Drug Use Trends in Aviation: Assessing the Risk of Pilot Impairment

Safety Study

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Abstract: This safety study examined trends in the prevalence of over-the-counter, prescription, and illicit drugs identified by toxicology testing of fatally injured pilots between 1990 and 2012.

Safety issue areas identified during the study include (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 Federal Aviation Administration policy regarding marijuana use; and (5) researching the relationship between drug use and accident risk.

As a result of this safety study, the National Transportation Safety Board makes recommendations to the Federal Aviation Administration and the 50 states, the District of Columbia, and the Commonwealth of Puerto Rico.

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Acronyms and Abbreviations

AME	Aviation Medical Examiner
AOPA	Aircraft Owners and Pilots Association
CAMI	Civil Aerospace Medical Institute
CAST	Commercial Aviation Safety Team
CFR	*Code of Federal Regulations*
CICTT	Common Taxonomy Team
DEA	US Drug Enforcement Administration
DHS	US Department of Homeland Security
DOT	US Department of Transportation
FAA	Federal Aviation Administration
FDA	US Federal Drug Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GAJSC	General Aviation Joint Steering Committee
ICAO	International Civil Aviation Organization
MDA	methylenedioxyamphetamine
MDEA	methylenedioxyethylamphetamine
MDMA	methylenedioxymethamphetamine
NTSB	National Transportation Safety Board
OTC	over-the-counter
PCP	phencyclidine
SAMHSA	Substance Abuse and Mental Health Services Administration

Executive Summary

Why the NTSB Did This Study

The use of over-the-counter (OTC), prescription, and illicit drugs is increasing in the US population. The National Transportation Safety Board (NTSB) is concerned about the possible safety implications of increased drug use in all modes of transportation. Yet, in most modes of transportation, data about drug use by vehicle operators is limited to a small proportion of operators and a short list of drugs. Aviation is the one mode in which the regulatory authority, the Federal Aviation Administration (FAA), routinely conducts extensive postaccident toxicology testing on fatally injured pilots. This study used the results from this testing to assess drug use in aviation. By assessing evidence of fatally injured pilots' drug use prior to flying and the associated potential for impairment, this study addressed a serious aviation safety issue and a growing transportation safety concern.

Purpose and Goals

This study examined trends in the prevalence of OTC, prescription, and illicit drugs identified by toxicology testing of fatally injured pilots between 1990 and 2012. The goals of this study were to describe the prevalence of OTC, prescription, and illicit drug usage among fatally injured pilots over time and evaluate the need for safety improvements related to pilots' use of drugs.

Scope

The study data were from the FAA Civil Aerospace Medical Institute toxicology database and the NTSB aviation accident database. Toxicology tests were used to identify recent use of a wide variety of drugs. Test results were categorized by drug type and potential for causing impairment. This study assessed the prevalence and trends in accident pilots with evidence of recent drug use; it did not reassess the likelihood of pilot impairment in any of these accidents. Due to the complexities of interpreting the source of ethanol identified in the body after death, toxicology results for ethanol and other alcohols were not analyzed in this study.

What the NTSB Found

The majority of pilots in this study were flying in general aviation operations when their fatal accident occurred because relatively fewer fatal accidents involve air carrier operations. Study results showed increasing trends in pilots' use of all drugs, potentially impairing drugs, drugs used to treat potentially impairing conditions, drugs designated as controlled substances, and illicit drugs. The most common potentially impairing drug pilots had used was diphenhydramine, a sedating antihistamine and an active ingredient in many OTC allergy formulations, cold medicines, and sleep aids. Although evidence of illicit drug use was found only in a small number of cases, the percentage of pilots testing positive for marijuana use increased during the study period, mostly in the last 10 years.

Pilots who did not have a medical certificate or whose certificate had expired were more likely than those with a medical certificate to have used potentially impairing drugs, drugs used to treat potentially impairing conditions, and drugs designated as controlled substances. The number of pilots without a current medical certificate has been increasing since 2005, and the trend is likely to continue. However, there has not been an increasing trend in the proportion of accidents for which the NTSB cited impairment from drugs or medical conditions over the study period. Further research is needed to understand the complex relationships among positive toxicology findings, impairment, and accidents. Also, because the FAA does not collect information about the number of pilots flying without a medical certificate, the accident rate of these pilots cannot currently be determined.

Safety Issues

Safety issue areas identified during the study include (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.

Study Significance

This study used the most accurate and comprehensive data available to describe and assess what we currently do and do not know about drug use in aviation, to identify potential safety risks, and to communicate the risks to those who can actively prevent them. However, it represents an early step toward understanding the specific relationships among a drug's effects, the effects of the underlying medical condition, and the risk of a transportation accident over time.

Recommendations

As a result of this safety study, the NTSB makes recommendations to the FAA and the 50 states, the District of Columbia, and the Commonwealth of Puerto Rico.

1 Introduction

This study examined trends in the prevalence of over-the-counter (OTC), prescription, and illicit drugs identified by toxicology testing of pilots who died in aviation accidents between 1990 and 2012. The study data were from the Federal Aviation Administration (FAA) Civil Aerospace Medical Institute (CAMI) toxicology database and the National Transportation Safety Board (NTSB) aviation accident database. This study assessed the prevalence and trends in evidence of recent drug use among pilots who died in aviation accidents; it did not reassess the likelihood of a pilot's impairment in any of these accidents.

1.1 Study Goals

The goals of this study were to describe the prevalence of OTC, prescription, and illicit drug usage among fatally injured pilots over time and evaluate the need for safety improvements related to pilots' use of drugs.

1.2 Pilot Drug Use

For many years, the NTSB has investigated operator impairment in accidents and has issued many recommendations to address the issue in all transportation modes. This study examined the issue of drug use in aviation. In a March 30, 1983, aviation accident, two pilots died when a nonscheduled cargo aircraft crashed during a landing attempt at Newark International Airport. 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. The NTSB 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 (NTSB 1984). The NTSB determined that neither inexperience nor inadequate training could explain the pilots' behavior and concluded that physiological and psychological factors, including the use of marijuana and phenylpropanolamine, impaired the flight crew's decision-making and flying abilities.

As a result of its investigation, the NTSB issued the following recommendation to 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) (Closed—Acceptable Action)

In response, the FAA developed the CAMI Bioaeronautical Sciences Research Laboratory in Oklahoma City, Oklahoma. Since 1990, CAMI has tested biological specimens from fatally injured pilots as part of NTSB accident investigations. Specimens are tested for a variety of OTC, prescription, and illicit drugs. NTSB investigators, human performance specialists, and

medical officers review the toxicology test results along with other medical information as part of the accident investigation. The effects of any toxicology findings on pilot performance are considered as the NTSB determines an accident's probable cause. Since 1990, the NTSB has cited pilot impairment due to drugs as a cause or contributing factor in 3.0% and impairment or incapacitation from a medical condition in 1.8% of fatal US civil aviation accidents. The proportion of accidents for which the NTSB cited pilot impairment from drugs or medical conditions has not changed appreciably over the study period.

1.3 Drugs and the Risk of a Transportation Accident

Thousands of natural and synthetic chemicals are currently available in a wide variety of herbal, medicinal, or illicit compounds; for the purposes of this study, all of these are considered "drugs." In this study, "all drugs" refers to all of the drugs identified by the FAA's toxicology testing.[1] Many of these drugs work to treat an illness or medical condition without negatively affecting a person's performance and are generally considered safe to use while flying an aircraft or operating a vehicle.

However, some drugs have the potential to significantly impair the user's level of alertness, judgment, reaction time, or behavior, leading to transportation accidents (Avalos and others 2014; Roth and others 2014; Li, Brady, and Chen 2013). Reducing accidents due to drug-related impairment will require understanding the relationships among a drug's effects, the effects of the underlying medical condition being treated, and the risk of a transportation accident over the period of time after a drug was taken. A full understanding of these complexities would allow the medical and transportation communities to effectively inform individual operators about which drugs they may take, which drugs are prohibited, and the safest timing for each drug's use. This study examines the most extensive data currently available on toxicology findings from fatally injured pilots and, therefore, represents an early step toward understanding the relationships among drug use, underlying medical conditions, and the risk of transportation accidents.

1.4 Drug Categories and Definitions

There are several different ways to categorize drugs. Many drugs overlap within the categories OTC, prescription, and illicit; identical drugs may be available both OTC and by prescription; and legally available drugs may be misused for illicit purposes (such as oxycodone or various forms of amphetamine).

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 study, these drugs are categorized as "potentially impairing."

[1] The FAA's Bioaeronautical Sciences Research Laboratory at CAMI can identify more than 1,300 different chemicals including a wide variety of drugs and their metabolites.

The US Drug Enforcement Administration (DEA) categorizes a subset of drugs as "controlled substances" because of their potential for abuse. These are divided into five Schedules. Drugs in Schedules II-V are legally available; examples include opioid pain relievers such as oxycodone and hydrocodone (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).[2] For this study, these drugs were categorized as "controlled substances." Most, but not all, controlled substances also carry a warning about driving or operating machinery and in this study were also categorized as "potentially impairing."

Schedule I controlled substances are considered to have no medical use and are not available legally (such as heroin).[3] These and a few Schedule II drugs such as cocaine and amphetamine that are available for medical use are often misused and these were categorized as "illicit drugs" for the purposes of this study. 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 as indicating a "potentially impairing condition"; they may or may not also be impairing.[4]

1.5 Societal Trends in Drug Use

Use of OTC, prescription, and illicit drugs is increasing in the US population. One general societal trend is the increasing use of prescription drugs, including the growing number of people in the United States who take multiple drugs. An increasingly obese and aging population, introduction of new drugs, and expanded uses for older drugs may contribute to increased use of commonly prescribed drugs, such as cholesterol lowering drugs, pain relievers, antidepressants, and drugs used to control high blood pressure or diabetes (Express Scripts 2014; Gu and others 2010; Kaiser Family Foundation 2010). There have been similar increasing trends in the use of prescribed controlled substances, such as prescription opioids, which are potentially impairing. Sales of prescription opioids more than tripled between 1999 and 2010 (Frieden 2013).

There has been a generally increasing trend in the societal use of illicit drugs that have no medical use and the nonmedical, illicit use of prescription drugs.[5] A national survey conducted in 2012 by the Substance Abuse and Mental Health Services Administration, US Department of

[2] *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.

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

[4] For a complete list of drugs and their categories in this study, see appendix A, "Drug and Metabolite Equivalents and Drug Categories Applied in this Study."

[5] *Nonmedical use* of prescription drugs means the user was not the person for whom the drug was prescribed or the person is using the drug for an effect other than the reason for which it was prescribed.

Health and Human Services, showed that 23.9 million respondents had used illicit drugs during the month before their interviews, an overall use rate of 9.2% in the US population ages 12–64 (SAMHSA 2013). Marijuana was the most commonly used illicit drug followed by the nonmedical use of prescription drugs, such as opioids and benzodiazepines. The highest illicit drug usage rates were observed in adults ages 18–25, but the trends indicate increasing illicit drug use rates for all age groups surveyed.

1.6 DOT and FAA Efforts to Reduce Accidents Due to 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.[6]

1.6.1 Pilot Medical Requirements

The FAA requires, with some exceptions, pilots to have a medical certificate to exercise the privileges of an airline transport, a commercial, or a private pilot certificate.[7] An FAA authorized Aviation Medical Examiner (AME) must conduct the medical certification process. There are three classes of medical certificates:

- A first-class medical certificate is required to exercise the pilot-in-command privileges of an airline transport pilot certificate. A first-class medical certificate is also required to act as a required flight crewmember in a Title 14 *Code of Federal Regulations* (CFR) Part 121 air carrier operation if the pilot is 60 or older. This medical certificate expires 12 calendar months after the month of issuance if the pilot is under 40 at the time of the medical exam, or 6 calendar months after the month of issuance if the pilot is 40 or older at the time of the medical exam.[8]
- A second-class medical certificate is required to exercise the privileges of a commercial pilot certificate or the second-in-command privileges of an airline transport pilot certificate in a 14 CFR Part 121 air carrier operation. A second-class medical certificate expires 12 calendar months after the month of issuance.[9]

[6] Title 14 *Code of Federal Regulations* (CFR) 120.1 defines the term *safety-sensitive personnel*, which includes pilots for 14 CFR Part 121 air carriers and Part 135 commuter and on-demand air carriers, certain air traffic controllers, and maintenance technicians.

[7] Pilot medical certification standards and procedures are provided at 14 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.

[8] An expired first-class medical certificate remains valid for flight operations requiring second- or third-class medical certificates.

[9] An expired second-class certificate remains valid for flight operations requiring a third-class certificate.

- A third-class medical certificate is required to exercise the privileges of a private, recreational, or student pilot certificate.[10] A third-class medical certificate expires 60 calendar months after the month of issuance for someone under the age of 40 at the time of the medical exam, or 24 calendar months after the month of issuance for someone 40 or older at the time of the medical exam.

Although pilot certificate types and medical certification classes are related, the type of operation a pilot is conducting determines which class of medical certificate is required. For example, a pilot with an airline transport pilot certificate is only required to hold a third-class medical certificate to conduct a personal flight.

Since September 2004, pilots holding a sport pilot certificate or higher may exercise the privileges of the sport pilot certificate by flying a light sport aircraft without an FAA medical certificate as long as they have a valid US driver's license and have not had an FAA medical certificate previously denied, suspended, or revoked.[11] A pilot using a US driver's license to meet the requirements of 14 CFR 61.23(c) must comply with all restrictions and limitations imposed by the pilot's driver's license and any judicial or administrative order applying to the operation of a motor vehicle. Although medical requirements for a driver's license vary by state, they are typically limited to ensuring adequate vision. Common driving restrictions include a daytime only limitation or the use of corrective lenses. Pilots flying a balloon or glider are not required to have a medical certificate or a driver's license.

The FAA identifies 15 conditions as disqualifying for routine medical certification but may provide an alternate means of certification if the condition is controlled.[12] Regardless of their medical certificate status, 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 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."

[10] Student pilots seeking sport pilot privileges in a light sport aircraft may use a valid US driver's license.

[11] Regulations at 14 CFR 61.23(c) explain the circumstances in which pilots may fly without a medical certificate. Pilots holding airline transport, commercial, or private pilot certificates may also fly without a medical certificate if they adhere to the limitations of the sport pilot certificate in light sport aircraft. The definition of light sport aircraft is provided at 14 CFR 1.1.

[12] The 15 disqualifying medical conditions, provided at 14 CFR Part 67, are angina pectoris, bipolar disease, cardiac valve replacement, coronary heart disease, diabetes mellitus requiring medication, unexplained loss of consciousness, epilepsy, heart replacement, myocardial infarction, permanent cardiac pacemaker, severe personality disorder, psychosis, substance abuse, substance dependence, and unexplained loss of control of nervous system function(s).

