Health-Related Factors Among Pilots in Aviation Accidents

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INTRODUCTION:	Health-related factors can impact aviation safety. This study investigated the published, historical aviation accidents that have been investigated by the U.S. National Transportation Safety Board (NTSB) to understand medical conditions and medication use that have been determined to be causal to mishaps.
METHODS:	A two-part approach was adopted for this study: 1) a scoping review was conducted to provide an overview of the current medical literature addressing medical factors and flight safety; and 2) a comprehensive review of aviation accident reports from the NTSB database from January 2013 to October 2022.
RESULTS:	The literature review demonstrated that psychiatric, cardiovascular, and neurological medications were the major categories of medications reported in fatal aircraft accidents. Age was not found to be a risk factor. Review of the NTSB database demonstrated that, among 15,654 mishaps, medical factors were associated in 703 (4.5%) accidents. NTSB data showed that cardiovascular (1.3%), psychiatric (0.23%), and endocrine diseases (0.17%) were the most commonly reported diseases among pilots. In accident reports, cardiovascular medications (1.49%), sedating antihistamines (0.91%), and alcohol (0.70%) were the most commonly used medications at the time of the accidents.
DISCUSSION:	Health-related factors were a small yet likely underestimated proportion of the factors associated with accidents. Cardiovascular diseases and treatment were the most important factors. It is important to continue to investigate the association between health-related factors and the commission of mishaps.
KEYWORDS:	aviation accidents, health-related factors, aviation safety.

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ealth-related factors can contribute to aviation accidents. Research has shown that while these factors are less common than mechanical failures, they can still significantly impact aviation safety. The U.S. Code of Federal Regulations, Chapter 14, §67 requires the pilot to be examined by an Aviation Medical Examiner (AME) and issued an airman medical certificate to qualify for flight. Additionally, 14 CFR \$61.53 prohibited pilots from carrying out any flying duties when they have or suspect certain medical conditions. The Federal Aviation Administration (FAA) summarized the AME's responsibilities and provided clarifying information within the AME Guide.⁸ This Guide provides information regarding specific treatments and medications that may pose a risk for pilots and how to proceed with the medical treatment and workup to apply for medical recertification. It facilitates the AME's performance of medical duties.

In recent years, the importance of health factors on aviation safety has gained more attention in the aviation industry with notable mental-health-related fatal commercial aircraft accidents (e.g., Germanwings Flight 9525), particularly due to the ongoing pandemic. Despite increased awareness, symptoms or

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medications have continued to be reported as impacting safety. There has been published literature examining health-related factors and their impact on aviation safety. However, further efforts were needed to link the literature to real-world accidents and to establish causality with respect to these factors. To better understand the current situation and promote aviation safety, this study investigated the medical conditions and medication use among pilots who had been determined to be causal to aviation accidents.

METHODS

This study adopted a two-part approach: 1) a scoping review was conducted to provide an overview of the current medical literature, using PubMed and Scopus; and 2) aviation accident reports from the National Transportation Safety Board (NTSB) database were comprehensively reviewed from the period of January 2013 to October 2022.

In the first part of the study, a literature review was conducted to identify all relevant papers on health-related factors in aviation accidents from the inception of each database. Papers discussing health conditions or symptoms in aviation accidents were included. At the same time, those that did not focus on human factors, did not involve aviation traffic, or were not in English were excluded. Potential health-related factors were reviewed and extracted from the papers, and a descriptive overview and comparison were generated from the studies.

In the second part of the study, online reports from January 2013 to October 2022 from the NTSB Monthly List of Aviation Accidents were reviewed. Health-related information, including chronic health conditions reported by the FAA or accident investigators, symptoms before or during flight, medications used by the pilot as reported, and medication levels detected by autopsy after the accidents, was extracted. A descriptive summary of the symptoms, conditions, and medications was compiled.

RESULTS

The study identified 20 eligible medical manuscripts on health-related factors in aviation accidents, ranging from 1968 to 2022 from PubMed and Scopus. There were seven cross-sectional studies, four narratives reviews, four machine learning methodology manuscripts, two retrospective cohort analyses, one case-control study, one legal discussion,¹⁷ one systematic review, and one technical note. These studies discussed health-related information found in aircraft accidents or methods to predict accidents. These results are summarized in **Table I** and the details of the studies are available upon request.

Chronic conditions, such as cardiovascular diseases, neurological conditions, psychological conditions, severe gastrointestinal disorders, young age, hypoxia, and fatigue, were identified in the published medical reports as factors during in-flight incapacitations by Bennett et al,¹ Canfield et al.,³ Froom et al.,⁹ Mohler and Booze,¹⁴ Siegel et al.,¹⁹ and Mason et al.¹³ Coronary artery disease and acute myocardial ischemia were the most frequently identified cardiovascular diseases, and acute myocardial ischemia can result from coronary artery disease or hypoxic conditions.^{2,3} Psychiatric history associated with active psychological conditions, emotions, acute mental shock following adverse life events, and suicides were the most commonly identified psychological conditions. A study reported that severe gastrointestinal disorders accounted for 59% of cases that jeopardized flight safety but were less concerning to investigators because, in the majority of cases, pilots had time to warn other crewmembers. Young age, particularly under 26 yr, was considered a risk factor. Hypoxia was considered a risk factor that might not be related to chronic health conditions (more likely due to environmental factors at altitude). Fatigue of pilots was also considered a risk factor that could impair judgement.

