2013–2017 Update to Drug Use Trends in Aviation

Safety Research Report

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National Transportation Safety Board

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Abstract: This safety research report provides updated information regarding trends in the prevalence of over-the-counter, prescription, and illicit drugs identified by toxicology testing of flying pilots who died in aviation accidents during the years 2013 through 2017. The data for this update were obtained from the Federal Aviation Administration (FAA) Civil Aerospace Medical Institute's Forensic Sciences Laboratory toxicology database and the National Transportation Safety Board's (NTSB) aviation accident database. This update did not assess the likelihood of a pilot's impairment in any of the accidents.

Safety issues identified during this research update include (1) the ongoing need for the FAA to publicize—for pilots' use—information about marijuana given its decriminalization in several states and its unchanged classification as an illicit drug per federal law; and (2) the continued need for the FAA to conduct research to assess the relationship between drug use and accident risk.

As a result of this safety research report, the NTSB makes one new recommendation to the FAA. The NTSB also reiterates one recommendation to the FAA and classifies one recommendation to the FAA.

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Executive Summary

Safety Research Topic

This safety research report provides updated information regarding trends in the prevalence of over-the-counter, prescription, and illicit drugs identified by toxicology testing of flying pilots who died in aviation accidents during the years 2013 through 2017. The National Transportation Safety Board's (NTSB) previous study, *Drug Use Trends in Aviation: Assessing the Risk of Pilot Impairment*, was published in 2014 and documented trends in toxicology results between 1990 and 2012. The data for both the first study and this update were obtained from the Federal Aviation Administration (FAA) Civil Aerospace Medical Institute's Forensic Sciences Laboratory toxicology database and the NTSB's aviation accident database.[1] Like the original study, this update did not assess the likelihood of a pilot's impairment in any of the accidents.

Over the 5 years between 2013 and 2017, 1,042 aviation accidents involving US pilots occurred in the United States in which the flying pilot was fatally injured. Of these, 952 pilots (91%) had available toxicology test results. Similar to the last 5 years of the 23-year period examined in the previous study, the average age of the pilots in this update was 56 years.

During the 5 years ending in 2017, 266 (28%) fatally injured pilots tested positive for at least one potentially impairing drug, 144 (15%) pilots tested positive for at least one drug indicating a potentially impairing condition, 94 (10%) pilots' test results indicated evidence of use of at least one controlled substance, and 47 (5%) tested positive for an illicit drug.

Sedating antihistamines continued to be the most common category of potentially impairing drugs found in pilots who died during the report period, with 11.9% testing positive for at least one drug in this category, which increased from 9.9% during the preceding 5 years. Sedating pain relievers, a category that includes opioids, was the second most common category of potentially impairing drugs at 5.3%. Of the 50 pilots who tested positive for sedating pain relievers, 46 were positive for at least one opioid.

Safety Issues

Safety issues identified during this research update include (1) the ongoing need for the FAA to publicize—for pilots' use—information about marijuana given its decriminalization in several states and its unchanged classification as an illicit drug per federal law; and (2) the continued need for the FAA to conduct research to assess the relationship between drug use and accident risk.

[1] An electronic data file containing the publicly releasable accident and toxicology data included in this report can be found in the NTSB Docket Management System, using the NTSB ID DCA19SS222.

Findings

- Over the entire period from 1990 to 2017, increasing trends were identified in the proportions of study pilots testing positive for at least one drug categorized as potentially impairing, used to treat a potentially impairing condition, or as a controlled substance.
- Pilot education regarding appropriate and inappropriate medication choices is increasingly important because of the rising trend of positive test results for potentially impairing drugs.
- The Federal Aviation Administration's November 2019 fact sheet on pilots and medication and over-the-counter medication guidance document provide easy-to-understand information to educate pilots about potentially impairing drugs and make them aware of less impairing alternative drugs.
- Increasing evidence of marijuana use by pilots in this research update indicates a safety hazard that has not been effectively addressed.
- The continuing increase in the prevalence of potentially impairing drug use by fatally injured pilots further supports the need for research to better understand the relationship between drug use and accident risk.

Recommendations

New Recommendation

To the Federal Aviation Administration

Revise the *Aeronautical Information Manual* and the *Pilot's Handbook of Aeronautical Knowledge*, FAA-H-8083-25B, to explicitly state marijuana's classification as an illicit drug per federal law and, thus, its prohibited use by airmen. (A-20-12)

Previously Issued Recommendation Reiterated in This Report

To the Federal Aviation Administration

A-14-95

Conduct a study to assess the prevalence of over-the-counter, prescription, and illicit drug use among flying pilots not involved in accidents, and compare those results with findings from pilots who have died from aviation accidents to assess the safety risks of using those drugs while flying.

Previously Issued Recommendation Reclassified in This Report

To the Federal Aviation Administration

A-14-92

Develop, publicize, and periodically update information to educate pilots about the potentially impairing drugs identified in your toxicology test results of fatally injured pilots, and make pilots aware of less impairing alternative drugs if they are available. [*This recommendation is classified "Closed—Acceptable Action" in section 4.1 of this report.*]

Figures and Table

Acronyms and Abbreviations

CAMI	Civil Aerospace Medical Institute
CFR	*Code of Federal Regulations*
DEA	US Drug Enforcement Administration
DOT	US Department of Transportation
FAA	Federal Aviation Administration
FDA	US Food and Drug Administration
GA	general aviation
GAO	Government Accountability Office
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
OTC	over-the-counter
THC	tetrahydrocannabinol

1 Introduction

This safety research report provides updated information regarding trends in the prevalence of over-the-counter (OTC), prescription, and illicit drugs identified by toxicology testing of flying pilots who died in aviation accidents during the years 2013 through 2017. The National Transportation Safety Board's (NTSB) previous study, *Drug Use Trends in Aviation: Assessing the Risk of Pilot Impairment* was published in 2014 and documented trends in toxicology results between 1990 and 2012 (NTSB 2014). The data for both the first study and this update were obtained from the Federal Aviation Administration (FAA) Civil Aerospace Medical Institute's (CAMI) Forensic Sciences Laboratory toxicology database and the NTSB's aviation accident database. These results demonstrate evidence of the use of drugs, some of which have the potential to cause impairment or are used to treat potentially impairing conditions. Evidence of the use of a drug does not necessarily indicate a pilot was impaired by its use or by an underlying condition. Like the original study, this update did not assess the likelihood of a pilot's impairment in any of these accidents.

For many years, the NTSB has investigated operator impairment in accidents and has issued several recommendations to address the issue in all transportation modes. An early recommendation addressing drug use in aviation was Safety Recommendation A-84-93, which was issued as a result of our investigation of a March 30, 1983, accident, in which two pilots of a nonscheduled cargo airplane died during an attempted landing at Newark Liberty International Airport. Our investigation determined that neither inexperience nor inadequate training could explain the pilots' substandard flying performance and concluded that physiological and psychological factors impaired the flight crew's decision-making and flying abilities (NTSB 1984).[1] Postaccident toxicological tests indicated one pilot had smoked marijuana and the other had taken phenylpropanolamine (an amphetamine-like drug found in decongestants and diet aids available at the time) within the 24 hours before the accident. As a result, the NTSB recommended that the FAA—

> Establish at the Civil Aeromedical Institute the capability to perform state-of-the-art toxicological tests on the blood, urine, and tissue of pilots involved in fatal accidents to determine the levels of both licit and illicit drugs at both therapeutic and abnormal levels. (A-84-93)

In response, the FAA developed the Forensic Sciences Laboratory in Oklahoma City, Oklahoma, and this recommendation was classified "Closed—Acceptable Action" in December 1990. The CAMI Laboratory has since tested biological specimens from fatally injured pilots for a variety of OTC, prescription, and illicit drugs as part of NTSB accident investigations. Along with other medical information, the effects of any toxicology findings on pilot performance are considered as the NTSB determines an accident's probable cause.

[1] The final accident report described the pilots' flying performance as substandard because of their high speed of descent; their unstabilized approach to the airport and runway, during which the airplane bounced after ground contact; and their failure to recover control of the airplane after the bounce.

1.1 Drug Categories and Definitions

Thousands of natural and synthetic chemicals are currently available in a wide variety of herbal, medicinal, or illicit compounds; for the purposes of this update, all of these are considered "drugs."[2] In addition, any reference in this study to "all drugs" means all of the drugs identified by the CAMI's toxicology testing.[3]

Drugs can be categorized in several different ways. For example, many drugs overlap within the categories OTC, prescription, and illicit; identical drugs may be available both OTC and by prescription; and legally available drugs (such as oxycodone or various forms of amphetamine) may be misused for illicit purposes. For some drugs, the US Food and Drug Administration (FDA) requires a warning about risks of impaired performance (such as for operating heavy machinery or driving) or alterations in behavior (such as aggression or hallucinations). In this research update, such drugs are categorized as "potentially impairing."