1.6.2 Information for Pilots and AMEs

Despite the regulatory prohibition in 14 CFR 91.17 against pilots' use of drugs that may adversely affect their performance, the FAA does not publish a list of prohibited or acceptable drugs for use by pilots. The FAA does publish its *Guide for Aviation Medical Examiners: Pharmaceuticals (Therapeutic Medications) Do Not Issue - Do Not Fly* (FAA 2014) identifying certain drugs and medical conditions that require additional review and approval, referred to as a special issuance, for pilots to receive medical certificates. In its guidance for AMEs, the FAA also identifies a list of drug classes as "Do Not Fly" and provides criteria to identify a safe interval between drug use and flight. The majority of these drugs, which include sedating antihistamines and opioid pain relievers, are known to cause drowsiness (FAA 2014). However, this information is written for physicians with the experience and training necessary to interpret the guidance and make medical decisions. The FAA does not provide a similar extensive resource targeted to pilots. Currently, the only comparable resources for pilots are those developed by pilot and industry groups, such as the Aircraft Owners and Pilots Association (AOPA), which provides a drug database for its members with information about drugs that may be acceptable or unacceptable to take when flying.[13]

1.6.3 Federal Drug Testing Rules in Transportation

The DOT and the US Department of Homeland Security (DHS) as well as their modal agencies have extensive regulations for screening personnel in safety-sensitive positions for illicit drug use.[14] The FAA, the Federal Railroad Administration (FRA), the Federal Motor Carrier Safety Administration (FMCSA), the Federal Transit Administration (FTA), the Pipeline and Hazardous Materials Safety Administration, and the US Coast Guard (Coast Guard) require that personnel in safety-sensitive positions within the industries they oversee submit to preemployment, reasonable suspicion, random, return to sensitive duty, and followup drug and alcohol testing (DOT 2014). In addition, there are requirements for testing these personnel following accidents. The mandatory testing in the transportation industry is limited to alcohol, opiates, marijuana, amphetamines, cocaine, and phencyclidine (PCP).[15] The FAA's list of safety-sensitive positions includes pilots flying for 14 CFR Part 121 air carriers and 14 CFR Part 135 commuter air carriers, on-demand air carriers, and commercial air tour operations.

[13] The drug database is available on the AOPA website: http://www.aopa.org/. However, access is limited to members.

[14] At 49 CFR Part 40, the DOT prescribes who must conduct drug and alcohol tests, how the tests must be conducted, and what procedures must be used during testing. The DOT and DHS modal agencies have additional regulations with mode-specific requirements at 14 CFR Part 120 (FAA), 49 CFR Part 382 (FMCSA), 49 CFR Part 219 (Federal Railroad Administration), 49 CFR Part 655 (FTA), 49 CFR Part 199 (Pipeline and Hazardous Materials Safety Administration), and 46 CFR Subpart 4.06 and Part 16 (Coast Guard).

[15] Alcohol testing is performed using breath and saliva. Urine is tested for morphine, codeine, 6-acetylmorphine (a metabolite of heroin), marijuana, amphetamine, methamphetamine, methylenedioxymethamphetamine (MDMA), methylenedioxyamphetamine (MDA), methylenedioxyethylamphetamine (MDEA), cocaine, and PCP.

1.7 NTSB Research and Efforts to Reduce Transportation Accidents Due to Impairment

The NTSB has a long history of working to reduce operator impairment in all modes of transportation.[16] In 2000, the NTSB issued a letter to the DOT and its modal administrations and the FDA addressing multi-modal concerns about the potential safety effects of drug use in transportation. The letter included 24 recommendations to the DOT, the FAA, the FMCSA, the FRA, the FTA, the Coast Guard, and the FDA.[17]

Most recently, the NTSB has focused on eliminating substance-impaired driving by placing this safety issue on the 2014 NTSB Most Wanted List, conducting a 2012 public forum on substance impaired driving (NTSB 2012a), and issuing a related safety report on alcohol-impaired driving that also highlighted the need for better data about drivers' use of drugs (NTSB 2013). In 2012, the NTSB also issued a recommendation letter to the Coast Guard to align its standards for postaccident toxicological testing of Coast Guard military personnel to be consistent with the requirements specified in 46 CFR 4.06-3.

The NTSB last examined pilot drug use in its safety study, *Alcohol and Other Drug Involvement in Fatal General Aviation Accidents, 1983 Through 1988* (NTSB 1992). The findings from toxicology tests performed in the early part of the study period were considered inconclusive because laboratory procedures were evolving during that time. A series of recommendations were issued to the FAA, the National Association of State Aviation Officials, and various state governors and legislative leaders to improve the frequency and quality of drug testing among pilots involved in accidents. Since those recommendations were issued over 20 years ago, US population demographics and societal patterns of drug use have changed. Scientific and technological advances also have improved the ability to identify various drugs and understand toxicology results. As a result, this study presented an opportunity to assess pilot drug use, using the most current and accurate data available.

[16] A list of the NTSB recommendations issued as of September 2014 concerning operator impairment in aviation is included in the public docket for this safety study, which is available on the NTSB Docket Management System website at http://www.ntsb.gov/investigations/dms.html.

[17] This recommendation letter, excerpts of associated correspondence, and the statuses of the 24 safety recommendations are available via the NTSB safety recommendations database at http://www.ntsb.gov/safetyrecs/private/QueryPage.aspx.

2 Methodology

For this study, 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 1990 and 2012 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.[18]

2.1 Toxicology Data

Since 1990, the CAMI Bioaeronautical Sciences Research Laboratory 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 NTSB aviation accident database records.

2.2 Accident Data

The current NTSB aviation accident database includes more than 350 possible data elements describing the event, the aircraft, and the pilot details of all NTSB aviation accident investigations since 1982. The NTSB aviation accident database also includes narrative fields, coded data elements categorizing the accident sequence, and the NTSB's findings of probable cause and contributing factors.

2.3 Study Dataset and Special Considerations

Study 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.[19] For cases 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

[18] Sufficient data were not available to compare the drugs identified during toxicology tests with those drugs the pilots had reported to the FAA during medical certification exams. Medical certification actions, such as approvals, denials, or special issuances of certification, also were not assessed. 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 is available in the public docket for this safety study, which is available on the NTSB Docket Management System website at http://www.ntsb.gov/investigations/dms.html.

[19] The CAMI toxicology database contains a relatively small number of results from pilots who were not fatally injured. However, these may include testing for reasons other than accident investigation, such as enforcement actions, and were therefore excluded. Throughout the rest of this report, the term "study pilots" is used to refer to pilots who died while actively flying an aircraft as identified in the NTSB aviation accident database records from 1990 through 2012 and who had available test results in the CAMI toxicology database.

the accident aircraft was included in the study dataset.[20] Pilot fatalities the NTSB determined to be the result of suicide or similar intentional acts were excluded from study analyses.

2.3.1 Drugs and Metabolites

Drugs are chemicals taken into the body to create an effect. They 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. Active metabolites also may be marketed as separate drugs. Sometimes, toxicology tests can identify the original drug and one or more of its metabolites. For example, diazepam (commonly marketed under the brand name Valium) is metabolized into nordiazepam, oxazepam, and temazepam. The latter two also have sedative effects and are marketed as separate drugs with the brand names Serax and Restoril, respectively.

Positive toxicology results for a drug and its metabolites do not usually mean the person took multiple drugs. For the purposes of this study, to avoid over counting the number of drugs identified in a pilot, an equivalence list was developed for metabolites and any duplicates were removed. In addition, if a specific drug was identified in multiple specimens for a pilot, it was counted as a single positive finding.[21]

2.3.2 Specimen Types

This study included toxicology results from pilots' blood and tissue specimens only. A drug that is present in urine but no longer found in the rest of the body no longer has any potential for impairment or general effect on the body. Drugs that were taken recently or regularly will generally be present in blood or tissue. Therefore, drugs found only in urine were excluded from study analyses. Toxicology results not related to drug use, such as carbon monoxide and cyanide levels, were also excluded.

2.3.3 Ethanol and Its Production in the Body After Death

Toxicology results for ethanol and other alcohols were not analyzed in this study. Ethanol is the specific alcohol found in fermented and distilled liquor. It is generally understood that ethanol significantly impairs pilots' performance, even at very low levels (Cook 1997). However, ethanol and other alcohols also can be produced by microbial action in body tissues after death, and this process occurs at different rates in different areas of the body (Kugelberg and Jones 1997). This makes interpreting postmortem toxicology results regarding ethanol consumption difficult. For example, an initial assessment of the study data showed more than 20% of pilots had at least one positive finding for an alcohol, most of which were likely due to production after death rather than consumption by the pilot. In contrast, the NTSB identified

[20] Study 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.

[21] The list of drugs and their metabolite equivalents and the drug categories used in this study are provided in appendix A, "Drug and Metabolite Equivalents and Drug Categories Applied in this Study."

ethanol use as a probable cause or contributing factor in less than 2% of fatal US civil aviation accidents between 1990 and 2012.

2.3.4 Postaccident Medical Treatment

In some cases, study pilots received postaccident medical care before they died. Drugs that are only available in intravenous forms (such as midazolam, a sedative also known as Versed, and atropine, marketed with brand names Sal-Tropine, AtroPen, and Atreza) and are routinely used during resuscitation attempts were excluded. In addition, any other drugs (such as morphine, fentanyl, or phenytoin (brand name Dilantin)) that may have been used during postaccident treatment were not analyzed in this study unless accident details indicated a pilot had used the drug(s) before the accident.

2.4 Drug Categorization

Drugs identified at least once in CAMI's toxicology tests were grouped based on their chemical structure, usual use, or effects into the following categories:[22]

- 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

[22] See appendix B, "Drug Category Definitions," for the drug category definitions used in this study.

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 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.[23]

The use of certain OTC and prescription drugs suggests the presence of a potentially impairing underlying medical condition. A conservative approach was taken to identify the drugs in the "potentially impairing condition" 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 categorized as being indicative of a potentially impairing condition because it is used primarily to treat epilepsy and trigeminal neuralgia, and either condition could be at least intermittently impairing.[24] 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.[25]

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.[26] 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.[27] For the purposes of this study, Schedule II-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 Schedule II-V drugs as controlled substances.[28]

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. All of the toxicology results from each case involving

[23] See appendix A for the list of drugs included in the illicit category and the list of drugs categorized as "potentially impairing."

[24] *Trigeminal neuralgia* is an irritation of a facial nerve, which causes severe pain often described as a stabbing sensation.

[25] The full list of identified drugs categorized as "potentially impairing condition" is included in appendix A.

[26] See the definitions of controlled substances by schedule at http://www.deadiversion.usdoj.gov/schedules/index.html.

[27] Although some state and local entities have changed regulations to allow prescribed use of marijuana, it remains classified as a Schedule I drug by the DEA and was categorized as an illicit drug for the purposes of this study.

[28] The list of identified drugs included in the "controlled substances" category is included in appendix A.

these three drugs were evaluated. 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 than would be expected for medical use, the findings were categorized as illicit.

Appendix C, "Expanded Methodology," provides a more thorough discussion of the "Drugs and Metabolites," "Specimen Types," "Ethanol and Its Production in the Body After Death," "Postaccident Medical Treatment," and "Drug Categorization" sections of this report.

3 Results

Most (96%) of the pilots in this study were conducting general aviation operations. Fewer fatal accidents involve air carrier operations. The following sections summarize results about the study pilots, accident types, drug categories, and drug use trends according to various pilot and flight operation characteristics.

3.1 Interpreting Results

For the purposes of this study, a positive toxicology finding meant that a drug was identified in a study 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.[29]

3.2 Study Pilots

The study population consisted of 6,677 fatally injured accident pilots, involved in 6,597 accidents for which the NTSB aviation accident database record could be matched to a record in the CAMI toxicology database. This included pilots with positive or negative toxicology results. These are referred to as study pilots throughout this report. All of the study pilots were fatally injured in domestic US civil aviation accidents between 1990 and 2012.

There were 7,575 domestic US civil aviation accidents that resulted in a pilot fatality during the study period. Of these, 6,597 accidents (87%) had corresponding records in both the NTSB and CAMI databases.[30]

Nearly all (98%) of the study pilots were male, with an average age of 50 years (range, 16 to 92). Figure 1 shows the annual increase in average age of study pilots from 1990 through 2012, along with comparison age information about the population of all active pilots. On average, study pilots were 5–15 years older than the population of active pilots (FAA 2013).

[29] The length of time a drug can be identified in blood or tissue varies widely, and a drug may be detectable by toxicology tests after its effects have worn off. Also, some drugs are not identifiable by toxicology testing, such as those that are new or ones that mimic chemicals produced by the human body like insulin and thyroid hormones.

[30] Matching may have not have been available because a toxicology test was not performed, the specimens were not suitable for testing, or accident details between the two databases differed significantly and could not be resolved.

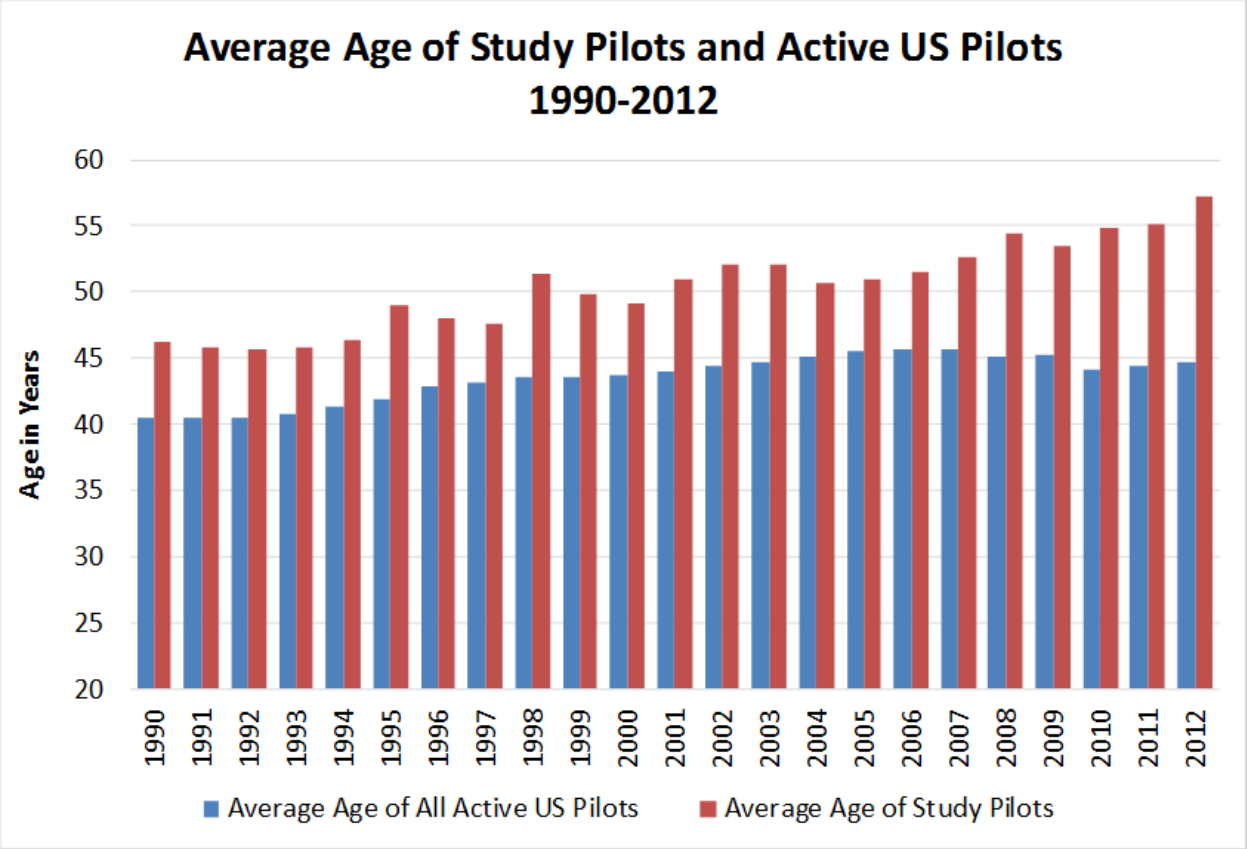

Figure 1. Average age of study pilots and all US pilots

The distribution of study pilots by highest certificate level appears in figure 2. Nearly half (47%) of study pilots held only a private pilot certificate and one-third (34%) held a commercial pilot certificate. Although 15% of study pilots held an airline transport pilot certificate, figure 3 shows that small percentages of study cases involved 14 CFR Part 121 air carrier or Part 135 commuter and on-demand air carrier operations. As shown in figure 3, the large majority (96%) of pilots in this study were flying in general aviation operations at the time of their fatal accident. Therefore, most of the available information on pilot drug use refers to general aviation operations. The distributions of pilot certificate level and type of flight operation for study pilots and accidents were similar to those for all US fatal civil aviation accidents (NTSB 2012b), indicating that the study dataset was representative of fatal US civil aviation accidents in general.

