuw, M. A., Schober, P., Schwarte, L. A., & Giannakopoulos, G. F. (2021). Operational experience of the Dutch helicopter emergency medical services (HEMS) during the initial phase of the COVID-19 pandemic: Jeopardy on the prehospital care system? *European Journal of Trauma and Emergency Surgery*, *47*(3), 703-711. https://doi.org/10.1007/s00068-020-01569-w

Introduction. The HEMS and HEMS-ambulance deliver prehospital medical care to severely injured and critically ill patients. The purpose of this study was to assess the effect of the COVID-19[33] pandemic on the incidence of trauma-related injuries and the emergency medical response to these injuries. The incidence, type, and characteristics of Dutch HEMS and HEMS-ambulance "Lifeliner 1"[34] dispatches were compared between the start of the COVID-19 nationwide lockdown orders and on year prior. **Methods.** The Dutch HEMS and HEMS-ambulance dispatches in the "Lifeliner 1" operational area for a two-month period in 2019, and again in 2020, were reviewed for dispatch, operational, patient, injury, and on-site treatment characteristics. The rate of positively tested COVID-19 HEMS personnel and the time that physicians were unable to take a call was also assessed. **Results.** The number of HEMS (helicopter and ambulance) dispatches significantly differed between pandemic and non-pandemic circumstances; HEMS "Lifeliner 1" was requested in 528 cases during the initial phase of the pandemic and in 630 cases one year prior. Of these, 298 (56.4%) of the COVID-19 cases and 314 (50.7%) of cases one year prior were cancelled. Further, the dispatch and cancellation rate differed over time such that week 2 and week 4 rates during the study period were less than the same weeks one year prior. Helicopter dispatches were more frequent than ambulance dispatches during the pandemic. Incident location type (i.e., the number of injuries that occurred at home), mechanisms of injury (e.g., self-inflicted, trauma-related, violence-related), and prehospital interventions (e.g., prehospital incubation, resuscitative efforts) did not differ between pandemic and non-pandemic circumstances. Three out of 13 (23.1%) HEMS personnel tested positive for COVID-19. Physicians who tested positive were unable to take call for 25 days on average. **Conclusion.** The number of HEMS

[33] Coronavirus Disease 2019.
[34] The Dutch ambulance helicopter (Lifeliner 1) services up to 80% of the Dutch population due to its operational location (Giannakopoulos et al., 2010; Giannakopoulos, et al., 2013).

deployments and cancelled missions significantly differed between pandemic and non-pandemic circumstances, with more mission cancellations and fewer deployments in the COVID-19 study period. Incident location type, mechanisms of injury, and prehospital interventions were not found to differ between circumstances. Future efforts should focus on the mental health aspects of the COVID-19 pandemic on HEMS operations.

Strauss, M., Dahmen, J., Hutter, S., Brade, M., & Leischik, R. (2021). Rescue operations lead to increased cardiovascular stress in HEMS crewmembers: A prospective pilot study of a German HEMS cohort. *Journal of Clinical Medicine*, *10*(8), 1602. https://doi.org/10.3390/jcm10081602

Introduction. HEMS operations are high-risk and high-stress, and likely pose a threat to cardiovascular health for these reasons. The purpose of this study was to compare the cardiovascular stress profile of HCMs during rescue operations to the cardiovascular profile during the resting phase between rescue situations (standby time) same-day. **Methods.** Twenty-one HCMs (1 female, 20 male; M_{Age} = 40.6 years, *SD* = 7.7) at a German rescue helicopter base participated in this study. Heart Rate (HR), SBP, and the rate of cardiac events[35] (e.g., arrhythmia, extrasystoles) were assessed in HCMs performing 52 total rescue operations to assess cardiovascular load. Long-term electrocardiography (ECG) was measured continuously over the working day to assess the rate of cardiac events. HR, long-term ECG, and long-term ambulatory blood pressure measurement devices recorded continuously throughout the day. **Results.** All measures were compared to their occurrence in "rescue operation" time compared to "standby" time. This comparison was made using a random-effects linear regression model. SBP increased by 7.4 ± 9.0 mmHg, on average, from standby time to rescue operation time, CI [5.1- 9.7]. Further, blood pressure mean and maximum were significantly higher during rescue operation time. M_{HR} was 13 bpm higher during rescue operation time than on standby time (CI [10.8- 15.3]). Further, maximum HR was 33.7 bpm higher, on average (CI [26.2- 40.8]). The rate of cardiac events was significantly higher during rescue operations than during standby time; the event rate increased from 11 per hour to 16.7 per hour. **Conclusion.** SBP, HR, and rate of cardiac events were higher during rescue missions than during standby time. Thus, rescue operations likely impose a significant load on the cardiovascular system during rescue operations. HCMs should be screened for cardiovascular health prior to participating in rescue operations to prevent cardiovascular events.

[35] Cardiovascular risk scores were computed from the European Society of Cardiology (ESC) risk score and based on a 10-year projection but are not a primary result.

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Note: An asterisk (*) indicates the reference has been annotated in this report.

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