Because of their potential for abuse, some drugs are categorized as "controlled substances" by the US Drug Enforcement Administration (DEA) and are divided into five schedules. Drugs in Schedules II through V are legally available; examples include opioid pain relievers such as oxycodone and hydrocodone (the active ingredients in drugs marketed with the names Percocet and Vicodin, respectively) and benzodiazepines such as diazepam and alprazolam (drugs marketed with the names Valium and Xanax, respectively).[4] Schedule I controlled substances are considered to have no medical use and are not available legally (such as heroin).[5]

For this research update, drugs in Schedules II through V were categorized as "controlled substances." Most, but not all, controlled substances also carry a warning about driving or operating heavy machinery and, in this update, were also categorized as "potentially impairing." Schedule I and a few Schedule II controlled substances, such as cocaine and amphetamine, that are available for medical use are often misused for illicit purposes and were categorized as "illicit drugs" for the purposes of this update. These drugs were also included in the "potentially impairing" category.

Finally, some drugs are used to treat medical conditions that may affect a person's performance; examples include seizure disorders or serious psychiatric disease. Drugs used to treat such conditions were categorized in this update as indicating a "potentially impairing condition;" they may or may not also be impairing.[6]

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[2] No categories or definitions were changed between the 2014 study and this update.

[3] The FAA's Forensic Sciences Laboratory at CAMI can identify more than 1,300 substances. For more information, see its Forensic Toxicology's WebDrugs database.

[4] *Opioids* are a class of drugs that include opium and other natural and synthetic drugs that mimic its effects. Often called narcotics, most opioids are medications used to treat moderate-to-severe pain, and all have sedating effects. Heroin is an illicit opioid.

[5] According to the DEA, marijuana continues to be categorized as Schedule I although some state and local entities have decriminalized its use.

[6] See appendix A, "Drug and Metabolite Equivalents and Drug Categories," for a complete list of the way each drug was categorized.

1.2 DOT and FAA Efforts to Reduce Pilot Impairment

In addition to CAMI's toxicology testing and aerospace medical research programs, the ongoing efforts of the US Department of Transportation (DOT) and the FAA to reduce pilot impairment risks include (1) establishing fitness for duty regulations and medical certification requirements for pilots, (2) providing drug use information to the physicians who provide medical certificates, and (3) conducting mandatory drug and alcohol testing for safety-sensitive aviation personnel.[7]

All pilots bear a responsibility to fly only when they are fit and to self-restrict from flying when they are aware of a medical condition or are using any drug that may negatively affect their performance. Title 14 *Code of Federal Regulations* (*CFR*) 61.53(a) prohibits a person from acting as pilot-in-command or as a required pilot flight crewmember while that person (1) "knows or has reason to know of any medical condition that would make the person unable to meet the requirements for the medical certificate necessary for the pilot operation" or (2) "is taking medication or receiving other treatment for a medical condition that results in the person being unable to meet the requirements for the medical certificate necessary for the pilot operation." Title 14 *CFR* 91.17 also states, "No person may act or attempt to act as a pilot crewmember of a civil aircraft…[w]hile using any drug that affects the person's faculties in any way contrary to safety."

1.3 NTSB 2014 Study and Recommendations

Based on the results of its 2014 study, the NTSB identified five issue areas for safety improvement: (1) enhancing the precautionary information about potentially impairing drugs and conditions provided to pilots; (2) improving information about active pilots without medical certificates; (3) enhancing communication among prescribers, pharmacists, and patients about the transportation safety risks associated with some drugs and medical conditions; (4) developing and publicizing additional FAA policy regarding marijuana use; and (5) researching the relationship between drug use and accident risk.

The NTSB issued six safety recommendations to address these issue areas: four to the FAA (A-14-92 through A-14-95) and two to the 50 states, the District of Columbia, and the Commonwealth of Puerto Rico (I-14-1 and I-14-2). The safety improvements initially requested in two of these recommendations—A-14-94 and A-14-95—were found to be ongoing issues in the update to the 2014 study and are discussed in the Safety Issues section of this report (see section 4).

The NTSB's 2014 study evaluated the number of pilots with positive toxicology findings by the validity of their medical certificates at the time of the accident. The results revealed that

[7] (a) Pilot medical certification standards and procedures are provided at Title 14 *Code of Federal Regulations* (*CFR*) Part 67, and the requirements for holding a medical certificate and the duration of medical certificates for various flight operations are provided at 14 *CFR* 61.23(b). Title 14 *CFR* 120.1 defines the term safety-sensitive personnel, which includes pilots for Part 121 air carriers and Part 135 commuter and on-demand air carriers, certain air traffic controllers, and maintenance technicians. Testing is performed on urine pre-employment, randomly, and postaccident. DOT-mandated drug testing is limited to identifying urinary metabolites of amphetamine, methamphetamine, cocaine, codeine, morphine, heroin, phencyclidine (PCP), methylenedioxymethamphetamine (MDMA), methylenedioxyamphetamine (MDA), methylenedioxyethylamphetamine (MDEA), tetrahydrocannabinol (THC), oxycodone, oxymorphone, hydrocodone, and hydromorphone.

pilots flying without valid FAA medical certification (including those who were not required to have a medical certificate) were significantly more likely to have evidence of use of potentially impairing drugs, drugs indicating potentially impairing medical conditions, controlled substances, and illicit drugs.[8] The 2014 study also found that the proportion of fatally injured pilots who were flying without a valid medical certificate was increasing. Because the accident risk posed by pilots flying without a medical certificate cannot be accurately determined due to the FAA's lack of data collection for these pilots, the NTSB recommended that the FAA:[9]

> Require pilots who are exempt from medical certification requirements to periodically report to you their status as an active pilot and to provide a summary of recent flight hours. (A-14-93)

On May 1, 2017, an alternative to holding an FAA medical certificate, known as BasicMed, became effective for certain pilots.[10] Under BasicMed, pilots who meet certain criteria (and whose aircraft and flight plans meet certain criteria) may fly for many years after their last FAA medical certificate is no longer officially valid. For a pilot who holds a medical certificate, the length of time it is valid changes based on the class of the certificate, the age of the pilot at the time the certificate is issued, and whether the certificate was issued with a time limitation (special issuance). Because no method has been developed to account for the number of pilots flying without a medical certificate or their flight hours, Safety Recommendation A-14-93 was classified "Closed—Unacceptable Action" in July 2018. Due to the complexity of determining the validity of FAA medical certificates and identifying which pilots had fully met the requirements of BasicMed, this research update did not evaluate toxicology findings based on the status of pilots' medical certification.

To address its finding of an increased number of deceased pilots who had marijuana use identified by toxicology testing, the NTSB recommended that the FAA, "Develop and distribute a clear policy regarding any marijuana use by airmen regardless of the type of flight operation" (A-14-94). In a May 13, 2018, response, the FAA reiterated its position that federal law and the Federal Aviation Regulations adequately addressed this issue, stating that "marijuana is an illicit drug per federal law and its use by airmen is prohibited." However, the NTSB noted that, although this statement was published in the July/August 2017 edition of the *FAA Safety Briefing*, the FAA's efforts to publicize this information to the general aviation (GA) community were insufficient and classified Safety Recommendation A-14-94 "Closed—Unacceptable Action" in July 2018.

To enhance communication among prescribers, pharmacists, and patients about the transportation safety risks associated with some drugs and medical conditions, the NTSB recommended that all 50 states, the District of Columbia, and the Commonwealth of Puerto Rico:

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[8] Federal regulation, 14 *CFR* 61.23b(2), enacted in 2004 allows pilots to fly light sport aircraft without an FAA medical certificate if they have a valid driver's license and their FAA medical certificate has not been suspended, revoked, or denied. See page 26 of the NTSB's 2014 study for the results of the analysis of toxicological findings by medical certificate status.

[9] Traditionally, the FAA has identified "active" pilots as those who maintain a valid medical certificate and, as part of the medical certificate application, collected information on pilots' lifetime and most recent 6 months of civilian flight hours. This data collection provides critical information that helps support the calculation of accident rates among pilots.

[10] For more information, see the FAA's BasicMed webpage.

> Include in all state guidelines regarding prescribing controlled substances for pain a recommendation that health care providers discuss with patients the effect their medical condition and medication use may have on their ability to safely operate a vehicle in any mode of transportation. (I-14-1)
>
> Use existing newsletters or other routine forms of communication with licensed health care providers and pharmacists to highlight the importance of routinely discussing with patients the effect their diagnosed medical conditions or recommended drugs may have on their ability to safely operate a vehicle in any mode of transportation. (I-14-2)

Both of these recommendations have an overall classification of "Open—Acceptable Response." Information about individual responses can be found by searching each recommendation number in the NTSB's Safety Recommendation database.