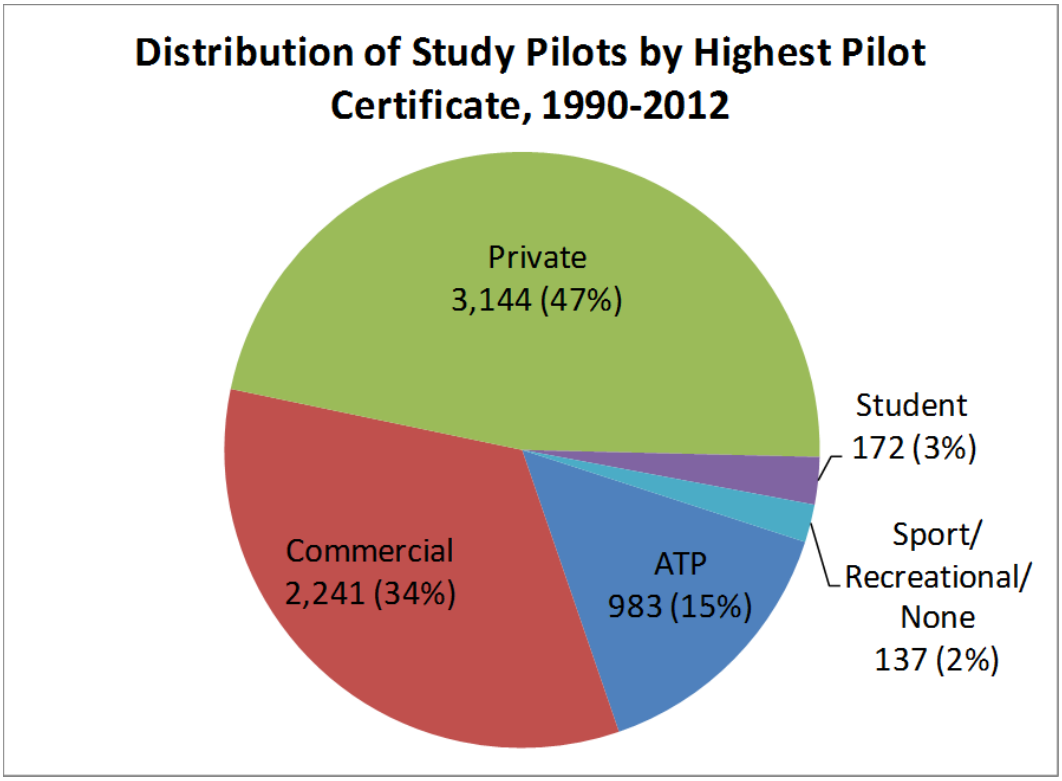

Figure 2. Study pilots by airman certificate level

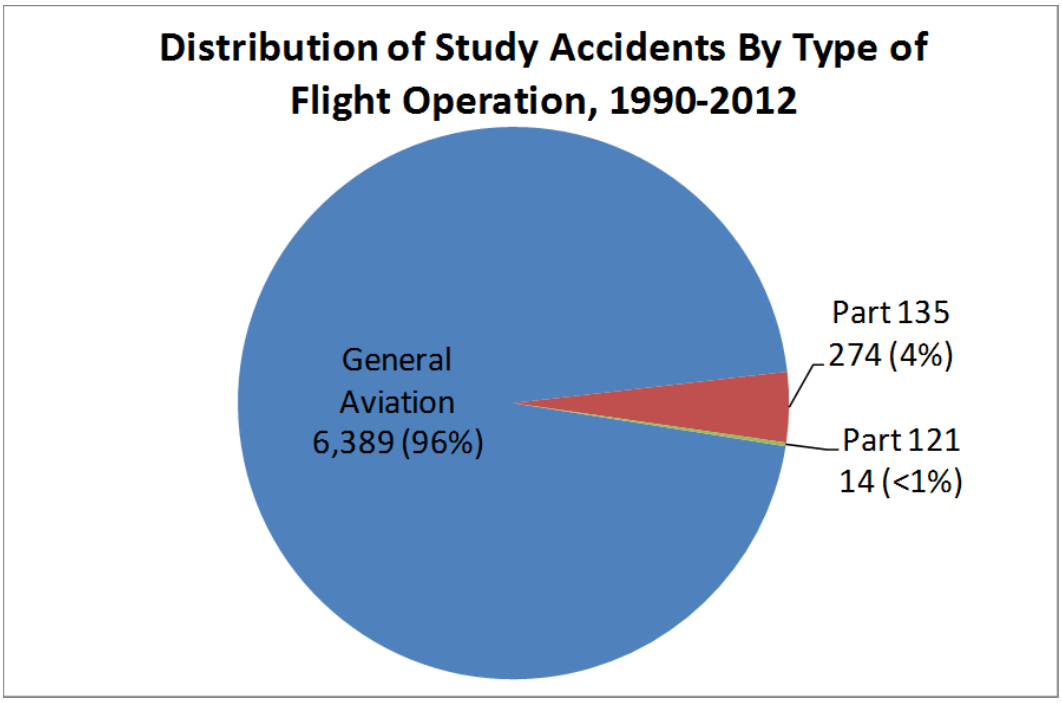

Figure 3. Study accidents by type of flight operation

3.3 Drug Prevalence

Figure 4 shows an increasing trend in positive toxicology findings from 1990 through 2012. Over the entire study period, an average of 25% of study pilots had at least one positive finding in blood or tissue specimens. However, the prevalence of positive toxicology findings increased markedly during the study period. The proportion of study pilots with at least one positive finding increased from less than 10% of pilots in 1990 to 40% in 2011.

Over the 23 years covered by this study, CAMI developed procedures to increase the number of drugs the toxicology laboratory can identify; between 1990 and 2008, there was a 44% increase in the number of drugs and metabolites it can identify. Over the course of the study, new drugs also became available and some drugs were removed from the market. Finally, the cutoff values for reporting acetaminophen and salicylates were increased in 2002, reducing the number of positive results over time (Canfield and others 2011). These changes had some effect on the number of positive toxicology findings. Nevertheless, the results reflect trends in the general population and likely indicate a significant increase in drug use by study pilots. To minimize the influence of these changes on the study results, the remaining analysis focused on drug categories rather than individual drugs.

In addition to a general increase in the proportion of study pilots with evidence of recent drug use, there was an increasing trend in the total number of drugs identified in those pilots with positive findings. Figure 4 also illustrates the increasing trend over the study period for study pilots with positive findings for multiple drugs. These findings were consistent with the previously discussed research findings that show increasing trends in drug use and the number of drugs being prescribed per person in the US population (Gu and others 2010).[31]

[31] See section 1.5, "Societal Trends in Drug Use," of this report.

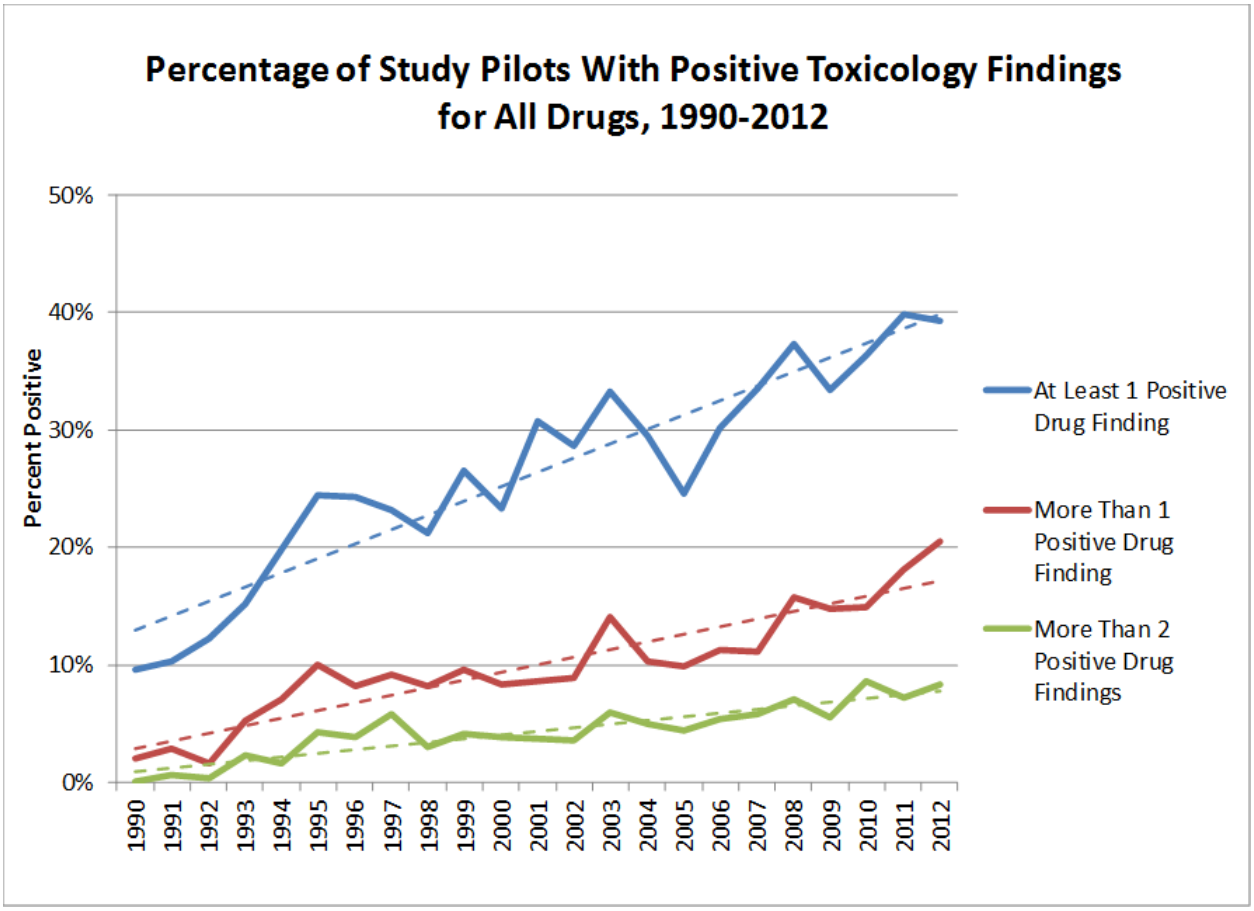

Figure 4. Percentages of study pilots with at least one positive and multiple toxicology findings

3.4 Drug Categories

For the purposes of this study, positive findings from the CAMI toxicology database were assigned to drug categories by their chemical structure, usual use, or effects. The following table shows the proportion of pilots with positive findings in each of those drug categories and the trends in positive findings during the study period. Each row in the table represents the percentage of study pilots with one or more positive toxicology findings in that category for each time period. The categories are rank ordered in the table by the most prevalent over the entire study period.

Table Trends in percentages of positive findings by drug categories

Drug category	1990-1997	1998-2002	2003-2007	2008-2012	Total for study period 1990-2014
Sedating antihistamines	5.6%	8.2%	8.3%	9.9%	7.5%
Nonsedating over-the-counter drugs	4.6%	6.8%	6.2%	7.3%	5.9%
Cardiovascular drugs	2.4%	4.2%	8.0%	12.4%	5.7%
Antidepressants	1.0%	4.5%	5.8%	5.3%	3.5%
Illicit drugs	2.3%	2.9%	2.9%	3.8%	2.8%
Sedating pain relievers	1.0%	2.4%	2.6%	4.4%	2.2%
Diet aids	1.2%	2.4%	2.0%	1.2%	1.6%
Benzodiazepines	1.3%	1.1%	0.8%	2.0%	1.3%
Other drugs	0.2%	1.5%	2.1%	1.9%	1.2%
Nonsedating pain relievers	0.6%	0.1%	2.6%	1.7%	1.1%
Blood thinners	1.6%	0.5%	0.1%	1.3%	1.0%
Anti-seizure drugs	0.7%	0.1%	0.6%	1.0%	0.6%
Prostate/erectile dysfunction drugs	0.0%	0.2%	0.8%	1.6%	0.5%
Anti-infective drugs	0.2%	0.7%	0.5%	0.6%	0.4%
Cholesterol lowering drugs	0.1%	0.0%	0.0%	2.0%	0.4%
Other psychotropic drugs	0.2%	0.3%	0.7%	0.8%	0.4%
Migraine drugs	0.3%	0.4%	0.4%	0.3%	0.4%
Prescription sleep aids	0.0%	0.0%	0.2%	1.5%	0.3%
Nausea and vertigo drugs	0.2%	0.1%	0.3%	0.3%	0.2%
Other neurologic drugs	0.1%	0.0%	0.4%	0.6%	0.2%
Oral diabetes drugs	0.0%	0.0%	0.1%	1.0%	0.2%
Emphysema and asthma drugs	0.2%	0.2%	0.0%	0.2%	0.1%

In the last 5 years of the study, 2008–2012, cardiovascular drugs were the most commonly identified category.[32] In addition to being the most prevalent category of drugs in recent years, the percentage of positive findings for cardiovascular drugs increased noticeably during the study period.

Over the entire study period, the most commonly identified drug category was sedating antihistamines. Antihistamines are typically used to treat allergy symptoms such as hives, itching, or nasal congestion; those that are particularly sedating are also found in OTC sleep aids. Most antihistamines are commonly available OTC either by themselves or in combination with other drugs. This category includes diphenhydramine (an active ingredient in multiple Benadryl

[32] The cardiovascular drug category included drugs used to treat high blood pressure, control heart rate, or treat heart failure. Drugs to treat high cholesterol or blood thinners were categorized separately. See Appendix A for a complete list of drugs included in each category.

and Unisom products). In our results, diphenhydramine was the most commonly identified sedating antihistamine overall and the single most commonly identified potentially impairing drug. (See figure 5.)