There were three major categories of medications found in fatal aircraft accidents: psychotropic, cardiovascular, and neurological medications.^{3,18} Substances such as alcohol, carbon monoxide, and other toxic gases were also found to be causes of fatal aircraft accidents.^{3,19,20}

The two studies interested in older age of the pilots found that aging was not considered a risk factor in aviation accidents.^{1,10} Studies have shown that pilots between 30–33 yr old have the lowest accident rates, while pilots under 26 yr old have the highest.¹ In general, pilots of older age tend to have lower accident rates compared to younger pilots. However, this may be influenced by the mandatory retirement age of 65 for pilots flying under 14 CFR Part 121 (Commercial Airline Carriers). Other factors such as physical lab results (e.g., liver function, kidney function) and the degree of atherosclerosis found at autopsy were not related to accidents.¹⁶

Pilots lacking knowledge due to a lack of training and inexperience was a major human factor contributing to accidents that occurred more frequently than health-related factors.^{4,11} However, health-related factors were also found to be very important in triggering human errors.^{6,9}

Recently, there have been studies that have explored the use of machine learning techniques to predict aviation accidents by analyzing human factors and other flight conditions.^{12,15,22} These methods allow a computer to learn and identify risk factors without requiring the explicit specification of those factors. In addition, some studies have employed virtual reality simulations of flight tasks and cognitive dysfunction screening to identify potential risks among pilots. These approaches hold promise for improving aviation safety by identifying and mitigating potential risks proactively.

Overall, 15,654 NTSB reports were reviewed from January 2013 to October 2022. The average age of the pilots involved in the accidents was 51.9 yr old and 92.2% were men. There were 703 (4.5%) reported health-related factors the pilots carried at the time of the accidents. The top 10 conditions are listed in **Fig. 1**. Cardiovascular diseases (1.33%) were the top diseases

Table I. Health-Related Factors Involved in Aviation Accidents.

CATEGORY	HEALTH-RELATED OR HUMAN FACTORS	REFERENCES
Chronic condition	Cardiovascular diseases: severe coronary artery disease, acute myocardial ischemia Neurological conditions Psychological conditions: psychiatric history, emotion, acute mental shock following life events, suicides Severe gastrointestinal disorders (considered not concerning)*: appendicitis Young age (<26 yr old) Hypoxia Fatigue	Canfield et al. ³ Bennett ¹ Booze et al. ² Froom et al. ⁹ Mohler et al. ¹⁴ Siegel et al. ¹⁹ Mason et al. ¹³
Medications	Psychotropic medications: alprazolam, amitriptyline, bupropion, buspirone, chlordiazepoxide, citalopram, clomipramine, diazepam, doxepin, fluoxetine, imipramine, lorazepam, mirtazapine, nefazodone, nordiazepam, norfluoxetine, oxazepam, paroxetine, sertraline, temazepam, trazodone, venlafaxine, zolpidem, desalkylflurazepam cardiovascular medications: amlodipine, atenolol, bisoprolol, clonidine, diltiazem, doxazosin, flecainide, labetalol, metoprolol, moricizine, nadolol Neurological medications: carbamazepine, phenytoin	Canfield et al. ³ Sen et al. ¹⁸
Substance	High blood alcohol concentration Carbon monoxide Smoke and toxic substances	Siegel et al. ¹⁹ Mason et al. ¹³ Bennett ¹ Taneja et al. ²⁰
NOT a risk factor	Age (>60) Age (less important than inexperience) Age between 30–33 age is protective. Physical lab results Degrees of atherosclerosis	Huster et al. ¹⁰ Bennett ¹ Weber et al. ²³ Scheinman et al. ¹⁶
Knowledge	Lack of training Inexperience	Karunakaran et al. ⁴ Kelly et al. ¹¹ Bennett ¹
Human error	Human error	Erjavac et al. ⁶ Froom et al. ⁹
Accident detection	Machine learning methodology VR-screening of cognitive function	Wan et al. ²² Perboli et al. ¹⁵ Madeira et al. ¹² Van Benthem et al. ²¹

*Severe gastrointestinal disorders accounted for 59% of the cases, but 3% recognized it as concerning because there was time to warn the other pilot.

presenting among the pilots, while psychiatric (0.23%) and endocrine (0.17%) conditions were the other top three conditions.