2 Methodology

2.1 Cases

The methodology for this safety research report was similar to that used for the NTSB's 2014 safety study.[11] Briefly, data from the NTSB's aviation accident database were matched with available testing results from the CAMI toxicology database for all domestic US civil aviation accident investigations between 2013 and 2017 in which the flying pilot died. The combined dataset was used to assess the prevalence and patterns of OTC, prescription, and illicit drugs used among study pilots and compared to the previously reported results.[12]

Since 1990, the FAA's Forensic Sciences Laboratory at CAMI has performed toxicology tests on accident pilots and maintained a database of results. Database records include a unique case number for each person tested, the drug or substance identified, the bodily tissue or fluid tested, the type of test performed, and the quantity measured in the specimen, if appropriate. The CAMI toxicology database also includes pilot and accident details that can be matched to the NTSB aviation accident database records.

Cases were limited to pilots who died as a result of an aviation accident, were identified in the NTSB aviation accident database, and had available test results in the CAMI toxicology database. For accidents involving multi-pilot crews or more than one pilot on board, only the pilot identified in the NTSB aviation accident records as the pilot presumed to be flying the accident aircraft was included in the dataset.[13] Pilot fatalities the NTSB determined to be the result of suicide or similar intentional acts were excluded from analyses.

2.2 Drugs and Metabolites

Drugs can be processed by the body in a variety of ways. Some drugs are changed into different chemicals as a result of body processes; the resulting chemicals are known as metabolites of the original drug. Some metabolites are inactive, but others can have active effects on the body. In addition, active metabolites may be marketed as separate drugs. For example, diazepam (commonly marketed under the brand name Valium) is metabolized into nordiazepam, oxazepam, and temazepam. The latter two metabolites have sedative effects and are marketed as separate drugs with the brand names Serax and Restoril, respectively.

The CAMI Laboratory can identify metabolites for many substances. Positive toxicology results for a drug and its common metabolites do not usually mean the person took multiple drugs. For the purposes of this update, to avoid overcounting the number of drugs identified in a pilot, an equivalence list was developed for metabolites and any duplicates were removed. In addition, if a

[11] For additional detail about the methodology used for this research update, see appendix B, "Expanded Methodology."

[12] The CAMI toxicology database contains personally identifiable information and, therefore, is not publicly available. An electronic data file containing the publicly releasable accident and toxicology data included in this report can be found in the NTSB Docket Management System, using the NTSB ID DCA19SS222.

[13] Analyses were limited to flying pilots to eliminate the possibility of including toxicology findings from pilots who may have been on board the accident aircraft but intentionally not flying the aircraft because of their drug use or medical condition.

specific drug was identified in multiple specimens for a pilot, it was counted as a single positive finding.[14]

This report included toxicology results from pilots' blood and tissue specimens only. Drugs found only in urine were excluded from analyses as they were unlikely to have been causing any effects on the body at the time of an accident.

Interpreting postmortem toxicology results regarding ethanol (the alcohol type found in beer, wine, and liquor) in fatally injured pilots is difficult because ethanol and other alcohols can also be produced by microbial action in body tissues after death. This process is more common in more severely injured tissue or when tissue is exposed to the elements for longer periods of time, and it occurs at different rates in different areas of the body (Kugelberg and Jones 2007). As a result, toxicology results for ethanol and other alcohols were not analyzed in this report.

2.3 Drug Categories

Drugs identified at least once in CAMI's toxicology tests were grouped based on their chemical structure, typical use, or effects into the following categories:[15]

- antidepressants
- anti-infective drugs
- anti-seizure drugs
- benzodiazepines
- blood thinners
- cardiovascular drugs
- cholesterol lowering drugs
- diet aids
- emphysema and asthma drugs
- illicit drugs
- migraine drugs
- nausea and vertigo drugs
- nonsedating over-the-counter drugs
- nonsedating pain relievers
- oral diabetes drugs
- other drugs
- other neurologic drugs
- other psychotropic drugs
- prescription sleep aids
- prostate/erectile dysfunction drugs
- sedating antihistamines
- sedating pain relievers

In addition, each drug was classified as either "potentially impairing" or not. Potentially impairing drugs were defined as those that carry an FDA warning regarding effects associated with

[14] See appendix A, "Drug and Metabolite Equivalents and Drug Categories."

[15] For more information, see appendix C, "Drug Category Definitions."

routine therapeutic use (such as sedation, hallucinations, or behavior changes) that could impair a pilot's judgment, decision-making, or reaction time, or those that carry a warning regarding driving or operating machinery. Illicit drugs were also included as potentially impairing.

The use of certain prescription and OTC drugs suggests the presence of an underlying medical condition that is potentially impairing. This update used a conservative approach to identify the drugs indicating a "potentially impairing condition." Although severe cold or allergy symptoms may be distracting, antihistamines and decongestants were not considered to indicate a potentially impairing condition. However, phenytoin was categorized as being indicative of a potentially impairing condition because it is used primarily to treat epilepsy and trigeminal neuralgia; either of these conditions could be at least intermittently impairing. Other examples of drugs categorized as indicating a potentially impairing condition include psychotropic drugs used to treat psychiatric disease and cardiovascular drugs primarily used to treat arrhythmias, which can cause sudden incapacitation.

Some of the drugs identified in fatally injured pilots were controlled substances, meaning they have been identified by the DEA as having some potential for abuse and their use without a prescription is considered illegal. These are further categorized by the DEA into five schedules based on the degree of potential for abuse and evidence for significant medical use.[16] Schedule I drugs, which include marijuana, are considered to have no medical use and high potential for abuse; they are not available by routine prescription. For the purposes of this update, Schedules II through V drugs, which are routinely available by prescription for medical use, were considered controlled substances. Schedule I drugs were generally categorized as both illicit and potentially impairing but not grouped with prescription Schedules II through V drugs as controlled substances.

There were three exceptions to this general rule. Cases involving amphetamine, methamphetamine, and cocaine were individually evaluated for proper categorization. All three are Schedule II drugs; amphetamine is marketed under the brand names Adderall and Dexedrine as a treatment for attention deficit hyperactivity syndrome and as a weight loss aid. It is also the major metabolite of methamphetamine, another legally available but infrequently prescribed drug marketed under the brand name Desoxyn for the treatment of obesity and attention deficit hyperactivity syndrome. Cocaine is used legally as a liquid numbing agent by dentists and physicians for mouth and nose procedures. If there were positive results for other Schedule I drugs, metabolites or forms of the drug present indicating an illicit source, or higher blood levels of the drug than would be expected for medical use, the findings were categorized as illicit.

For the purposes of this update, a positive toxicology finding meant that a drug was identified in a pilot's blood or tissue. Identified drugs included those that were potentially impairing and those that were not. A positive finding did not necessarily indicate the pilot was impaired or doing anything improper, only that the pilot had used an identifiable drug at some point before the accident.

[16] For more information, see the definitions of controlled substances by schedule provided on the DEA's Diversion Control Division's website.

3 Results

Over the 5 years between 2013 and 2017, there were 1,042 aviation accidents in the United States in which the flying pilot was fatally injured. Of these, 952 pilots (91%) had available toxicology test results. Similar to the last 5 years of the 23-year period examined in the previous study, the average age of the pilots in this research update was 56 years. The distribution by highest pilot certificate is shown in figure 1. Compared with the data from 1990–2012, the percent of pilots who held a sport, recreational, or no pilot certificate in the most recent report period increased by 2% and the corresponding percentage of private pilots decreased by the same 2%. In terms of flight operations, 1 pilot (<1%) was flying under Part 121, 28 pilots (3%) were flying under Part 135, and 924 pilots (97%) were conducting GA operations.

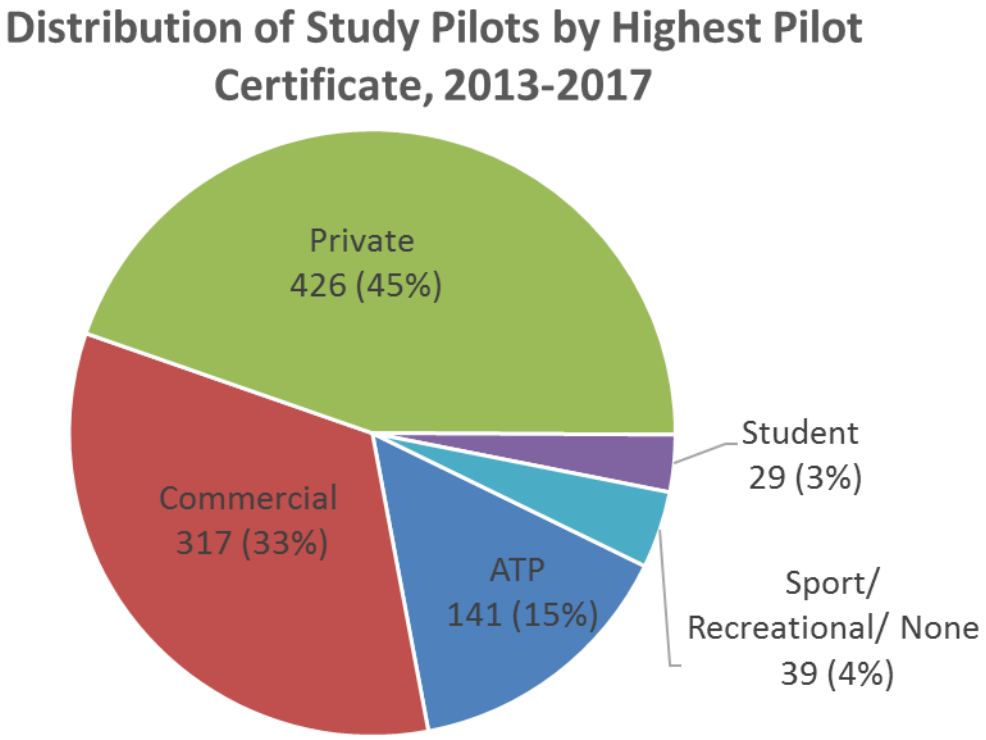

Figure 1. Distribution of study pilots by highest pilot certificate from 2013–2017.