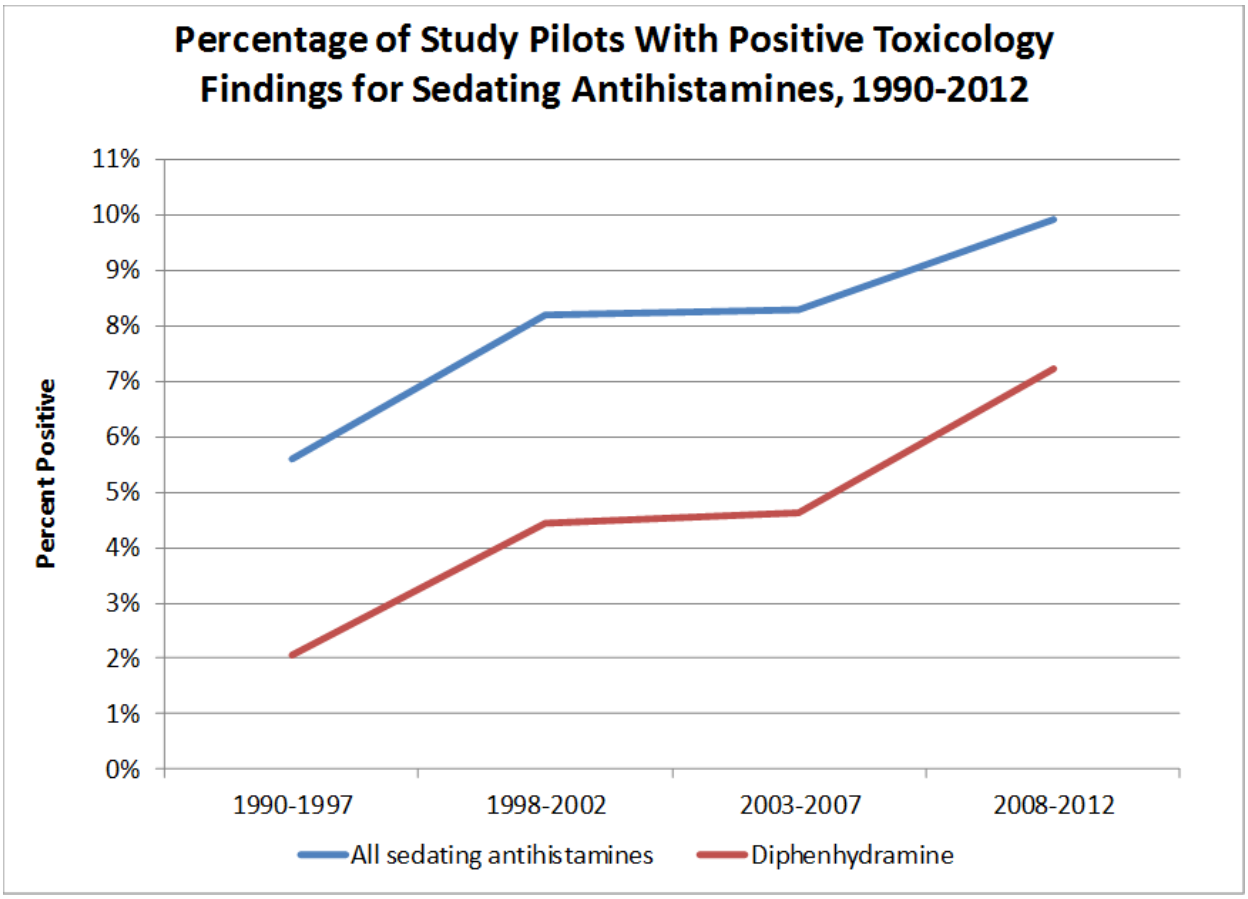

Figure 5. Trends in positive toxicology findings for sedating antihistamines

Illicit drugs accounted for a small proportion of all the positive findings during the study period. However, the percentage of study pilots testing positive for at least one illicit drug increased from 2.3% in the 1990–1997 period to 3.8% in the 2008–2012 period, and the highest annual percentage was 5% in 2011. The increasing trend in illicit drug results was largely attributed to increasing positive findings for marijuana use among study pilots. Marijuana was the most commonly identified illicit drug, and the percentage of study pilots testing positive for marijuana increased from 1.6% in the 1990–1997 period to 3.0% in the most recent 5-year period 2008–2012.[33]

[33] The increasing trend in positive findings for marijuana was identified by linear-by-linear association, chi-squared statistic, SPSS version 19, χ^2=8.226, df=1, p=0.004.

3.5 Potentially Impairing Drugs and Conditions

Over the entire study period, there were increasing trends in the proportions of study pilots testing positive for at least one drug identified as potentially impairing, used to treat a potentially impairing condition, or as a controlled substance. The increasing trends in use for all of these drugs were statistically significant.[34] (See figure 6.)

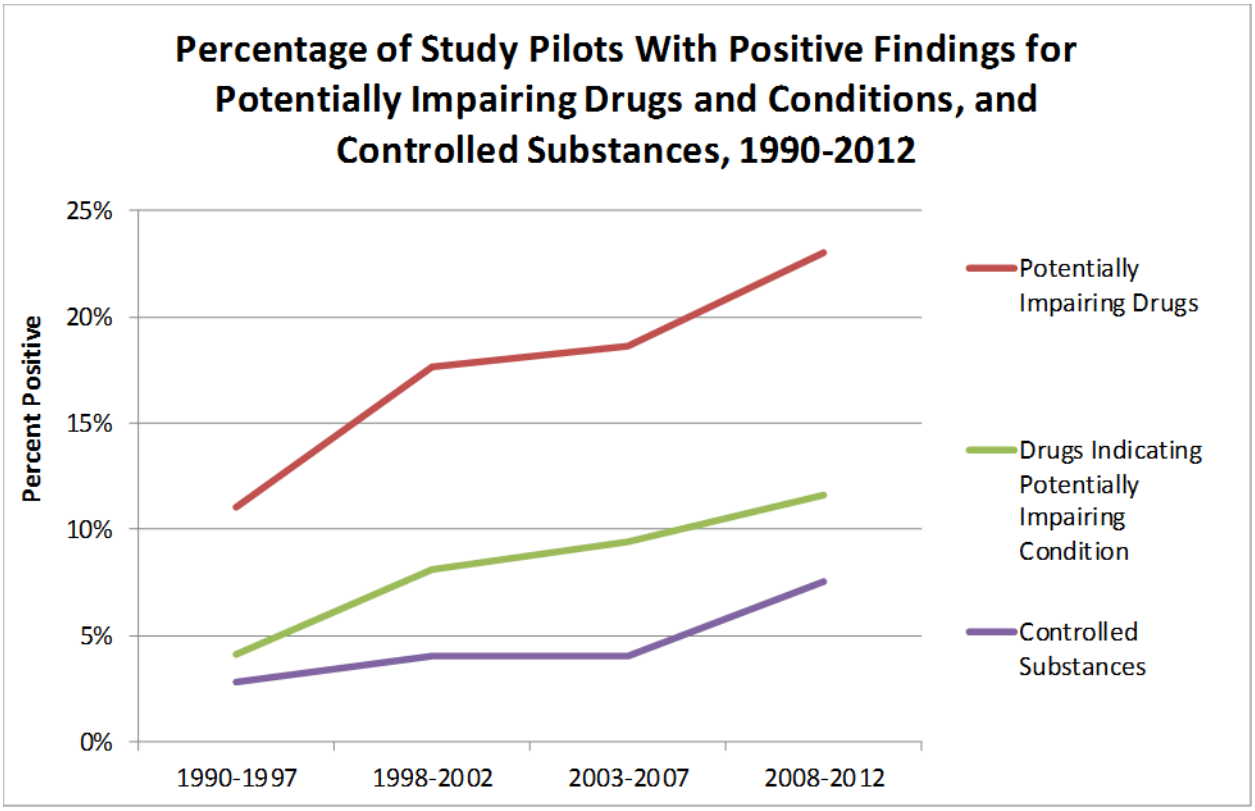

Figure 6. Trends in percentages of potentially impairing drugs and conditions, and controlled substances

In addition to an increasing proportion of study pilots testing positive for potentially impairing drugs, the number of potentially impairing drugs identified per pilot also increased. The proportion of study pilots testing positive for more than one potentially impairing drug increased from 3% in the 1990–1997 period to more than 6% in the 2008–2012 period.[35] The use of multiple potentially impairing drugs is particularly concerning because the effects of some drugs taken in combination may be greater than simply adding the effects of the individual drugs (Blumenthal and Garrison 2011, 50).

The number of controlled substances identified per study pilot also increased, with about 2% of study pilots testing positive for more than one controlled substance in the most recent

[34] Potentially impairing drugs, χ^2= 92.571, df=1, p<0.001; potentially impairing condition, χ^2=77.181, df=1, p<0.001; and controlled substances, χ^2=37.591, df=1, p<0.001.

[35] Linear-by-linear association, chi-squared statistic, more than one potentially impairing drug, χ^2=25.057, df=1, p<0.001.

5-year period.[36] The most commonly identified controlled substances used by study pilots were hydrocodone (an active ingredient in Vicodin and Lortab) and diazepam (marketed under the brand name Valium).[37] Hydrocodone and diazepam each accounted for about 20% of the controlled substances identified in study pilots. Although the proportions were smaller among pilots, these findings were consistent with data for the general US population indicating that prescriptions for opioids more than tripled between 1999 and 2010 (Frieden 2013).

Using prescribed controlled substances does not necessarily disqualify a pilot from medical certification, only from flying after recent use. The FAA medical guidance to AMEs allows occasional use of prescribed controlled substances such as opioid pain relievers as long as the underlying condition has improved and pilots wait at least five dosing intervals after last use before flying (FAA 2014).

3.6 Accident Characteristics

A comparison of accidents in this study by type of flight operation indicated that study pilots flying general aviation operations were more likely to show evidence of recent drug use than those who were flying in 14 CFR Part 121 air carrier or Part 135 commuter and on-demand air carrier operations. As shown in figure 7, the proportion of study pilots with positive toxicology findings was higher in general aviation operations for all drugs, potentially impairing drugs, drugs used to treat potentially impairing medical conditions, and illicit drugs.[38] None of the study pilots flying in 14 CFR Part 121 air carrier operations had toxicology findings indicating recent use of illicit drugs; the 2% of air carrier cases with positive findings for illicit drugs shown in figure 7 involved Part 135 operations.

[36] Linear-by-linear association, chi-squared statistic, more than one controlled substance, χ^2=7.587, df=1, p=0.006.

[37] *Hydrocodone* is an opioid analgesic used for the treatment of moderate to moderately severe pain and as a cough suppressant; it is typically sold in combination with other drugs such as acetaminophen. Hydrocodone is the most commonly prescribed opiate in the United States, with about 143 million prescriptions for products containing hydrocodone dispensed in 2012 (DEA 2013b). *Diazepam* is in the benzodiazepine class of drugs that produce central nervous system depression, most commonly used to treat insomnia and anxiety. There were 15 million prescriptions for diazepam dispensed in the United States in 2011 (DEA 2013a).

[38] These differences were statistically significant for all drugs χ^2=15.058, df=1, p<0.001, potentially impairing drugs χ^2=9.351, df=1, p=0.002, and drugs indicating potentially impairing conditions χ^2=6.851, df=1, p=0.009.

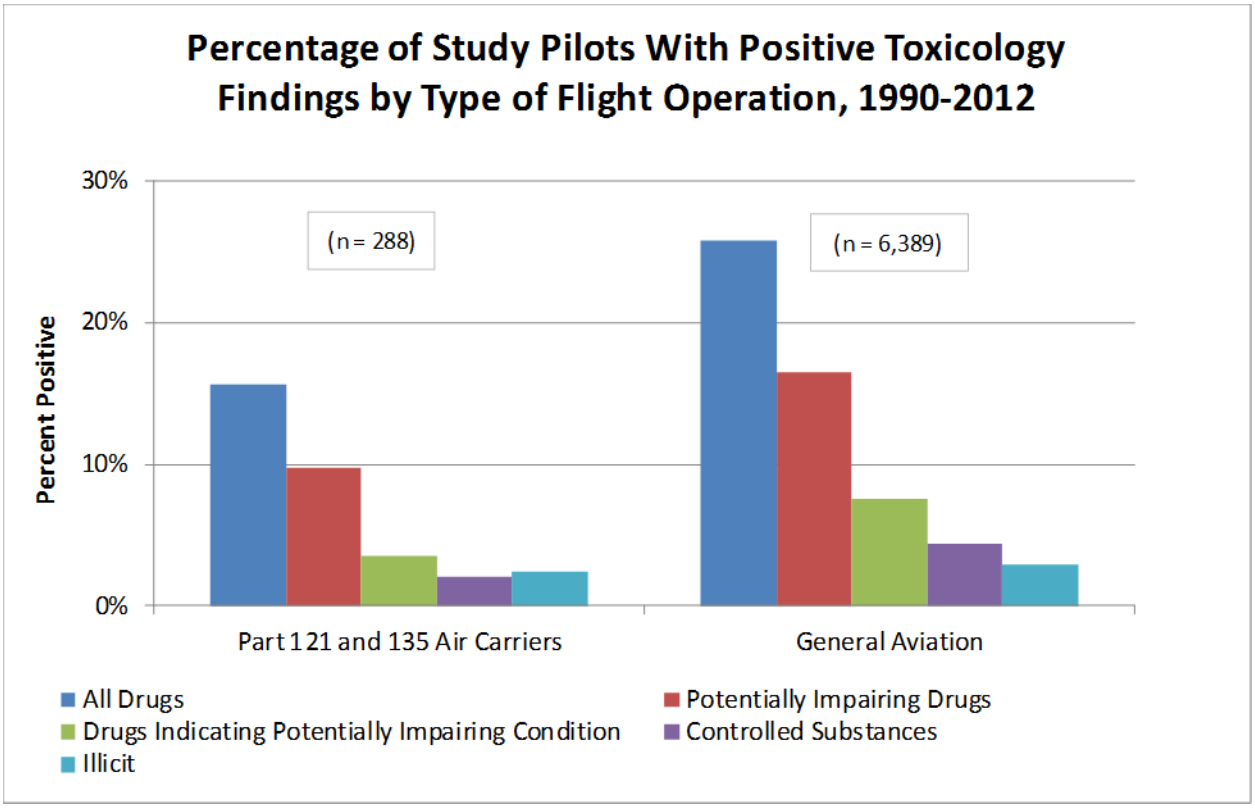

Figure 7. Potentially impairing drugs and conditions, controlled substances, and illicit drugs by type of flight operation

Pilots' use of potentially impairing drugs seems as if it would increase their risk of experiencing certain types of accidents. However, a comparison of the distribution of accident events for study cases from 2008 through 2012 involving pilots with and without evidence of potentially impairing drugs found no significant difference in distribution of accident types.[39] The largest difference in the accident types was that a greater proportion of study pilots testing positive for potentially impairing drugs had experienced loss of control in flight (50% compared to 45% of pilots without positive toxicology results for potentially impairing drugs) but the difference was not statistically significant.[40] The type of accident a pilot experienced therefore could not be directly associated with evidence of recent use of potentially impairing drugs.

The similarity in the distribution of accident circumstances highlights important issues related to drug use, impairment, and accident causation. First, simply knowing that a person recently used a potentially impairing drug may not be sufficient evidence to determine whether a person's performance was significantly degraded by that drug at a given time. Second, it is difficult to determine if a person's impairment caused or contributed to an accident without

[39] The current NTSB aviation accident database includes fields to describe accident circumstances using categories developed by the Commercial Aviation Safety Team (CAST)/International Civil Aviation Organization (ICAO) Common Taxonomy Team (CICTT). Definitions and related documentation for these categories can be found at http://www.intlaviationstandards.org/. This analysis includes only cases from 2008 through 2012 because the NTSB adopted a new method for coding these occurrence data in the NTSB aviation accident database in 2008.