The use of medications was not prevalent among pilots with accidents (**Fig. 2**). The most frequently used medications (1.5%) were cardiovascular medications, such as treatments for



Fig. 1. Diseases or conditions presenting at the time of accidents.

hypertension and hyperlipidemia. About 0.9% of pilots were using sedating antihistamines, 0.7% demonstrated evidence of alcohol use, 0.5% were using antidepressants, 0.5% were using opioids, 0.5% were using antipyretics (e.g., NSAIDs and acetaminophen), 0.4% were using psychotropic medications (e.g., alprazolam, ketamine, clonazepam), 0.4% were using cannabinoids (e.g., THC, marijuana, or CBD), and 0.3% were using stimulant substances (i.e., cocaine, amphetamine). Around 0.2% of pilots were using medication for benign prostatic hyperplasia or erectile dysfunction treatments, 0.2% were using sleep aids, and 0.1% were using acid reducers. Other medications, such as decongestants and diabetic medications, were used by fewer than 0.1% of pilots.

DISCUSSION

This study identified significant gaps between the published literature and existing investigatory data on human aviation factors deemed contributory to aviation accidents. The results of our study suggest that while regulations and the FAA provide guidance on aviation safety, the effects and causality of health-related factors could be improved. Our scoping review demonstrated that, while most medical publications reported



Medication Use Among Pilots

Fig. 2. The prevalences of medication use among the pilots at the time of the accidents.

descriptive analysis from case series or study cohorts, very few studies were able to provide evidence on the associations between health-related factors and aviation risks.

Our results suggest that health-related factors presented in a very small proportion of accidents and among total flights. For example, in 2021 FAA air traffic controllers managed 13,028,643 flights and 1646 accidents were reported.⁷ Among all the accidents, there were only 24 (1.5%) accidents (with reports currently finalized within the NTSB database) that report diseases and conditions relevant to this investigation. However, the rate may be underestimated due to the low reporting rate. NTSB captures medications through postmortem tests and rely on pilots' medical information if the accident was not fatal. It was reported that medication uses were far under-reported among pilots. A study by DeJohn et al. found that in fatal aircraft accidents, 66% of the pilots truthfully reported cardiovascular medication use, and only 4% of the pilots reported psychiatric medication.⁵ This suggested that the actual medication use, as well as the prevalence of medical conditions, could be higher than what was discovered by this study. Therefore, the authors call for more efforts in investigation and establishing a reliable reporting and supportive system for pilots and their providers. The system should aim to implement measures to support pilots in the safe use of medications and encourage liberal reporting of medication use and other medical issues. This could directly help to aid not only a culture of safety, but the quality of our data, leading to an improved understanding of related risk.

DeJohn et al. also identified 189 pilots who had fatal aviation accidents were using cardiovascular medications during 2009–2014, while this study reported 234 fatally injured pilots used cardiovascular medication around the time the accidents occurred between 2013–2022.⁵ The difference can be from time variation and improved health statuses among pilots as well as less aviation accidents over the past 10 yr.

Among all the human factors presented, cardiovascular disease in the mishap pilot was the most commonly attributed by accident investigators as being the medical condition felt to be causal to a fatal aircraft accident within the review period. Further studies will, however, be needed to explore the burden of this chronic disease and the overall risk to other pilots and the greater airspace. New evidence is needed to provide information on which specific cardiovascular conditions and what physiological degrees increase risk. The clinical management of these health conditions needs to be studied and pertinent policies regarding best clinical practices need to be established. The study results also provided further directions for the reporting and supportive system regarding how to prepare and allocate the resources for the pilots and their medical providers.

Rapid onset of symptoms or conditions with an unpredictable clinical course (e.g., fatigue or respiratory symptoms, cardiovascular symptoms) may be missed during periodic medical examinations. According to the FAA, pilots are required to report any symptoms to their AMEs that may impair their ability to operate safely.⁸ The AME will then evaluate and judge whether the pilot should continue or avoid their duties. These symptoms could include dizziness, chest pain, or vision impairment. These policy mechanisms ensure that pilots have access to medical advice when necessary and help them maintain their ability to fly safely, preventing potential risks to safety.

This study has several limitations. The literature review was limited to published manuscripts in English. Due to these documents' varied quality and focus, it did not include unpublished reports, white papers, abstracts, or other documentation. Instead, we reviewed the NTSB reports as a more reliable and formal source of information, especially for medication use which was recorded by postmortem test results. As mentioned previously, studies reported that medical conditions were under-reported by pilots, so this study, to certain extent, might underestimate the results by only examining accident data.⁵ However, it is important to understand that certain diseases, such as cardiology and psychiatric, and medications such as sedating antihistamines are the priority to be considered from a policy perspective using the existing knowledge base. Additionally, this study focused on pilots and their health-related factors, although maintenance personnel also play a significant role in flight safety. Human factors such as human errors and knowledge deficiencies can lead to increased stress and fatigue for pilots, increasing the risk of accidents due to aircraft malfunctions.²⁴

In conclusion, this research study found that medical conditions and medication usage had a low rate among pilots involved in aviation accidents. Among these, cardiovascular diseases and related treatments were the pathology that most frequently contributed to accidents. The findings provide valuable insights into the current state of aviation safety and can be used to inform efforts to improve the aviation industry. It is crucial to continue investigating the causal relationships between healthrelated factors and aviation accidents and to mitigate risk at every opportunity.

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