As shown in figure 2, the general trend for overall drug use has continued to increase among fatally injured pilots in the 5 years since the original study period from 1990 to 2012. (The years covered by this report are indicated by thick bold lines in the figure.) In 2017, 48% of these pilots tested positive for at least one substance, and the number of pilots with more than one positive finding decreased. However, data from later years are needed to prove that this decrease indicates a real trend.

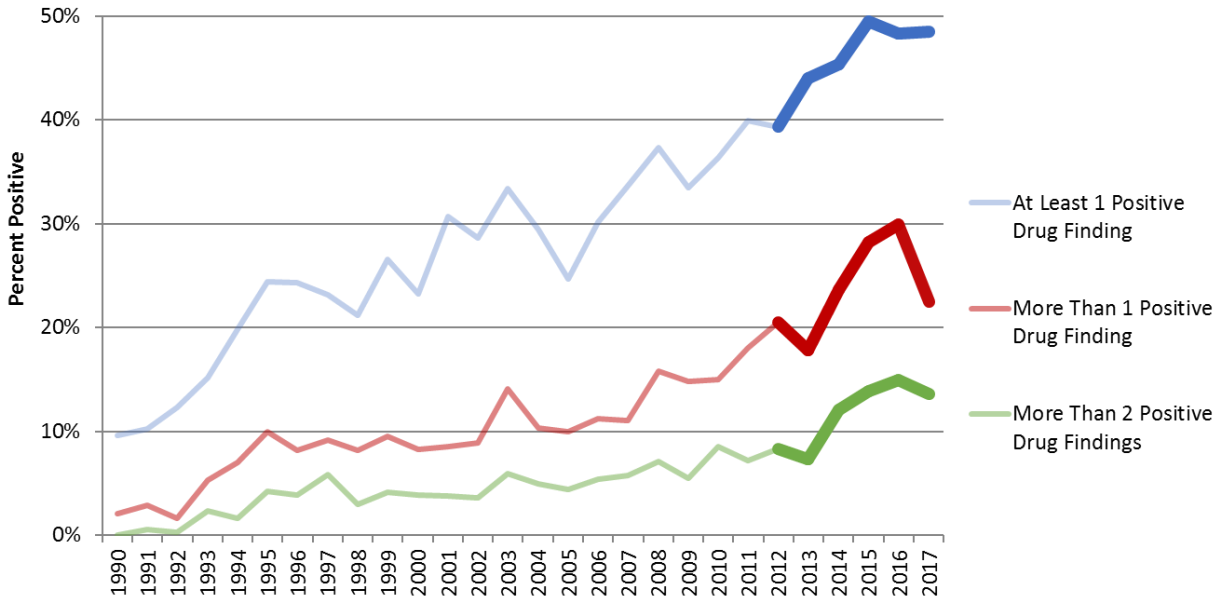

Figure 2. Percentage of study pilots with positive toxicology findings for all drugs, 1990–2017.

Over the period between 2013 and 2017, the FAA's Forensic Sciences Laboratory added the capacity to identify a new parent compound—mitragynine—found in the currently unregulated herbal product kratom.[17] However, this substance was not identified among any of the pilots in this report. No other detection limits changed. As a result, the findings are directly comparable to the preceding 5 years of results.

Figure 3 shows a graphical representation of results indicating potential pilot impairment, with the most recent period highlighted with thick bold lines. As shown in figure 3, during the 5 years from 2013 through 2017, 266 (28%) pilots were positive for at least one potentially impairing drug, 144 (15%) pilots were positive for at least one drug indicating a potentially impairing condition, 94 (10%) pilots had evidence of at least one controlled substance, and 47 (5%) pilots were positive for an illicit drug. In the previous 5 years (2008 through 2012), 3.8% of fatally injured pilots were positive for an illicit drug and 3.0% were positive for marijuana. The NTSB concludes that over the entire period from 1990 to 2017, increasing trends were identified in the proportions of study pilots testing positive for at least one drug categorized as potentially impairing, used to treat a potentially impairing condition, or as a controlled substance.

[17] Dr. Philip Kemp, Manager, Forensic Sciences Laboratory, CAMI, e-mail message to the NTSB Chief Medical Officer, Dr. Mary Pat McKay, April 19, 2019.

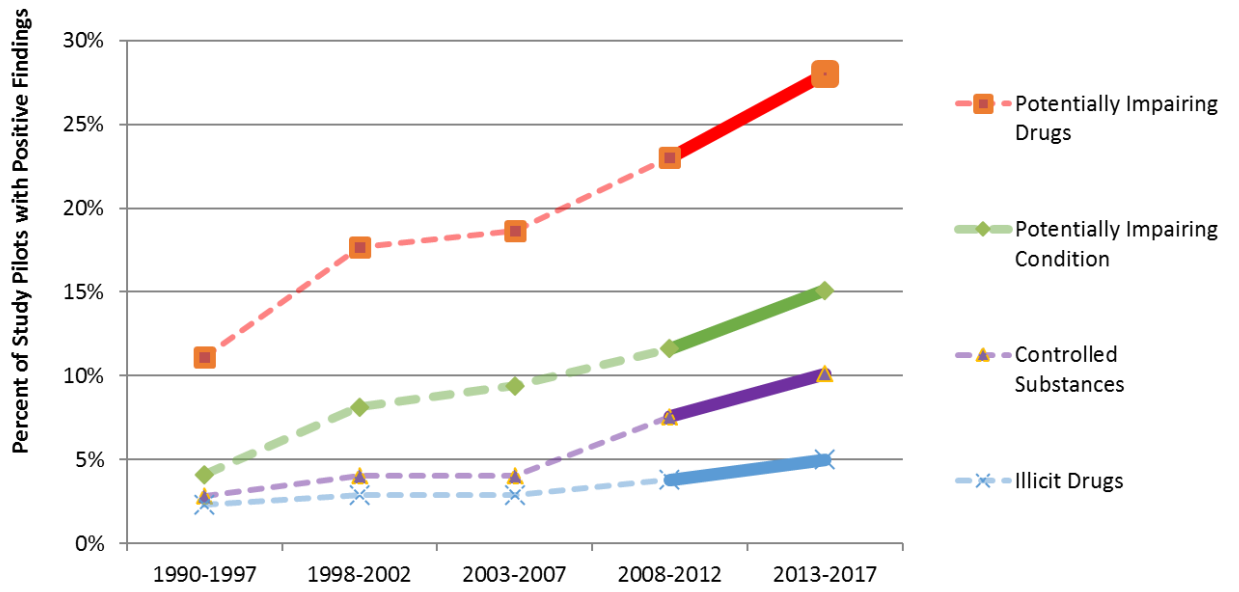

Figure 3. Percentage of study pilots with positive toxicology findings for potentially impairing drugs and conditions, controlled substances, and illicit drugs, 1990–2017.

Tetrahydrocannabinol (THC), the main psychoactive compound in marijuana, or its metabolites were identified in 77% of the 47 fatally injured pilots during the report period who were positive for at least one illicit drug. Cocaine was identified in 15%, and methamphetamine was found in 13% (some pilots had more than one illicit drug identified). Four percent of all the pilots in this report were positive for use of marijuana.

The following table shows the proportion of pilots with at least one positive finding in each drug category. Each row in the table represents the percentage of study pilots with one or more positive toxicology finding in that category for each time period. The categories in the table are rank ordered by the most prevalent over the current period of this report (2013–2017).

Sedating antihistamines continued to be the most common category of potentially impairing drugs found in pilots who died during the study period; the percentage positive for at least one drug in this class was 11.9%, up from 9.9% in the preceding 5 years. Sedating pain relievers, a category that includes opioids, was the second most common category of potentially impairing drugs at 5.3% in the most recent time period. Of the 50 pilots who were positive for sedating pain relievers, 46 were positive for at least one opioid.

The three most common drugs indicating a potentially impairing condition were hydrocodone, a sedating opioid used to treat severe pain; citalopram, an antidepressant; and diazepam, a sedating benzodiazepine used to treat severe anxiety and muscle spasms.