[40] Pearson chi-squared statistic, χ^2=2.240, df=1, p=0.134.

knowing specific information about the person's performance during the accident sequence. Various drugs can affect human performance in a variety of ways. Impairing effects of a drug may manifest in obvious ways, such as degraded decision-making, difficulty speaking, or diminished ability to control an aircraft. Impairing effects may also negatively affect performance in more subtle ways, such as affecting a pilot's ability to perform preflight inspection and fuel-planning tasks or respond appropriately to an inflight emergency.

3.7 Pilot Characteristics

Further analysis of toxicology findings and pilot characteristics indicated that drug usage was not evenly distributed among all study pilots. For example, a comparison of findings by pilot age indicated that use of all drugs, potentially impairing drugs, drugs used to treat potentially impairing medical conditions, and controlled substances was more common among older study pilots (shown in figure 8).[41] The increasing trends with age were statistically significant for each of these drug categories.[42]

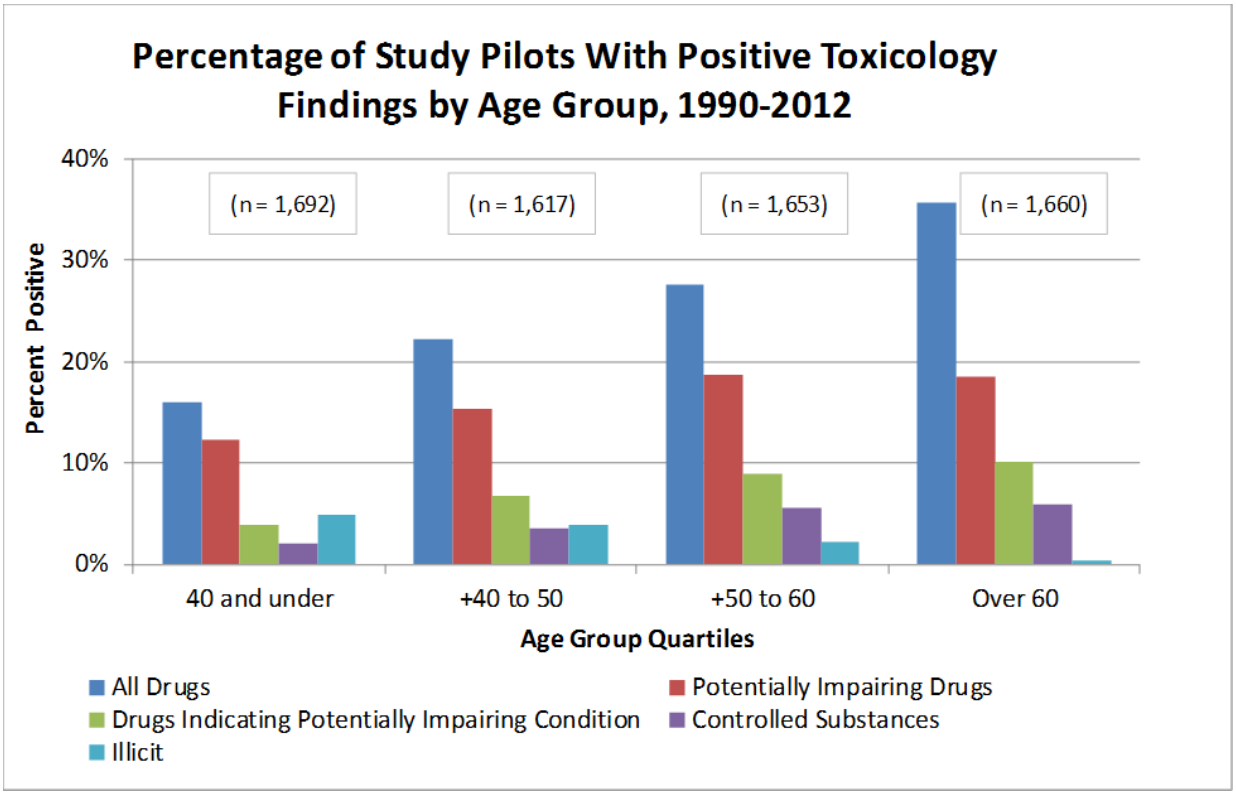

Figure 8. Potentially impairing drugs and conditions, controlled substances, and illicit drugs by pilot age group

[41] In this chart and the remaining charts in the report, the number of study pilots per category may not sum to the total study population due to missing data. The pilot age categories were selected to approximate quartiles, rounded to the nearest decade.

[42] Linear-by-linear chi-squared statistic, all drugs, χ^2=183.674, df=1, p<0.001; potentially impairing drugs, χ^2=30.082, df=1, p<0.001; potentially impairing condition, χ^2=50.783, df=1, p<0.001; and controlled substances, χ^2=35.060, df=1, p<0.001.

The US pilot population is aging along with the rest of the US population (Higgins and others 2013). Of the 610,576 active civilian pilots as of December 31, 2012, 20% (122,703) were age 60 or older (FAA 2013).[43] An aging pilot population may contribute to the likelihood of pilots taking more drugs. Findings of increased drug use with age were consistent with data for the US population in general. For example, a Centers for Disease Control and Prevention/National Center for Health Statistics analysis of National Health and Nutrition Examination Survey data for 2007–2008 found a significant trend in prescription drug use by age; with 88% of all persons 60 and older reporting that they used one or more prescription drugs in the preceding month (Gu and others 2010).

Illicit drugs were an exception to the pattern of increased drug use among older study pilots. As also shown in figure 8, there was a decreasing trend with age in the percentage of study pilots testing positive for illicit drugs.[44] This finding was consistent with results from the previously cited national survey conducted by the Substance Abuse and Mental Health Services Administration (SAMHSA 2013) that found the highest illicit drug usage among the youngest group of adults surveyed.

[43] For statistical analysis purposes, the FAA defines an active pilot as one who holds both an airman certificate and at least a third-class medical certificate (FAA 2013).

[44] This trend was statistically significant; linear-by-linear association chi-squared statistic, $\chi^2 = 70.470$, df=1, $p<0.001$.

In addition to age, the prevalence of positive toxicology findings differed among study pilots by certificate level. Study records from the years 2005 through 2012 indicate that study pilots with a sport pilot certificate only were more likely than those with private, commercial, or airline transport pilot certificates to have positive findings for all drugs, for potentially impairing drugs, and for drugs used to treat potentially impairing conditions.[45] (See figure 9.) The increased prevalence of positive findings for fatally injured sport pilots was notable because they are not required to have a medical certificate and are therefore likely making decisions about using particular drugs without periodic interaction with an AME.

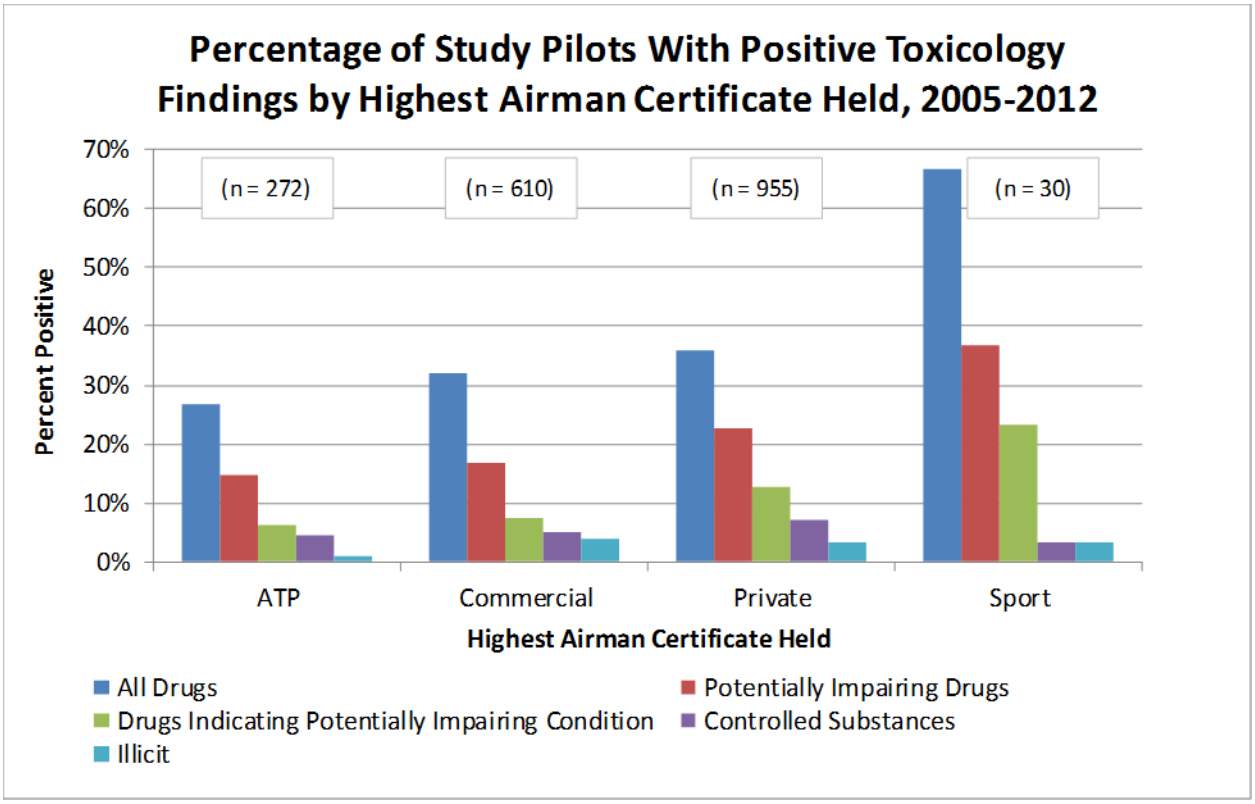

Figure 9. Potentially impairing drugs and conditions, controlled substances, and illicit drugs by pilot certificate

[45] The finding was statistically significant: Pearson chi-squared statistic, all drugs χ^2=23.033, df=3, p<0.001; potentially impairing χ^2=18.164, df=3, p<0.001; and potentially impairing condition χ^2=21.295, df=3, p<0.001. Comparison of results by highest level of pilot certificate were limited to years 2005 and later because the Sport Pilot and Light Sport Aircraft Rule became effective in September 2004, and the FAA US Civil Airmen Statistics (2013) indicated that the first sport pilot certificate was issued in 2005.

3.8 Medical Certification

To better examine the relationship between positive toxicology findings and pilots flying without medical certification, study pilots involved in accidents between 2005 and 2012 were categorized based on whether they had a medical certificate that was still within the duration limits of a third-class certificate at the time of the accident. As shown in figure 10, the proportion of pilots with positive findings was higher for each category of drugs (all drugs, potentially impairing drugs, drugs used to treat potentially impairing conditions, controlled substances, and illicit drugs) among those study pilots who had never held or held an expired FAA medical certificate at the time of the accident than study pilots with an FAA medical certificate that was still within the duration limit of a third-class certificate. All of these differences were statistically significant.[46]

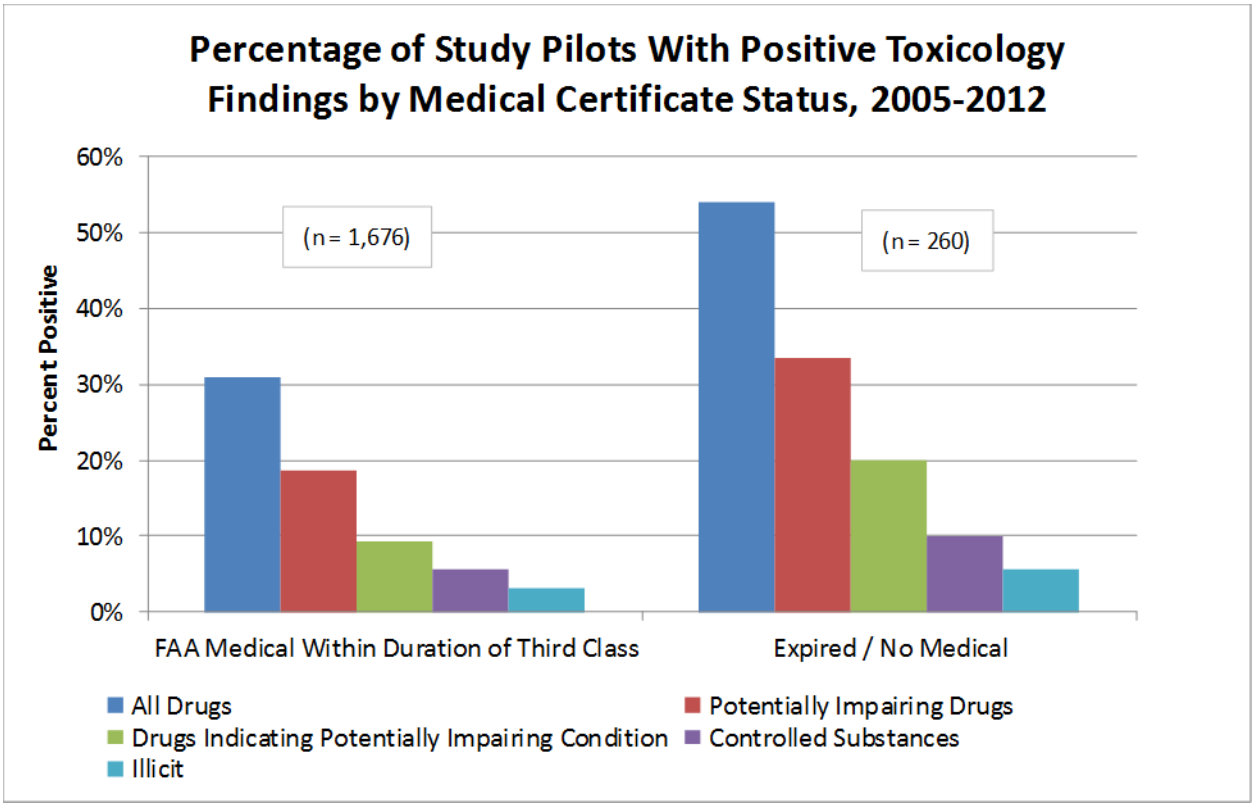

Figure 10. Potentially impairing drugs and conditions, controlled substances, and illicit drugs by medical certificate status

[46] Pearson chi-squared statistic, all drugs χ^2=52.477, df=1, p<0.001; potentially impairing χ^2=30.620, df=1, p<0.001; potentially impairing condition χ^2=27.670, df=1, p<0.001; controlled substances χ^2=7.208, df=1, p=0.007; and illicit drugs χ^2=4.249, df=1, p=0.039.

A further comparison of study pilots' medical status from 1990 through 2012 shows a stable trend in the percentage of study pilots without a current medical certificate until 2004.[47] On average, 6% (range 4.2%–7.3%) of study pilots during this period did not have a valid third-class medical certificate. However, there was a noticeable change in that pattern starting in 2005. The Sport Pilot and Light Sport Aircraft Rule that created the option of using a US issued driver's license as an alternative to medical certification when exercising the privileges of a sport pilot certificate in a light sport aircraft became effective on September 1, 2004.[48] The graph of medical certification status of study pilots per year shown in figure 11 illustrates the change in the percentage of study pilots with medical certificates in 2005 and after. By 2012, about 24% of study pilots (54 of the 229 study pilots in 2012) either did not have a medical certificate or had allowed their medical certificates to expire, often because they were operating under the privileges of a sport pilot certificate.