Finally, a comparison of the distribution of accident events for study cases from 2013 through 2017 involving pilots with and without evidence of potentially impairing drugs found no significant difference in distribution of accident types. This finding was the same as that found in the previous study for the period between 2008 and 2012.

Table. Trends in positive findings by drug category.

Drug Category	1990–1997	1998–2002	2003–2007	2008–2012	2013–2017
Cardiovascular drugs	2.4%	4.2%	8.0%	12.4%	18.2%
Sedating antihistamines	5.6%	8.2%	8.3%	9.9%	11.9%
Antidepressants	1.0%	4.5%	5.8%	5.3%	7.1%
Nonsedating OTC drugs	4.6%	6.8%	6.2%	7.3%	7.0%
Cholesterol-lowering drugs	0.1%	0.0%	0.0%	2.0%	6.9%
Sedating pain relievers	1.0%	2.4%	2.6%	4.4%	5.3%
Illicit drugs	2.3%	2.9%	2.9%	3.8%	4.9%
Prostate/erectile dysfunction drugs	0.0%	0.2%	0.8%	1.6%	3.5%
Benzodiazepines	1.3%	1.1%	0.8%	2.0%	3.0%
Nonsedating pain relievers	0.6%	0.1%	2.6%	1.7%	2.6%
Prescription sleep aids	0.0%	0.0%	0.2%	1.5%	2.6%
Other neurologic drugs	0.1%	0.0%	0.4%	0.6%	1.5%
Other psychotropic drugs	0.2%	0.3%	0.7%	0.8%	1.5%
Blood thinners	1.6%	0.5%	0.1%	1.3%	1.4%
Diet aids	1.2%	2.4%	2.0%	1.2%	1.4%
Other drugs	0.2%	1.5%	2.1%	1.9%	1.3%
Anti-seizure drugs	0.7%	0.1%	0.6%	1.0%	1.2%
Oral diabetes drugs	0.0%	0.0%	0.1%	1.0%	0.7%
Anti-infective drugs	0.2%	0.7%	0.5%	0.6%	0.5%
Emphysema and asthma drugs	0.2%	0.2%	0.0%	0.2%	0.3%
Nausea and vertigo drugs	0.2%	0.1%	0.3%	0.3%	0.3%
Migraine drugs	0.3%	0.4%	0.4%	0.3%	0.0%

4 Safety Issues

4.1 Information for Pilots About Potentially Impairing Drugs

The NTSB's 2014 study found that pilots lack access to information about potentially impairing drugs and nonimpairing alternates. As a result, the NTSB recommended that the FAA, "Develop, publicize, and periodically update information to educate pilots about the potentially impairing drugs identified in your toxicology test results of fatally injured pilots, and make pilots aware of less impairing alternative drugs if they are available" (A-14-92). A 2014 report by the Government Accountability Office (GAO) on the FAA's online medical application process indicated comments from experts and pilot groups (including some aviation medical examiners and the Aircraft Owners and Pilots Association) suggesting that the FAA create and make public lists of approved and unapproved drugs (GAO 2014). Similarly, on July 1, 2014, the General Aviation Joint Steering Committee, which includes the FAA and pilot organizations as participants, voted to adopt two new "safety enhancement" efforts that highlight the need to create a database of disqualifying drugs and underlying medical conditions as a reference for pilots and a related education course to inform pilots about the risks of impairment.[18]

Over the subsequent 5 years, the FAA has highlighted its Do Not Issue/Do Not Fly list, which is primarily aimed at aviation medical examiners, and published a "Condition Inspection" in the May/June 2018 *FAA Safety Briefing* that directly addressed sedating antihistamines and available alternates. The NTSB limited the scope of Safety Recommendation A-14-92 to drugs actually found in pilots' toxicology results and has identified in this report a list of potentially impairing drugs and those that indicate potentially impairing conditions (see appendix A). Instead of addressing the entire list of identified medications, in November 2019, the FAA published two new sets of information. The FAA published a fact sheet titled "Pilots and Medication," which was developed as a General Aviation Joint Steering Committee Safety Enhancement (FAA 2019a). The published information provides guidance to pilots for reading and understanding medication labels and explains FAA recommendations regarding how long a pilot should wait after using a potentially impairing drug before flying. The FAA also published a guidance document titled "What Over-the-Counter (OTC) medications can I take and still be safe to fly?" that sorts a number of OTC medications into clear-cut "Go" versus "No-Go" categories (FAA 2019b).

The NTSB concludes that pilot education regarding appropriate and inappropriate medication choices is increasingly important because of the rising trend of positive test results for potentially impairing drugs. The NTSB also concludes that the FAA's November 2019 fact sheet on pilots and medication and OTC medication guidance document provide easy-to-understand information to educate pilots about potentially impairing drugs and make them aware of less impairing alternative drugs. Therefore, the NTSB classifies Safety Recommendation A-14-92 to the FAA "Closed—Acceptable Action."

[18] See the Safety Enhancements website for more information about "Flight After Use of Medication with Sedating Effects," SE-15, and "Medication List for Pilots," SE-30.

4.2 Marijuana Use by Pilots

There is evidence taking illicit drugs significantly elevates the risk of having an aviation accident (Li, Brady, and Chen 2011). Even though the DEA defines marijuana as a Schedule I drug on its controlled substances list, states have taken steps to allow the possession, sale, and use of marijuana within their borders. As of July 2019, 34 states, the District of Columbia, Guam, Puerto Rico, and the US Virgin Islands have approved comprehensive, publicly available medical marijuana/cannabis programs, and 12 additional states allow the use of "low tetrahydrocannabinol (THC), high cannabidiol (CBD)" products for medical reasons in limited situations or as a legal defense (National Conference of State Legislatures 2019b). Ten states and the District of Columbia now have legalized small amounts of marijuana for adult recreational use (National Conference of State Legislatures 2019a).

According to a 2016 review of data from respondents included in the National Survey of Drug Use and Health, adult marijuana use appears to increase among adults over age 26 after states pass medical marijuana laws, with more than 7% of respondents in this age group reporting use in the preceding month (Martins and others 2016). A 2018 literature review suggests that the use rate may be greatest among those age 50 and older (Lloyd and Striley 2018).

The DOT has issued statements clarifying that despite recent legal changes, positive drug tests for marijuana among transportation operators subject to routine preemployment, random, and postaccident testing will not be considered acceptable even with a prescription (DOT 2009; DOT 2014). However, the NTSB notes that, in this update, no pilots with toxicological evidence of marijuana use were engaged in flight operations subject to DOT drug and alcohol testing requirements.

Although the FAA has stated to the NTSB in correspondence concerning Safety Recommendation A-14-94 that "marijuana is an illicit drug per federal law and its use by airmen is prohibited" and published that information in the July/August 2017 edition of the *FAA Safety Briefing*, it is unclear whether this information is generally known or understood among GA pilots. The NTSB concludes that increasing evidence of marijuana use by pilots in this research update indicates a safety hazard that has not been effectively addressed. The NTSB notes that FAA policy and regulation regarding alcohol use is plainly stated in the *Aeronautical Information Manual* and the *Pilot's Handbook of Aeronautical Knowledge*, FAA-H-8083-25B, and that these are logical places for similar information regarding marijuana. Therefore, the NTSB recommends that the FAA revise the *Aeronautical Information Manual* and the *Pilot's Handbook of Aeronautical Knowledge*, FAA-H-8083-25B, to explicitly state marijuana's classification as an illicit drug per federal law and, thus, its prohibited use by airmen.

4.3 Research Needs

The results documented in this report highlight evidence of increasing use of potentially impairing drugs among pilots fatally injured in accidents who were mostly flying GA operations. These results mimic findings in the general US population where accidental poisonings and overdoses of alcohol and other drugs killed 70,237 Americans in 2017, up 9.6% from 2016 (CDC 2018). Opioids were involved in the majority of cases, but benzodiazepines were second (involved in 11,537 of all overdose deaths), most often in combination with opioids (National Institute on Drug Abuse 2019).

Although opioid prescribing across the United States had decreased somewhat since a peak in 2012, almost 58 opioid prescriptions were still written for every 100 Americans in 2017 (CDC 2019). Benzodiazepine prescribing also increased, particularly among primary care physicians (Agarwal and Landon 2019). Among those pilots in this report who tested positive for drugs indicating a potentially impairing condition, an opioid was the most common (hydrocodone) and a benzodiazepine (diazepam) was the third most common.

Of course, drugs being prescribed, used as OTC remedies, or misused for their psychoactive effects not only potentially affect flying safety, but also driving safety. It is very likely that most pilots evaluated in this report, as well as pilots who did not have accidents, drove themselves to the airfield where their flights originated. Fatally injured drivers are not evaluated for drug use as reliably or in a manner as consistent as the fatally injured pilots represented in the dataset for this report.

In fact, in the National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System annual report file for 2017, only 57% of fatally injured drivers were tested for drugs (NHTSA 2017). The tests that were performed varied by state and jurisdiction, including which drugs were tested for, how the test was performed, what type of specimen was tested, and what level of detected drug was considered "positive." Recognizing that improved toxicology testing of drivers involved in fatal and nonfatal accidents will provide needed information regarding drug use by crashing drivers, the NTSB has made many recommendations—most recently, to NHTSA—regarding drug testing.[19]

NHTSA has also performed significant work to evaluate drug use by drivers not involved in crashes. The National Roadside Survey, an evaluation of alcohol and drug use by drivers performed in 2007 and again from 2013 through 2014, obtained specimens from a sample of drivers and tested them for alcohol and a panel of other potentially impairing drugs. Participation was anonymous and voluntary with about 71% of eligible drivers agreeing to participate (NHTSA 2015). Overall, the 2013–2014 survey found 22% of participating drivers were positive for at least one tested-for drug.[20]

As in assessing drug use among drivers, the critical next step in understanding the relationship between drug use and aviation accidents is to compare the prevalence of drug use among fatally injured pilots with the prevalence among active pilots who have not had an accident. Like the NTSB's 2014 study, the results presented in this research update indicate that fatally injured pilots are increasingly showing evidence of having used a wide variety of drugs, which suggests a potentially serious aviation safety problem. However, as with the 2014 study, this update found no reliable relationship between the evidence of drug use and the circumstances of the fatal accidents. Further research may identify increased accident risk associated with some drugs or combinations of drugs, which would support improved guidance or limitations on use of

[19] On November 21, 2012, the NTSB recommended that NHTSA, "Develop and disseminate to appropriate state officials a common standard of practice for drug toxicology testing, including (1) the circumstances under which tests should be conducted, (2) a minimum set of drugs for which to test, and (3) cutoff values for reporting the results (H-12-33). This recommendation is currently classified "Open—Acceptable Response."

[20] For a list of tested-for substances, see page 59 in the report describing the methodology of the National Roadside Survey.

those drugs while flying. Conversely, some drugs believed to be "potentially impairing" may not be correlated with accident risk and concerns about their specific effects may be reduced.

As a result of identifying this research need in 2014, the NTSB recommended that the FAA—

> Conduct a study to assess the prevalence of over-the-counter, prescription, and illicit drug use among flying pilots not involved in accidents, and compare those results with findings from pilots who have died from aviation accidents to assess the safety risks of using those drugs while flying. (A-14-95)

In a May 2018 response, the FAA indicated that it has an approved protocol for conducting the recommended study using de-identified samples collected during routine FAA medical examinations. As a result, this recommendation is currently classified "Open—Acceptable Response," although the study has not yet begun.

The NTSB concludes that the continuing increase in the prevalence of potentially impairing drug use by fatally injured pilots further supports the need for research to better understand the relationship between drug use and accident risk. Therefore, the NTSB reiterates Safety Recommendation A-14-95 to the FAA.

5 Conclusions

5.1 Findings

- Over the entire period from 1990 to 2017, increasing trends were identified in the proportions of study pilots testing positive for at least one drug categorized as potentially impairing, used to treat a potentially impairing condition, or as a controlled substance.
- Pilot education regarding appropriate and inappropriate medication choices is increasingly important because of the rising trend of positive test results for potentially impairing drugs.
- The Federal Aviation Administration's November 2019 fact sheet on pilots and medication and over-the-counter medication guidance document provide easy-to-understand information to educate pilots about potentially impairing drugs and make them aware of less impairing alternative drugs.
- Increasing evidence of marijuana use by pilots in this research update indicates a safety hazard that has not been effectively addressed.
- The continuing increase in the prevalence of potentially impairing drug use by fatally injured pilots further supports the need for research to better understand the relationship between drug use and accident risk.

6 Recommendations

6.1 New Recommendation

To the Federal Aviation Administration

Revise the *Aeronautical Information Manual* and the *Pilot's Handbook of Aeronautical Knowledge*, FAA-H-8083-25B, to explicitly state marijuana's classification as an illicit drug per federal law and, thus, its prohibited use by airmen. (A-20-12)

6.2 Previously Issued Recommendation Reiterated in This Report

To the Federal Aviation Administration

A-14-95

Conduct a study to assess the prevalence of over-the-counter, prescription, and illicit drug use among flying pilots not involved in accidents, and compare those results with findings from pilots who have died from aviation accidents to assess the safety risks of using those drugs while flying.

6.3 Previously Issued Recommendation Reclassified in This Report

To the Federal Aviation Administration

A-14-92

Develop, publicize, and periodically update information to educate pilots about the potentially impairing drugs identified in your toxicology test results of fatally injured pilots, and make pilots aware of less impairing alternative drugs if they are available. [*This recommendation is classified "Closed—Acceptable Action" in section 4.1 of this report.*]

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Report Date: February 13, 2020

Appendixes

Appendix A: Drug and Metabolite Equivalents and Drug Categories

Substance Category	Parent Substance	Common or Brand Name	Potentially Impairing	Impairing Condition	Controlled Substance	Illicit Drug
Antidepressants	Amitriptyline	Vanatrip, Elavil, Endep	*	*		
	Bupropion	Wellbutrin, Chantix	*	*		
	Citalopram	Celexa	*	*		
	Duloxetine	Cymbalta	*	*		
	Fluoxetine	Prozac	*	*		
	Imipramine	Elavil	*	*		
	Mirtazapine	Remeron	*	*		
	Nortriptyline	Pamelor, Aventyl	*	*		
	Paroxetine	Paxil, Brisdelle	*	*		
	Quetiapine	Seroquel	*	*		
	Sertraline	Zoloft	*	*		
	Venlafaxine	Effexor	*	*		
Anti-infective drugs	Fluconazole	Diflucan				
	Trimethoprim	Primsol, Trimpex, Proloprim				
Anti-seizure drugs	Carbamazepine	Carbatrol, Tegretol	*	*		
	Gabapentin	Neurontin	*	*		
	Lamotrigine	Lamictal	*	*		
	Levetiracetam	Keppra	*	*		
	Phenobarbital	Solfoton, Luminal	*	*		
	Primidone	Mysoline	*	*		
Benzodiazepines	Alprazolam	Xanax	*	*	*	
	Chlordiazepoxide	Librium	*	*	*	
	Clonazepam	Klonopin	*	*	*	

Substance Category	Parent Substance	Common or Brand Name	Potentially Impairing	Impairing Condition	Controlled Substance	Illicit Drug
Benzodiazepines (Continued)	Diazepam	Valium	*	*	*	
	Lorazepam	Ativan	*	*	*	
Blood thinners	Clopidogrel	Plavix				
	Ticlopidine	Ticlid				
	Warfarin	Coumadin				
	Atenolol	Tenormin				
	Atropine	Atreza, Sal-Tropine, AtroPen				
	Benazepril	Lotensin				
	Bisoprolol	Zebeta				
	Carvedilol	Coreg				
	Chlorthalidone	Thalitone, Hygroton				
	Clonidine	Catapres, Kapvay				
Cardiovascular drugs	Diltiazem	Cardizem				
	Doxazosin	Cardura, Doxadura, Cascor				
	Enalapril	Vasotec, Epaned				
	Flecainide	Tambocor		*		
	Furosemide	Lasix				
	Hydrochlorothiazide	Aquazide, Hydrodiuril, Microzide				
	Irbesartan	Avapro				
	Labetalol	Normodyne, Trandate				
	Losartan	Cozaar				
	Metoprolol	Lopressor, Metoprolol, Toprol				
	Minoxidil	Loniten (oral), Rogaine (topical)				
	Nadolol	Corgard				
	Nitrate	Monoket		*		
	Propranolol	Inderol				

Substance Category	Parent Substance	Common or Brand Name	Potentially Impairing	Impairing Condition	Controlled Substance	Illicit Drug
Cardiovascular drugs (Continued)	Quinapril	Accupril				
	Quinidine	Quin-G, Cardioquin, Quinora		*		
	Ramipril	Altace				
	Sotalol	Betapace, Sorine				
	Telmisartan	Micardis				
	Torsemide	Demadex		*		
	Triamterene	Dyrenium				
	Valsartan	Diovan				
	Verapamil	Calan SR, Isoptin SR, Verelan				
Cholesterol	Atorvastatin	Lipitor				
	Pravastatin	Pravachol				
	Rosuvastatin	Crestor				
Diet aids	Ephedrine	Bronkaid	*			
	Phentermine	Adipex-P			*	
Emphysema and asthma drugs	Albuterol	Ventolin, ProAir				
	Isoproterenol	Isuprel				
	Montelukast	Singulair				
Illicit drugs	Amphetamine	Amphetamine	*			*
	Cannabinoids	Marijuana	*			*
	Cocaine	Cocaine	*			*
	Methamphetamine	Methamphetamine	*			*
	Methylone	Molly	*			*
Nausea/vertigo	Ondansetron	Zofran		*		
Nonsedating OTC drugs	Dextromethorphan	Cough suppressant				
	Famotidine	Pepcid				
	Fexofenadine	Allegra				
	Guaifenesin	Mucinex				