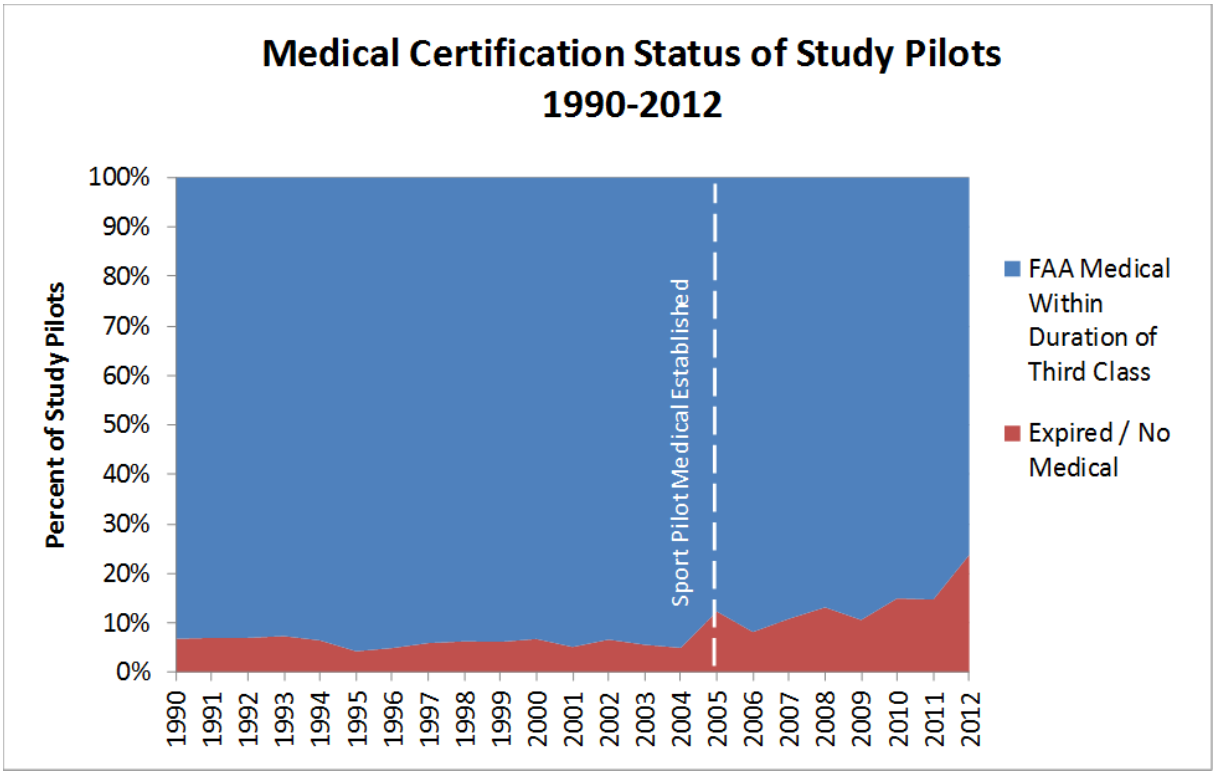

Figure 11. Trend in medical certification of study pilots by year

[47] Duration of a third-class medical was calculated from the date of the pilot's last medical if applicable, the pilot's age at last medical, and the duration requirements of 14 CFR 61.23 at the time of the accident. Before September 16, 1996, the duration of a normal issuance third-class medical was valid through the end of the 24th month after the date of examination. Between September 16, 1996, and July 24, 2008, the duration of the third-class medical increased to the 36th month after issuance for pilots younger than 40 at the time of the examination, and on July 24, 2008, the duration requirement increased to the 60th month after issuance for pilots younger than 40 at the time of the exam. Due to the complexities of determining the validity of a medical certificate for each study pilot and flight operation, this comparison did not take into account special issuances or the validity of the pilot's medical certificate for the requirements of the operation being conducted at the time of the accident, only the time since last examination.

[48] This also includes pilots holding a private, commercial, or airline transport pilot certificate who are exercising the privileges of the sport pilot certificate in a light sport aircraft.

A further comparison of study pilots' medical certificate status by age group for accidents between 2005 and 2012 (see figure 12) shows a significantly larger percentage of older study pilots flying without medical certificates.[49] In light of the previously discussed evidence of an aging pilot population, these data suggest that the trend in pilots flying without medical certification is likely to continue increasing.

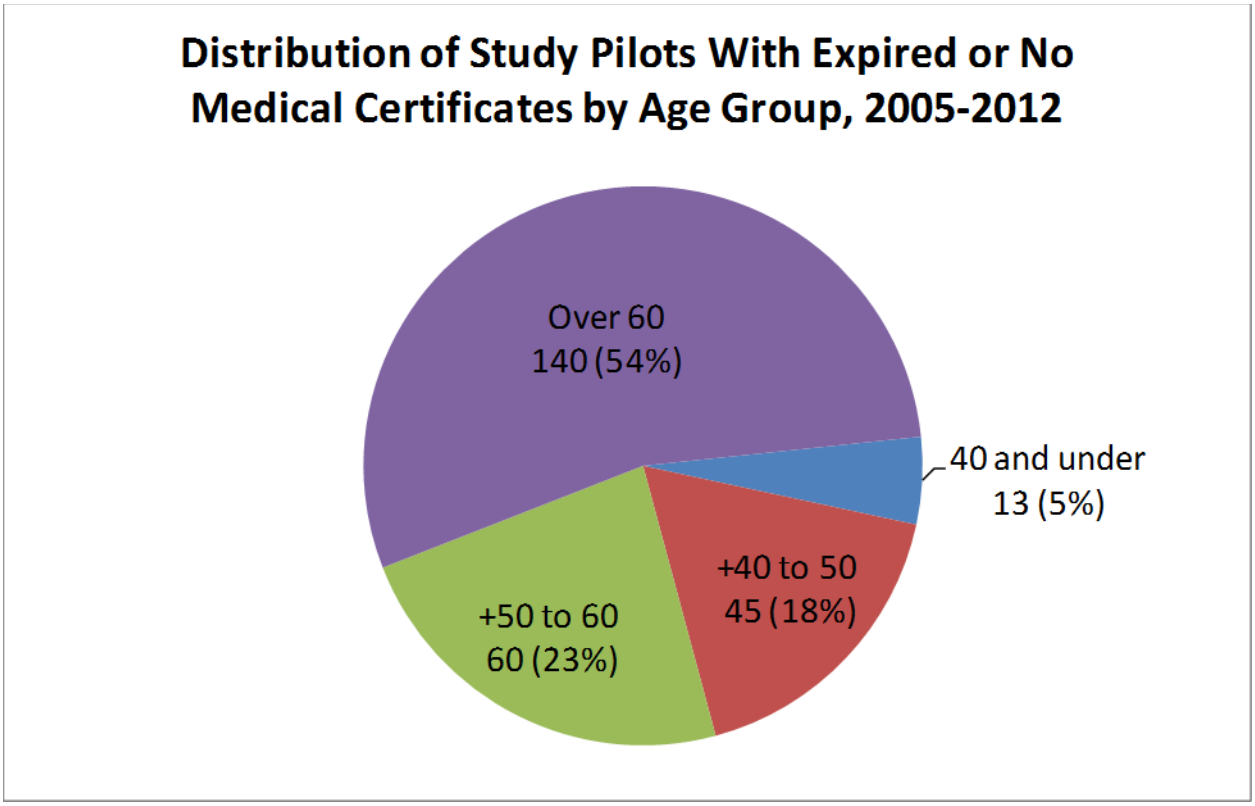

Figure 12. Distribution of medical certificate status by study pilot age group

[49] Pearson chi-squared statistic, χ^2=67.842, df=3, p<0.001.

4 Safety Issues

4.1 Study Findings

This study identified the following findings:

- The percentage of study pilots with positive toxicology findings for all drugs, including potentially impairing drugs, drugs used to treat potentially impairing conditions, and controlled substances increased from just less than 10% of study pilots in 1990 to 40% in 2011.
- The percentages of study pilots with positive toxicology findings for multiple drugs, multiple potentially impairing drugs, and multiple controlled substances also increased during the study period.
- The patterns of increasing prevalence of drug use and use of multiple drugs identified in study pilots' toxicology test results are consistent with observed trends of increasing drug use by the US population in general.
- Sedating antihistamines were the most commonly identified drug category in toxicology test results of study pilots.
- Diphenhydramine (an active ingredient in Benadryl and Unisom products) was the most commonly identified sedating antihistamine and the most commonly identified potentially impairing drug in this study.
- The percentage of study pilots testing positive for marijuana use increased over the study period, primarily in the last decade.
- The distribution of accident event types has been generally similar for study pilots with and without evidence of recent use of potentially impairing drugs.
- Study pilots who did not have a medical certificate or whose medical certificate had expired were more likely to have positive toxicology findings for all drugs, potentially impairing drugs, drugs used to treat potentially impairing conditions, controlled substances, and illicit drugs.
- The percentage of study pilots without a current medical certificate has been increasing since 2005, and the available pilot demographic data suggest that the increasing trend of pilots flying without medical certificates will continue.

4.2 Safety Issue Areas

Based on the similarity of trends in drug use identified in the CAMI toxicology data and the large body of research literature examining drug use in the US population, the NTSB concludes that findings of increasing drug use and increasing use of multiple drugs by fatally injured study pilots are indicative of similar trends in drug use by the US pilot population in general. The NTSB further concludes that the overall risk of drug-related pilot impairment is increasing due to the growing use of potentially impairing drugs.

The NTSB identified five issue areas for safety improvement based on the results of this study: (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.

4.2.1 Providing Pilots More Information about Potentially Impairing Drugs

CAMI toxicology data indicated that sedating antihistamines have historically been the most commonly identified category of drugs found in fatally injured study pilots, and their use continued to increase during the study period. In the most recent 5-year period examined in this study, 2008–2012, about 10% of study pilots showed evidence of recently using one or more sedating antihistamines. One drug in particular, diphenhydramine (an active ingredient in many Benadryl and Unisom products) accounted for a large and increasing proportion of the category and was the single most commonly identified potentially impairing drug found in study pilots.

Other research has found similar evidence of the prevalence of diphenhydramine use among accident pilots involved in a subset of accidents. A working group of the General Aviation Joint Steering Committee (GAJSC) recently analyzed a random sample of a decade of NTSB general aviation accidents involving loss of aircraft control during approach and landing.[50] GAJSC concluded that drugs prohibited by the FAA contributed to 12% of the general aviation loss-of-control accidents included in its analysis, and cited previous FAA research reporting that 42% of pilots involved in all fatal accidents tested positive for drugs or medications, and diphenhydramine was detected in over 6% of all fatal accident pilots (FAA and others 2013). Based on the GAJSC findings, the FAA and 11 pilot and industry groups sent a letter to pilots in July 2013 expressing concern that pilots are taking potentially impairing drugs while operating aircraft without fully understanding their adverse effects (FAA and others 2013). The letter also expressed concern that pilots might not be aware of the prevalence of sedating antihistamines in many OTC drugs.

Pilots may not appreciate the potentially impairing effects of diphenhydramine because it is so widely used in OTC cold and allergy products. However, diphenhydramine can significantly impair performance. For example, one driving simulator study found a single dose of diphenhydramine impaired driving ability more than a blood alcohol concentration of 0.100gm/dL (Weiler and others 2000).[51] There are alternatives to diphenhydramine, such as fexofenadine (commonly marketed with the brand name Allegra) and loratadine (commonly marketed with the brand name Claritin), that do not have the same potential for impairment.

[50] The Loss-of-Control working group of the GAJSC, a joint initiative of the FAA, academia, and aviation industry representatives, reviewed accident data and docket materials from NTSB investigations of general aviation accidents in which the NTSB determined the probable cause to include loss of aircraft control.

[51] The *per se* legal blood alcohol concentration limit for drivers in all 50 states, the District of Columbia, and the Commonwealth of Puerto Rico is currently 0.08 gm/dL. In 2013, the NTSB recommended to the National Highway Traffic Safety Administration (H-13-1) and the 50 states, the District of Columbia, and the Commonwealth of Puerto Rico (H-13-5) that this limit be decreased to 0.05 gm/dL because of evidence that impairment occurs at levels lower than 0.08 gm/dL.

However, consumers may not be aware of less impairing alternatives; one study found that only one in five adults reads label warnings when buying an OTC drug for the first time (Harris Interactive 2002). Results from this study indicate that an increasing percentage of accident pilots chose to fly while taking potentially impairing OTC and prescription drugs, which suggests that some pilots are either unaware of the risks of potential impairment from those drugs or consider the risks acceptable.

This is not a new problem. In response to similar concerns 30 years ago, the NTSB issued the following recommendation to the FAA:

> Review the research and literature on the potential effects on pilot performance of both licit and illicit drugs, in both therapeutic and abnormal levels, and use that to develop and actively disseminate to pilots usable guidelines on potential drug interactions with piloting ability. (A-84-94). (Closed—Unacceptable Action)

In its November 29, 1984, response, the FAA disagreed with the recommendation, stating in part that it recommended that pilots

> use no drugs while acting as a crewmember unless they have consulted with an [AME] as to the drug's possible effect on the crewmember's performance. The policy of the FAA has always been to rely on AME's to counsel pilots as to acceptable and unacceptable medications to be used while flying.

The current version of the FAA's *Pilot's Handbook of Aeronautical Knowledge* (2008, 16-15) states, "The safest rule is not to fly as a crewmember while taking any medication, unless approved to do so by the FAA. If there is any doubt regarding the effects of any medication, consult an AME before flying." Since 1984, the NTSB has continued to investigate accidents in all modes due to impairment, and in 2000 issued the following recommendation to the DOT:

> Develop, with assistance from experts on the effects of pharmacological agents on human performance and alertness, a list of approved medications and/or classes of medications that may be used safely when operating a vehicle. (I-00-2) (Closed—Unacceptable Action)

The DOT and the FAA disagreed with this recommendation. In its March 30, 2000, response, the FAA stated, "Any list that encourages and facilitates the airman's self-determination of the risks posed by various medical conditions and their treatment raises the potential for error, for inappropriate complacency, and, ultimately, for pilot impairment."

The NTSB also issued the following recommendation to the FAA:

> Develop, then periodically publish, an easy-to-understand source of information for pilots on the hazards of using specific medications when flying. (A-00-5) (Closed—Acceptable Action)

In response to this recommendation, in 2005, the FAA published a brochure, *Medications and Flying* (FAA 2010), cautioning pilots about the potential negative effects of some OTC drugs when flying. The brochure identifies 10 common types of OTC drugs and their potential side

effects. The brochure also discusses the potential impairing effects of some prescription drugs, but it does not provide information about any specific prescription drugs or other potentially impairing drugs identified in toxicology tests. Data included in this study from CAMI's toxicology tests indicate that accident pilots' use of potentially impairing drugs has continued to increase since the FAA published that brochure.

The FAA now makes its *Guide for Aviation Medical Examiners* (FAA 2014) publicly available on its website. The guide is for physicians who have specific training in aeromedical health concerns. The AME guide includes a discussion of medical conditions and provides examples of drugs and drug classes that should not be used while flying. However, the AME guide is written for physicians and not intended as a guide for pilots nor is it written in such a manner as to be readily understood by the public. Currently, the only resources written for and available to pilots are unofficial databases and information developed by pilot groups, such as AOPA. Although these may be extensive databases that reference information published by the FAA, they may not be accessible by all pilots and are not the same as official FAA guidance.