Substance Category	Parent Substance	Common or Brand Name	Potentially Impairing	Impairing Condition	Controlled Substance	Illicit Drug
Nonsedating OTC drugs (Continued)	Loratadine	Claritin				
	Oxymetazoline	Afrin				
	Pseudoephedrine	Sudafed				
	Ranitidine	Taladine, Zantac				
Nonsedating pain relievers	Acetaminophen	Tylenol, Genapap, Valorin				
	Colchicine	No trade name				
	Diclofenac	Cataflam, Voltaren				
	Flufenamic acid	No trade name				
	Ibuprofen	Advil, Motrin				
	Indomethacin	Indocin				
	Naproxen	Naprosyn				
Oral diabetes drugs	Glipizide	Glucotrol, Glipizide				
	Glyburide	Glynase		*		
	Pioglitazone	Actos				
	Sitagliptin	Januvia		*		
Other drugs	Hydroxychloroquine	Placquenil	*	*		
	Levamisole	Levamisole				
	Naltrexone	Revia, Vivitrol		*		
	Quinine	Qualaquin, Quinamm				
	Tamoxifen	Nolvadex, Soltamox, Tamoxifen				
	Timolol	Depends on use				
Other neurologic drugs	Amphetamine	Adderall	*		*	
	Baclofen	Gablofen, Lioresal	*	*		
	Donepezil	Aricept	*	*		
	Methylphenidate	Ritalin		*	*	
	Pramipexole	Mirapex		*		
Other psychotropic drugs	Buspirone	Buspar, Vanspar	*	*		

Substance Category	Parent Substance	Common or Brand Name	Potentially Impairing	Impairing Condition	Controlled Substance	Illicit Drug
Other psychotropic drugs (Continued)	Clomipramine	Anafranil	*	*		
	Clozapine	Clozaril, FazaClo, Versacloz	*	*		
	Doxepin	Sinequan	*	*		
	Meprobamate	Equanil, Miltown	*	*	*	
	Nordoxepin	metabolite (Sinequan)	*	*		
	Olanzapine	Zyprexa	*	*		
	Trazodone	Oleptro	*	*		
Prescription sleep aids	Zolpidem	Ambien	*		*	
	Zopiclone	Imovane	*		*	
Prostate/erectile dysfunction drugs	Alfuzosin	Uroxatral				
	Sildenafil	metabolite (Viagra)				
	Solifenacin	Vesicare				
	Tadalafil	Adcirca, Cialis				
	Tamsulosin	Flomax				
	Terazosin	Hytrin				
	Vardenafil	Levitra, Staxyn				
	Yohimbine	Erex, Testomar, Yocon				
Sedating antihistamines	Cetirizine	Zyrtec	*			
	Chlorpheniramine	Chlor-Trimeton	*			
	Diphenhydramine	Benadryl, Unisom, Nytol	*			
	Doxylamine	Aldex, Unisom, Nytol	*			
	Hydroxyzine	Atarax, Vistaril	*			
	Pheniramine	Delhist, Theraflu	*			
	Phenylpropanolamine	No longer sold in the US	*			
Sedating pain relievers	Buprenorphine	Buprenex	*	*	*	
	Butalbital	Fiorinal	*	*	*	
	Codeine	(opiate, no trade name)	*	*	*	

Substance Category	Parent Substance	Common or Brand Name	Potentially Impairing	Impairing Condition	Controlled Substance	Illicit Drug
Sedating pain relievers (Continued)	Cyclobenzaprine	Flexeril	*	*	*	
	Hydrocodone	Dilaudid, Vicodin, Lortab	*	*	*	
	Methadone	Methadose, Diskets, Dolophine	*	*	*	
	Morphine	(opiate, no trade name)	*	*	*	

Appendix B: Expanded Methodology

This report updated previous work that explored trends in toxicology results based on drug categories rather than individual drugs. The original methodology addressed a number of nuances in the raw data to ensure that results were comparable among cases, that the drugs identified had been used before the accident, and to prevent overcounting of multiple positive results. Specifically, there were differences in the availability of fluid and tissue specimens per pilot, test results that included both drugs and metabolites of the same drugs, and changes in the availability of drugs over the study period as new drugs became available and some drugs were removed from the market. In addition, there were some cases where the pilot died after receiving medical care and drugs administered during resuscitation efforts were included in postmortem toxicology findings. The following research methodology was developed to simplify the data and ensure that identified drugs were not overcounted.

Specimen Types

Specimens are collected for the CAMI Bioaeronautical Sciences Research Laboratory by the pathologist performing the autopsy for the local medicolegal jurisdiction where the accident occurred. CAMI provides instructions, specimen containers, and shipping instructions that include a chain of custody process. Specimens of multiple types of tissue, blood, urine, bile, and vitreous fluid are requested. However, based on the condition of the remains, not every type of fluid or tissue was available in every case; what was available varied. For this research, positive results were defined as being able to isolate and identify a drug in any specimen other than urine, regardless of the amount identified.

In some cases, the pilot's urine tested positive for a drug or metabolite that was not identified in blood or tissue, which indicates that a longer period of time had elapsed between use of the drug and the toxicology testing than if the drug were also found in blood or tissue. After ingestion, drugs are eliminated from the body in a number of ways, including through the urine. A drug and its metabolites may be detectable for days to weeks in urine but generally disappear more quickly from blood and tissue. A drug that is present in urine but no longer found elsewhere in the body no longer has any potential to impair performance. Thus, urine drug tests may be positive for a long time after any physical or psychological effect from the drug would have disappeared. Although this study did not seek to determine impairment at the time of the accident, drugs found only in the urine after death are not indicative of a pilot's potential for impairment or adverse effects while flying and were therefore excluded from study analyses.

Drugs and Metabolites

In some cases, the CAMI toxicology laboratory tests for the original drug and one or more metabolites of that drug, as well as multiple tissues to verify its findings. The fact that some metabolites are also marketed as separate drugs further complicates the interpretation of positive toxicology findings. For example, diazepam (brand name Valium) is metabolized into three main chemicals: nordiazepam, oxazepam, and temazepam. However, oxazepam is also marketed separately under the brand name Serax, and temazepam is marketed as a standalone drug under the brand name Restoril.

To prevent overcounting the number of drugs identified, an equivalency table was used for this report to equate the original drugs with their identified metabolites, and any duplicates were removed. Individual drugs were then grouped into categories for analysis based on their chemical nature, drug class, typical use, or effects. Therefore, choices to equate active metabolites to a parent drug, such as equating temazepam to diazepam, had little risk of influencing the results (they are both psychoactive benzodiazepines). Duplicate findings resulting from positive findings for a single drug in multiple specimens or through the equating of metabolites were then removed to leave one result for a specific drug in a given pilot.

Ethanol and Its Production in the Body After Death

Ethanol, the specific alcohol found in fermented and distilled liquors, is a social drug that acts as a central nervous system depressant. After ingestion, at low doses, it impairs judgment, psychomotor functioning, and vigilance; at higher doses, alcohol can cause coma and death. Title 14 *CFR* 91.17(a) prohibits any person from acting or attempting to act as a crewmember of a civil aircraft while having 0.040 gm/dL or more alcohol in the blood. The effects of alcohol on pilots are generally well understood; alcohol significantly impairs pilots' performance, even at very low levels (Cook 1997).

Postmortem toxicological testing routinely tests for ethanol. However, ethanol and other alcohols can also be produced by microbial action in postmortem tissues, which may occur at different rates in different areas of the body (Kugelberg and Jones 2007). The possibility of postmortem production complicates the interpretation of ethanol findings and the determination of whether a pilot ingested alcohol before a fatal accident.

Given the complexities of interpreting the results of postmortem ethanol testing and the fact that this research was not designed to determine impairment at the time of an accident, ethanol and other alcohol toxicology results were excluded from further analysis in the original study and this research update.

Postaccident Medical Treatment

In some cases, pilots received medical care before they died. The combined accident and toxicology records were reviewed for all pilots with positive toxicology findings for any drugs that are only available in intravenous forms and are routinely used during resuscitation attempts (such as midazolam, marketed under the brand name Versed, and atropine, marketed under the brand names Sal-Tropine, AtroPen, and Atreza). The associated cases were also reviewed for any additional drugs that may have been used as part of postaccident treatment, and those results were also excluded from study analyses.

Morphine and fentanyl are opioid analgesics that are available in several forms and may be used chronically or acutely during resuscitation attempts. Morphine is an opioid analgesic commonly used intravenously as part of the emergency treatment of acute injury. However, it is also a metabolite of codeine and is available orally in a long-acting preparation (marketed under the brand name MSContin). Codeine, although available in an intravenous formulation, is rarely used that way in the United States; however, the oral forms are common. In addition to treating pain, codeine acts as a cough suppressant and is marketed under brand names such as Tylenol #3 and Robitussin-AC. Thus, when morphine was the only opioid identified on toxicology testing and other drugs indicating postaccident treatment were also identified, the NTSB assumed that the

identified morphine was part of the treatment attempt and removed it from further analysis. However, if it was identified in conjunction with codeine or other codeine metabolites and there was no record of postaccident administration of it or other resuscitation-specific drugs, it was assumed that codeine was taken orally before the accident.