Despite the FAA's concerns about creating and maintaining any list of drugs, the FAA's historic position that pilots should consult with their AMEs when making decisions about flying after taking certain drugs is becoming less viable as a growing number of pilots are flying without FAA medical certification. As a result, these pilots typically do not have contact with an AME. Results from this study indicate that an increasing percentage of study pilots were flying without medical certification and that those pilots were more likely to have recently used potentially impairing drugs. Based on study data indicating that an increasing percentage of pilots were flying without medical certification, the NTSB concludes that an increasing number of pilots are flying without a medical certificate and will likely make decisions about their medical fitness to fly, including use of drugs while flying, without periodic interaction with an AME.

To make better decisions about their fitness to fly, pilots must actively seek out the information and medical advice necessary to understand the potential effects of any drugs, such as impairment. The FAA can assist pilots with these decisions by providing more information about potentially impairing drugs. In its recent report on the FAA's online medical application process, the Government Accountability Office received comments from experts and pilot groups (including some AMEs and AOPA) suggesting that the FAA should create and make public lists of approved and unapproved drugs (GAO 2014). Similarly, on July 1, 2014, the GAJSC, 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.[52] The NTSB concludes that the FAA does not provide pilots with adequate information to make informed decisions about which drugs are safe or unsafe to use while flying. The NTSB understands the FAA's concerns about whether it is feasible to develop and maintain a list of drugs that is comprehensive and current. However, the NTSB believes the FAA does not need to provide comprehensive information, only the information most relevant to the pilot community. The FAA already has the most applicable

[52] The safety enhancements, "Flight After Use of Medication with Sedating Effects," SE-15, and "Medication List for Pilots," SE-30, are referenced at http://www.gajsc.org/safety-enhancements/.

source of information available in the results of its toxicology testing of accident pilots. Therefore, the NTSB recommends that the FAA develop, publicize, and periodically update information to educate pilots about the potentially impairing drugs identified in its toxicology test results of fatally injured pilots, and make pilots aware of less impairing alternative drugs if they are available.

4.2.2 Assessing the Safety of Pilots Without Medical Certificates

Findings from this study indicate that pilots without an FAA medical certificate who were fatally injured in accidents were more likely than pilots with at least a third-class medical certificate to have toxicological evidence of recent use of drugs, potentially impairing drugs, drugs that indicate a potentially impairing condition, controlled substances, and illicit drugs. The study findings further indicate that accident pilots conducting 14 CFR Part 121 and Part 135 operations subject to DOT mandatory drug and alcohol testing requirements for safety-sensitive aviation personnel were less likely than those conducting general aviation operations to have toxicological evidence of recent use of drugs, potentially impairing drugs, drugs that indicate a potentially impairing condition, controlled substances, and illicit drugs. Therefore, the NTSB concludes that FAA medical certification requirements and DOT mandatory drug and alcohol testing requirements for safety-sensitive aviation personnel have been associated with fewer toxicological findings of impairing drugs and conditions among accident pilots subject to those requirements. Conversely, these results suggest that allowing pilots to fly without a medical certificate could contribute to an increased risk of pilot impairment while flying because study pilots without an FAA medical certificate were more likely to have toxicological evidence of impairing drugs and conditions. Study data also indicate that the proportion of study pilots flying without a valid medical certificate more than doubled since the Sport Pilot and Light Sport Aircraft Rule went into effect in September 2004. In combination, these findings suggest an increased risk of accidents due to pilot impairment for this group of pilots. However, there has not been a corresponding increase in the proportion of accidents in which the NTSB determined that impairment contributed to the accident. It is not currently possible to compare the safety of medically certificated pilots with those flying under the Sport Pilot and Light Sport Aircraft Rule because there is limited information about the number and flight activity of pilots without medical certificates.

Each year, the FAA publishes a US Civil Airmen Statistics study using information from its official airmen certification records. For statistical analysis purposes, the FAA defines an active pilot as one who holds both an airman certificate and a valid medical certificate (FAA 2013).[53] Because there is no medical requirement for pilots holding only a sport pilot certificate or pilots flying gliders only, statistics for those pilots are based on the total number of airmen certificates on record in those categories. According to the US Civil Airmen Statistics study, the FAA had issued about 4,500 sport pilot certificates as of 2012, which accounted for less than 1% of all estimated active pilots.

However, the changes to medical certification requirements in the Sport Pilot and Light Sport Aircraft Rule also apply to pilots holding higher-level airmen certificates but flying light sport aircraft and exercising the privileges of a sport pilot certificate. According to

[53] A valid medical certificate is defined as being within the duration of the third-class medical.

14 CFR 61.23(b), pilots may fly light sport aircraft as long as they hold a valid driver's license and have not had an FAA medical certificate denied, suspended, or revoked. Thus, an airline transport pilot who develops a serious medical condition and believes the condition might lead to a denial of medical certification may allow the medical certificate to expire and continue to fly light sport aircraft with a valid driver's license.

Similar to pilots holding medical certificates for the flight operations they are conducting, pilots flying without a medical certificate must adhere to federal regulations at 14 CFR 61.53 and 91.17, which prohibit a person from acting as pilot-in-command while that person "knows or has reason to know of any medical condition that would make the person unable to operate the aircraft in a safe manner." Title 14 CFR 91.17 also states, "No person may act or attempt to act as a crewmember of a civil aircraft…[w]hile using any drug that affects the person's faculties in any way contrary to safety." However, without consulting an AME or comprehensive guidance about approved drugs and conditions, it is difficult to establish how pilots are supposed to know or have reason to know whether their medical conditions or drug use would be unsafe.

The accident data in this study suggest that the group of pilots flying without a medical certificate is much larger than the group of pilots with only sport pilot certificates. For example, about 9% of study pilots since 2005 without a medical certificate had only sport pilot certificates; the rest held private, commercial, or airline transport pilot certificates. As a result, neither counting recently issued medical certificates nor counting pilot certificates on record captures the existence or flight experience of the majority of pilots flying without a medical certificate. Without this information, measures of aviation safety, such as the accident rate per pilot, fatalities per flight hour, and fatal accident rate per flight hour, cannot be determined or compared with historical data and other information to determine trends in aviation safety. The NTSB concludes that although this study found an association between fatally injured pilots flying without a medical certificate and increased evidence of such pilots using drugs with impairing effects, there has not been a corresponding increase in the proportion of accidents in which the NTSB determined that impairment contributed to the accident. The NTSB further concludes that the accident risk for pilots flying without a medical certificate cannot be accurately determined because the FAA does not collect information about the number of these pilots or their flight activity.

Petitions by pilot groups, proposed congressional action, and the FAA's recently announced rulemaking efforts on medical certification all suggest that this group of pilots will expand, if pilots will be allowed to fly a much wider range of aircraft without a medical certificate.[54] The NTSB believes that without collecting additional data, the FAA will be unable

[54] In March 2012, AOPA and the Experimental Aircraft Association filed a joint petition with the FAA to allow pilots to conduct certain flight operations without having to hold an FAA-issued medical certificate. See the AOPA and Experimental Aircraft Association petition to the FAA at http://www.aopa.org/-/media/files/aopa/home/news/allnews/2012/march/aopa_eaa_file_medical_exemption_petition/120319aopa-eaa-petition-for-exemption.pdf. The General Aviation Pilot Protection Act of 2013, H.R. 3708, 113th Congress, and the companion General Aviation Pilot Protection Act of 2014, S. 2103, 113th Congress, propose allowing pilots to use a valid state driver's license in place of the traditional medical certificate if the flights are not for compensation; conducted under visual flight rules, at or below 14,000 feet; no faster than 250 knots; and in aircraft with no more than 6 seats and no more than 6,000 pounds gross takeoff weight. The proposed legislation would also require the FAA to provide Congress with a report on the resulting impact on general aviation safety within 5 years of enactment. The FAA's rulemaking effort, "Limited Private-Pilot Privileges for Pilots Who Do Not Currently Hold an FAA Airman Medical Certificate

to accurately assess the safety of this group of pilots. The NTSB also believes that requiring pilots without a medical certificate to periodically identify themselves as active pilots and report a summary of recent flight hours would provide the FAA with the minimum information necessary to assess the accident risk of this group. The NTSB is aware that on February 4, 2014, the FAA initiated a rulemaking effort, "Private Pilot Privileges without a Medical," to consider expanding the group of flight operations exempt from medical certification requirements. This rulemaking effort will provide an opportunity to address this important limitation to its current oversight of airmen certification. Therefore, the NTSB recommends that the FAA require pilots who are exempt from medical certification requirements to periodically report to the FAA their status as an active pilot and to provide a summary of recent flight hours.

4.2.3 Guidelines for Prescribing Controlled Substances for Pain

This study found an increasing proportion of fatally injured accident pilots had toxicological evidence indicating they had used controlled substances. Although not all controlled substances are potentially impairing, the majority are, and they all have the potential for misuse and abuse. There is no reason to believe that pilots who are willing to fly after using controlled substances are unwilling to drive in the same condition, and the NTSB has investigated accidents and made recommendations regarding impairment by drugs and medical conditions across all the modes. Although no similarly extensive toxicology study is currently possible among operators in other modes of transportation, these results are consistent with data for the general US population, which shows that sales of opioids and other controlled substances have increased substantially over the past 15 years.[55] This makes it highly likely that a similar trend exists across other transportation operators.

Use of opioid pain relievers has contributed to a significant increase in the use of controlled substances over the last 20 years (The American Academy of Pain Medicine and the American Pain Society 1997). Opioids are also the largest contributor to the increased misuse of and fatal accidental overdoses from prescribed controlled substances. As a result, national guidelines for the prescription of chronic opioid therapy were developed by the American Pain Society and American Academy of Pain Medicine in 2009. These guidelines specifically recommend that "Clinicians should counsel patients on chronic opioid therapy about transient or lasting cognitive impairment that may affect driving and work safety. Patients should be counseled not to drive or engage in potentially dangerous activities when impaired or if they describe or demonstrate signs of impairment" (Chou and others 2009).

Some states have attempted to address misuse and overdose of opioids and other controlled substances by developing guidelines regarding prescribing these substances to treat painful conditions. Although some of these state guidelines include a specific recommendation that health care providers discuss transportation risks with patients when prescribing opioids or

(Private Pilot Privileges without a Medical)," was initiated on February 4, 2014. Information provided in the July 2014 Report on Significant DOT Rulemakings abstract for this effort states, "This rulemaking would consider allowing certain operations to be conducted by individuals exercising private-pilot privileges without holding a current FAA airman medical certificate. The intended effect of this action is to provide relief from having to obtain a medical certificate for pilots engaged in low-risk flying, such as private pilots operating a small, general aviation aircraft."

[55] For example, sales of prescription opioids more than tripled between 1999 and 2010 (Frieden 2013).

other controlled substances, others do not. For example, guidelines from Utah (Sundall 2009) and Washington (Washington State Agency Medical Directors Group 2010) discuss driving risks, but guidelines from Ohio (Ohio.gov 2013), Rhode Island (State of Rhode Island 2014), and Oregon (Oregon Medical Group 2014) do not. However, even when existing state guidelines address driving, they do not address risks in all modes of transportation.

The NTSB concludes that states' guidelines for health care providers regarding prescribing controlled substances for pain provide an opportunity to highlight the importance of discussing risks in all transportation modes when prescribing these medications. Therefore, the NTSB recommends that the 50 states, the District of Columbia, and the Commonwealth of Puerto Rico 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.

4.2.4 Communicating the Transportation Safety Risks of Potentially Impairing Drugs and Medical Conditions

Although states are attempting to address concerns about prescribing controlled substances for pain, most of the drugs found in the toxicology results in this study were OTC or non-opioid prescription medication. Whether operating a car, truck, aircraft, train, or marine vessel, individuals are responsible for determining whether they are sufficiently alert and healthy enough to do so. However, without information regarding the risks of drug use in transportation, an individual may be unable to make a reasonable safety assessment or decision.

Individuals may obtain information on risks associated with regular or occasional use of a drug from a variety of sources. Such sources include written instructions from a health care provider, the internet, the drug's package label or insert, or the drug's FDA medication guide when required.[56] However, people without medical training may find various forms of written drug information difficult to comprehend (Shiffman and others 2011) and instructions related to driving hard to understand and recall (Smyth and others 2013).

Health care providers, such as doctors, physician assistants, nurses, and pharmacists, are involved in the process of patients obtaining prescription drugs and may be involved in the choice of OTC drugs. These interactions are opportunities for patients and their health care providers to discuss the potential risks any drug or medical condition poses to transportation safety.

It is not known how often these issues are discussed as part of health care providers' communications with patients. Although the increase in use of all types of drugs is well documented in the general population, no similarly extensive study of toxicology results has been performed outside of aviation. Increasing evidence of pilots' use of potentially impairing drugs suggests that the current level of communication has not been sufficiently effective to

[56] Drugs identified with specific risks are required to have an additional set of information known as a "medication guide." A list of such drugs and links to the guides are available at http://www.fda.gov/drugs/drugsafety/ucm085729.htm.

prevent use of these drugs by pilots near the time of flight. There is no reason to believe that this issue is unique to aviation, and it is unlikely that operators in any other modes of transportation are any better informed. The NTSB concludes that current written and oral communications are not effectively informing patients about the risks their medical conditions and drug use may pose when operating a vehicle in any mode of transportation. Therefore, the NTSB recommends that the 50 states, the District of Columbia, and the Commonwealth of Puerto Rico 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.

4.2.5 Statement on Marijuana Policy

Although illicit drug use has historically been identified in only a small percentage of accident pilots, the results of this study indicate that marijuana use recently increased among fatally injured pilots. Illicit drug use is particularly concerning to transportation safety because, unlike typical therapeutic use of drugs in which impairment is often an undesired side effect, illicit drug users are often actively seeking the impairing effects of the drug. Not surprisingly, there is evidence showing that taking illicit drugs significantly elevates the risk of having an aviation accident.[57]

Even though the DEA defines marijuana as a Schedule I drug on its controlled substances list, some states have taken steps to allow the possession, sale, and use of marijuana within their borders. As of August 2014, marijuana has been approved for medical use in 23 states and the District of Columbia, decriminalized in 16 states and the District of Columbia, and legalized by Washington and Colorado (National Conference of State Legislatures 2014). In addition, National Survey on Drug Use and Health results indicate that marijuana use in the general population has increased over the last decade (SAMHSA 2013).

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, in this study, most pilots with toxicological evidence of marijuana use were not engaged in flight operations subject to DOT drug and alcohol testing requirements.

In addition to the general prohibition regarding civil aircrew members' drug use "contrary to safety," at 14 CFR 91.17, the FAA's medical certification regulations at 14 CFR 67.107, 67.207, and 67.307 identify substance dependence as a disqualifying condition and specifically include dependence on marijuana.[58] However, the FAA has no other specific

[57] Using data from random drug testing and postaccident testing among employees of 14 CFR Parts 121 and 135 air carrier operators, Li and others (2011) estimated that the odds of involvement in an aviation accident were increased 10-fold among pilots who tested positive for an illicit drug compared with those who did not test positive for drugs. The authors estimated that about 1.2% of commercial aviation accidents were attributable to illicit drug use.

[58] These regulations define dependence as "increased tolerance; manifestation of withdrawal symptoms; impaired control of use; or continued use despite damage to physical health or impairment of social, personal, or occupational functioning."

regulations or publically available policies regarding medical or recreational marijuana use by airmen who are not subject to routine DOT drug testing.