Similarly, fentanyl is an opioid analgesic available in transdermal patches for the treatment of chronic severe pain and is also commonly used in its intravenous formulation in hospitals to treat acutely painful conditions. Each case involving a positive finding for fentanyl was investigated and the NTSB's investigation documentation was reviewed for additional information. In two cases in this report, the pilots' fentanyl was documented to have been from postaccident treatment and was removed from further analysis.

Drug Categorization

In addition to grouping by drug categories, each drug was classified as either "potentially impairing" or not. Potentially impairing drugs were defined as those that carry an FDA warning regarding effects associated with routine therapeutic use (such as sedation, hallucinations, or behavior changes) that could impair a pilot's judgment, decision-making, or reaction time. All illicit drugs were also classified as potentially impairing.

Furthermore, use of some prescription and OTC drugs suggests the presence of a potentially impairing underlying medical condition. A conservative approach was taken to identify the drugs in this category. Although severe cold or allergy symptoms may be distracting, antihistamines and decongestants were not considered to indicate a potentially impairing condition. However, phenytoin was identified in this category because it is used primarily to treat epilepsy and trigeminal neuralgia, and either condition could be at least intermittently impairing. Other examples include opioid pain drugs because they suggest a moderate-to-severe level of pain; psychotropic drugs (such as antidepressants and anxiolytics), which suggest an underlying psychiatric disease; and drugs used to treat migraines, which suggest sudden, intermittent, acute, severe headaches that may occur with neurologic symptoms.

Among the cardiovascular drugs, many drugs used to treat hypertension may also be used to control certain cardiac arrhythmias. Although hypertension alone is unlikely to cause symptoms, an arrhythmia might be acutely impairing. Only those drugs primarily used to treat arrhythmias were included in the "potentially impairing condition" category. Note that these conditions are only potentially impairing; no attempt was made to ascertain anything about the presence, degree, or success in treating any of these conditions, and no attempt was made to ascertain if there was impairment at the time of the accident. Although addiction to or withdrawal from illicit drugs may be impairing, illicit drugs were not categorized in this group.

Some of the drugs identified in study pilots were controlled substances, meaning they have been identified by the DEA as having some potential for abuse, and their use without a prescription is considered illegal. These are further categorized by the DEA into five schedules based on the degree of potential for abuse and evidence for significant medical use.[1] Schedule I drugs are considered to have no medical use and high potential for abuse; they are not available by routine prescription. This category includes drugs such as heroin, ecstasy (methylenedioxymethamphetamine), and marijuana.

[1] For more information, see the definitions of controlled substances by schedule provided on the DEA's Diversion Control Division's website.

For the purposes of this research, Schedule II-V drugs were considered controlled substances. Schedule I drugs were categorized as illicit and potentially impairing but analyzed separately from other prescribed controlled substances.

Special Considerations

Although most drugs and their active metabolites remained in the same categories, methamphetamine, its primary metabolite amphetamine, and their stereoisomers have unique considerations.[2] Methamphetamine is a Schedule II controlled substance but was generally categorized as illicit for this analysis (see below). Amphetamine is a Schedule II controlled substance that can be used to treat neurological conditions and has been used as a diet aid. It is also the primary metabolite of methamphetamine. For the purposes of this research, when pilots had positive findings for both drugs, the amphetamine was equated to methamphetamine and categorized as illicit. Positive findings for amphetamine alone at low levels (without also finding methamphetamine) were categorized as an "other neurologic drug" and as a controlled substance. In two cases, levels of amphetamine were so high as to have been potentially toxic and would not have been achievable with medical use. These were categorized as illicit use.

Cocaine also required special consideration in this research methodology. In a dilute solution, it is a Schedule II drug used as a topical anesthetic on mucous membranes (such as before dental or nasal procedures). As a powder or solid concentrate (rock) it is also commonly used illicitly by injection, inhalation (smoking), or snorting. Like methamphetamine, all positive findings for cocaine were reviewed to determine whether they should be categorized as a controlled substance or illicit drug. When used as a topical anesthetic the amount of cocaine is very small and should not lead to intoxication or impairment. When the use is illicit, doses may be very high. Each case with a positive finding for cocaine or its metabolites was reviewed for the amount found and any other positive findings in blood or tissue. In all cases the use of cocaine was determined to have been illicit.

In many cases, information available from the toxicology testing was used to classify much of the amphetamine and cocaine findings as evidence of illicit use. However, there was no information available regarding whether the use of other controlled substances, such as opioids or benzodiazepines, was medicinal (prescribed and used for a medicinal purpose) or illicit (abused or used for purposes other than prescribed). Therefore, all of the other Schedule II-V drugs were classified as controlled substances.

Finally, it was not possible to compare drugs identified during toxicology tests with drugs the pilot had reported to the FAA. This was because over most of the study period, drug use pilots reported to the FAA was obtained and maintained in paper rather than electronic format. There was also no attempt to assess medical certification actions such as deferrals, denials, or special issuances of certification. This study should not be interpreted as an attempt to retroactively determine or assess the likelihood of pilot impairment in any of the study cases. However, flying under the effects of potentially impairing drugs represents a potential safety hazard, and any increased use of such drugs represents an increased risk of pilot impairment and future accidents.

[2] Chemically, stereoisomers are molecules that have the same molecular formula and sequence of atoms but have different three-dimensional orientations in space.

Appendix C: Drug Category Definitions

Throughout this report, chemical or generic drug names are not capitalized, and drug brand names (that is, the names given by the companies that make the drugs) are capitalized.

Antidepressants are used to treat depression. Examples include Prozac, Zoloft, and Wellbutrin.

Anti-infective drugs are used to treat infections, such as antibiotics, antibacterials, antifungals, antivirals, and antimalarials. Examples include Diflucan and Aralen.

Anti-seizure drugs were initially intended to prevent seizures but are also used to treat nerve pain and psychiatric diseases, such as bipolar disease. Examples include Neurontin, Tegretol, and Topamax.

Benzodiazepines are primarily used to treat anxiety. Examples include Valium, Xanax, and Ativan.

Blood thinners are used to slow or prevent blood from forming clots. Examples include Plavix and Coumadin.

Cardiovascular drugs are used to treat high blood pressure and heart failure or to control heart rhythm. Examples include Lopressor, Norvasc, and Avapro.

Cholesterol-lowering drugs are used to treat high cholesterol. Examples include Lipitor and Crestor.

Diet aids promote weight loss by increasing metabolism or depressing appetite. Examples include Adipex-P and Pondimin.

Emphysema and asthma drugs are used to treat lung diseases and breathing problems. Examples include Singulair and theophylline.

Illicit drugs are Schedule I drugs as defined by the US Drug Enforcement Administration. The drugs, by definition, have no accepted medical use and a high potential for abuse. Their use can lead to psychological or physical dependence. Examples include marijuana, heroin, and ecstasy. In this study, Schedule II drugs cocaine and amphetamine were also defined as illicit when there was evidence that they were used for nonmedical purposes.

Migraine drugs are used to treat moderate-to-severe head or neck pain. Examples include butalbital and Ergomar.

Nausea and vertigo drugs are used to treat an upset stomach or a feeling of dizziness. Examples include Phenergan, Antivert, and cyclizine.

Nonsedating over-the-counter drugs are used to treat allergy, cold, and heartburn symptoms. Examples include Zantac, Pepcid, Robitussin, Claritin, Allegra, and Sudafed.

Nonsedating pain relievers are used to treat pain and reduce fever. Examples include Advil and Naprosyn.

Oral diabetes drugs are used to control blood sugar levels in people with type 2 diabetes. Examples include Glucotrol and Actos.

Other drugs include quinine, which is used to treat leg cramps, and Plaquenil, which is used to treat malaria infections and autoimmune diseases, such as lupus and rheumatoid arthritis.

Other neurologic drugs are used to treat neurologic disorders other than seizures such as Parkinson's disease and attention deficit disorder. Examples include Mirapex, Ritalin, and Adderall.

Other psychotropic drugs are used to treat psychiatric diseases other than depression. Examples include Desyrel, Zyprexa, and Chantix.

Prescription sleep aids are used to treat problems of falling and staying asleep. Examples include Ambien and Imovane.

Prostate/erectile dysfunction drugs are used to treat an enlarged prostate gland, which can cause urinary difficulties, or male sexual problems. Examples include Flomax and Viagra.

Sedating antihistamines are drugs used to treat allergic symptoms and also cause sleepiness. Examples include diphenhydramine, Chlor-Trimeton, and NyQuil.

Sedating pain relievers are prescribed for moderate-to-severe pain. Examples include Vicodin, Percocet, and Flexeril.

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