Based on data showing an increasing trend in marijuana use among adults in the United States in general, changing state laws and federal enforcement policies regarding marijuana use, and study results that indicate increasing prevalence of marijuana use among study pilots, the NTSB concludes that there is a gap in the FAA's policies regarding marijuana that may lead to confusion about the agency's position on marijuana use by pilots not subject to mandatory DOT drug and alcohol testing requirements. The NTSB therefore recommends that the FAA develop and distribute a clear policy regarding any marijuana use by airmen regardless of the type of flight operation.

4.2.6 Future Research Needs

This study examined trends in the prevalence of drugs used by pilots who died as a result of an aviation accident. The results indicate that fatally injured pilots are increasingly showing evidence of having used a wide variety of drugs. The increasing use of potentially impairing drugs, drugs that indicate potentially impairing medical conditions, controlled substances, and illicit drugs among fatally injured pilots as discussed in this study suggest a potentially serious aviation safety problem.

However, this study found no reliable relationship between the evidence of drug use and the circumstances of the fatal accident. The differences between the NTSB's determination of probable cause and the recent GAJSC analyses of NTSB data from loss-of-control accidents mentioned earlier in this report highlight the complexity of interpreting the relationships among evidence of a drug's use, its effects, the effects of underlying medical conditions, and the risk of a transportation accident.[59]

The next step in understanding the relationships between drug use and accidents is to compare the prevalence of drug use among fatally injured pilots with the prevalence in pilots flying without having an accident. 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 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.

The NTSB concludes that additional research is required to assess the complex relationship between pilots' use of drugs and associated accident risk. Therefore, the NTSB recommends that the FAA conduct a study to assess the prevalence of OTC, 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.

[59] See section 4.2.1, "Providing Pilots More Information about Potentially Impairing Drugs," of this report.

5 Conclusions

1. Findings of increasing drug use and increasing use of multiple drugs by fatally injured study pilots are indicative of similar trends in drug use by the US pilot population in general.

2. The overall risk of drug-related pilot impairment is increasing due to the growing use of potentially impairing drugs.

3. An increasing number of pilots are flying without a medical certificate and will likely make decisions about their medical fitness to fly, including use of drugs while flying, without periodic interaction with an Aviation Medical Examiner.

4. The Federal Aviation Administration does not provide pilots with adequate information to make informed decisions about which drugs are safe or unsafe to use while flying.

5. Federal Aviation Administration medical certification requirements and US Department of Transportation mandatory drug and alcohol testing requirements for safety-sensitive aviation personnel have been associated with fewer toxicological findings of impairing drugs and conditions among accident pilots subject to those requirements.

6. Although this study found an association between fatally injured pilots flying without a medical certificate and increased evidence of such pilots using drugs with impairing effects, there has not been a corresponding increase in the proportion of accidents in which the National Transportation Safety Board determined that impairment contributed to the accident.

7. The accident risk for pilots flying without a medical certificate cannot be accurately determined because the Federal Aviation Administration does not collect information about the number of these pilots or their flight activity.

8. States' guidelines for health care providers regarding prescribing controlled substances for pain provide an opportunity to highlight the importance of discussing risks in all transportation modes when prescribing these medications.

9. Current written and oral communications are not effectively informing patients about the risks their medical conditions and drug use may pose when operating a vehicle in any mode of transportation.

10. There is a gap in the Federal Aviation Administration's policies regarding marijuana that may lead to confusion about the agency's position on marijuana use by pilots not subject to mandatory US Department of Transportation drug and alcohol testing requirements.

11. Additional research is required to assess the complex relationship between pilots' use of drugs and associated accident risk.

6 Recommendations

As a result of this safety study, the National Transportation Safety Board makes the following recommendations:

To the Federal Aviation Administration:

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)

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)

Develop and distribute a clear policy regarding any marijuana use by airmen regardless of the type of flight operation. (A-14-94)

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)

To the 50 states, the District of Columbia, and the Commonwealth of Puerto Rico:

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)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Adopted: September 9, 2014

7 Appendix A: Drug and Metabolite Equivalents and Drug Categories Applied in this Study

Drug Category	Drug Identified by CAMI	Drug and Metabolite Equivalent	Common Brand or Trade Name(s)	Potentially Impairing	Potentially Impairing Condition	Controlled Substance
Antidepressants	Amitriptyline	Amitriptyline	Vanatrip, Elavil, Endep	*	*	
	Bupropion	Bupropion	Wellbutrin, Zyban	*	*	
	Bupropion Metabolite	Bupropion	Metabolite of Wellbutrin, Zyban	*	*	
	Citalopram	Citalopram	Celexa	*	*	
	Di-N-desmethylcitalopram	Citalopram	Metabolite of Celexa	*	*	
	N-Desmethylcitalopram	Citalopram	Metabolite of Celexa	*	*	
	Desipramine	Desipramine	Norpramin	*	*	
	Duloxetine	Duloxetine	Cymbalta	*	*	
	Fluoxetine	Fluoxetine	Prozac, Rapiflux, Sarafem	*	*	
	Norfluoxetine	Fluoxetine	Metabolite of Prozac, Rapiflux, Sarafem	*	*	
	Imipramine	Imipramine	Elavil	*	*	
	Mirtazapine	Mirtazapine	Remeron	*	*	
	Nortriptyline	Nortriptyline	Pamelor, Aventyl	*	*	
	Paroxetine	Paroxetine	Paxil, Brisdelle	*	*	
	Quetiapine	Quetiapine	Seroquel	*	*	
	Desmethylsertraline	Sertraline	Metabolite of Zoloft	*	*	
	Sertraline	Sertraline	Zoloft	*	*	
	Desmethylvenlafaxine (O-)	Venlafaxine	Effexor	*	*	
	Venlafaxine	Venlafaxine	Effexor	*	*	

Drug Category	Drug Identified by CAMI	Drug and Metabolite Equivalent	Common Brand or Trade Name(s)	Potentially Impairing	Potentially Impairing Condition	Controlled Substance
Anti-Infective Drugs	Chloroquine	Chloroquine	Aralen			
	Fluconazole	Fluconazole	Diflucan			
	Trimethoprim	Trimethoprim	Primsol, Trimpex, Proloprim			
Anti-Seizure Drugs	Carbamazepine	Carbamazepine	Carbatrol, Tegretol	*	*	
	Gabapentin	Gabapentin	Neurontin	*	*	
	Lamotrigine	Lamotrigine	Lamictal	*	*	
	Levetiracetam	Levetiracetam	Keppra	*	*	
	10-hydroxycarbazepine	Oxcarbazepine	Metabolite of Oxtellar, Trileptal	*	*	
	Oxcarbazepine	Oxcarbazepine	Oxtellar, Trileptal	*	*	
	Phenobarbital	Phenobarbital	Solfoton, Luminal	*	*	*
	Phenytoin	Phenytoin	Dilantin	*	*	
	Topiramate	Topiramate	Topamax	*	*	
	Valproic Acid	Valproic Acid	Depakene, Stavzor	*	*	
Benzodiazepines	Alpha-hydroxyalprazolam	Alprazolam	Metabolite of Xanax	*	*	*
	Alprazolam	Alprazolam	Xanax	*	*	*
	Chlordiazepoxide	Chlordiazepoxide	Librium	*	*	*
	Norchlordiazepoxide	Chlordiazepoxide	Metabolite of Librium	*	*	*
	7-Amino-clonazepam	Clonazepam	Klonopin	*	*	*
	Diazepam	Diazepam	Valium	*	*	*
	Nordiazepam	Diazepam	Nordaz and metabolite of Valium	*	*	*
	Oxazepam	Diazepam	Serax and metabolite of Valium	*	*	*
	Temazepam	Diazepam	Restoril and metabolite of Valium	*	*	*

Drug Category	Drug Identified by CAMI	Drug and Metabolite Equivalent	Common Brand or Trade Name(s)	Potentially Impairing	Potentially Impairing Condition	Controlled Substance
Benzodiazepines (continued)	Desalkylflurazepam	Flurazepam	Metabolite of Dalmane	*	*	*
	Lorazepam	Lorazepam	Ativan	*	*	*
Blood Thinners	Clopidogrel	Clopidogrel	Plavix			
	Salicylate	Salicylate	Metabolite of aspirin			
	Ticlopidine	Ticlopidine	Ticlid			
	Warfarin	Warfarin	Coumadin			
Cardiovascular Drugs	Amlodipine	Amlodipine	Norvasc			
	Atenolol	Atenolol	Tenormin			
	Benazepril	Benazepril	Lotensin			
	Bisoprolol	Bisoprolol	Zebeta			
	Carvedilol	Carvedilol	Coreg			
	Chlorthalidone	Chlorthalidone	Thalitone, Hygroton			
	Clonidine	Clonidine	Catapres, Kapvay			
	Diltiazem	Diltiazem	Cardizem			
	Doxazosin	Doxazosin	Cardura, Doxadura, Cascor			
	Flecainide	Flecainide	Tambocor		*	
	Furosemide	Furosemide	Lasix			
	Hydrochlorothiazide	Hydrochlorothiazide	Aquazide H, Hydrodiuril, Microzide			
	Irbesartan	Irbesartan	Avapro			
	Labetalol	Labetalol	Normodyne, Trandate			
	Losartan	Losartan	Cozaar			
	Metoprolol	Metoprolol	Lopressor, Toprol			
	Minoxidil	Minoxidil	Loniten			
	Moricizine	Moricizine	Ethmozine			

Drug Category	Drug Identified by CAMI	Drug and Metabolite Equivalent	Common Brand or Trade Name(s)	Potentially Impairing	Potentially Impairing Condition	Controlled Substance
Cardiovascular Drugs (continued)	Nadolol	Nadolol	Corgard			
	Nifedipine	Nifedipine	Adalat CC, Afeditab CR, Procardia			
	N-acetylprocainamide	Procainamide	Metabolite of Procan SR, Pronestyl		*	
	Procainamide	Procainamide	Procan SR, Pronestyl		*	
	Propranolol	Propranolol	Inderol			
	Quinidine	Quinidine	Quin-G, Cardioquin, Quinora		*	
	Sotalol	Sotalol	Betapace, Sorine			
	Triamterene	Triamterene	Dyrenium			
	Valsartan	Valsartan	Diovan			
	Norverapamil	Verapamil	Calan SR, Isoptin SR, Verelan			
	Verapamil	Verapamil	Calan SR, Isoptin SR, Verelan			
Cholesterol Lowering Drugs	Atorvastatin	Atorvastatin	Lipitor			
	Gemfibrozil	Gemfibrozil	Lopid			
	Pravastatin	Pravastatin	Pravachol			
	Rosuvastatin	Rosuvastatin	Crestor			
Diet Aids	Ephedrine	Ephedrine		*		
	Fenfluramine	Fenfluramine	Pondimin			*
	Phendimetrazine	Phendimetrazine	Plegine			*
	Phenmetrazine	Phenmetrazine	Adipost, Bontril			*
	Phentermine	Phentermine	Adipex-P			*

Drug Category	Drug Identified by CAMI	Drug and Metabolite Equivalent	Common Brand or Trade Name(s)	Potentially Impairing	Potentially Impairing Condition	Controlled Substance
Emphysema and Asthma Drugs	Montelukast	Montelukast	Singulair			
	Theophylline	Theophylline	Elixophyllin, Theo-24			
Illicit[a]	Tetrahydrocannabinol (Marijuana)	Cannabinoids	Marijuana	*		
	Tetrahydrocannabinol Carboxylic Acid	Cannabinoids	Metabolite of marijuana	*		
	Anhydroecgonine Methyl Ester	Cocaine	Metabolite of cocaine	*		
	Benzoylecgonine	Cocaine	Metabolite of cocaine	*		
	Cocaethylene	Cocaine	Metabolite of cocaine if ethanol present	*		
	Cocaine	Cocaine	Cocaine	*		
	Ecgonine Ethyl Ester	Cocaine	Metabolite of cocaine	*		
	Ecgonine Methyl Ester	Cocaine	Metabolite of cocaine	*		
	Amphetamine	Methamphetamine	Metabolite of methamphetamine when with other indications of methamphetamine	*		
	D-Methamphetamine	Methamphetamine	Methamphetamine	*		
	L-Methamphetamine	Methamphetamine	Indication of methamphetamine when with other indications of methamphetamine	*		
	Methamphetamine	Methamphetamine	Methamphetamine	*		
	Methylenedioxymeth-amphetamine (MDMA)	Methylenedioxymeth-amphetamine (MDMA)	Ecstasy	*		

[a] For the purposes of this study, drugs believed to have been used illicitly were not included in the controlled substance category. For details, see the "Expanded Methodology" in appendix C.

Drug Category	Drug Identified by CAMI	Drug and Metabolite Equivalent	Common Brand or Trade Name(s)	Potentially Impairing	Potentially Impairing Condition	Controlled Substance
Migraine Drugs	Butalbital	Butalbital	Fiorinal	*	*	*
	Ergotamine	Ergotamine	Ergomar		*	
Nausea And Vertigo Drugs	Cyclizine	Cyclizine	Bonine, Cyclivert, Marezine	*	*	
	Meclizine	Meclizine	Antivert	*	*	
	Metoclopramide	Metoclopramide	Metozolv, Reglan	*	*	
	Promethazine	Promethazine	Pentazine, Phenergan	*	*	
Nonsedating Over-the-Counter Drugs	Acetaminophen	Acetaminophen	Tylenol, Paracetamol			
	Cimetidine	Cimetidine	Tagamet			
	Dextromethorphan	Dextromethorphan	Robitussin			
	Dextrorphan	Dextromethorphan	Robitussin and metabolite of dextromethorphan			
	Nordextrorphan	Dextromethorphan	Metabolite of Robitussin			
	Famotidine	Famotidine	Pepcid			
	Azacyclonol	Fexofenadine	Metabolite of Allegra			
	Fexofenadine	Fexofenadine	Allegra			
	L-Methamphetamine	L-Methamphetamine	Vick's inhaler (assumed when no other indications of methamphetamine)			
	Lansoprazole	Lansoprazole	Prevacid			
	Loratadine	Loratadine	Claritin			
	Nizatidine	Nizatidine	Axid			
	Omeprazole	Omeprazole	Prilosec			
	Oxymetazoline	Oxymetazoline	Afrin			
	Pantoprazole	Pantoprazole	Protonix			
	Pseudoephedrine	Pseudoephedrine	Sudafed			
	Ranitidine	Ranitidine	Zantac			

Drug Category	Drug Identified by CAMI	Drug and Metabolite Equivalent	Common Brand or Trade Name(s)	Potentially Impairing	Potentially Impairing Condition	Controlled Substance
Nonsedating Pain Relievers	Fenoprofen	Fenoprofen	Nalfon			
	Ibuprofen	Ibuprofen	Advil, Motrin			
	Naproxen	Naproxen	Naprosyn			
	Salicylamide	Salicylamide	BC headache powder			
Oral Diabetes Drugs	Glipizide	Glipizide	Glucotrol, Glipizide			
	Pioglitazone	Pioglitazone	Actos			
Prescription Sleep Aids	Zolpidem	Zolpidem	Ambien	*		*
	Zopiclone	Zopiclone	Imovane	*		*
Prostate/Erectile Dysfunction Drugs	Alfuzosin	Alfuzosin	Uroxatral			
	Desmethylsildenafil	Sildenafil	Metabolite of Revatio, Viagra			
	Sildenafil	Sildenafil	Revatio, Viagra			
	Sildenafil Metabolite	Sildenafil	Metabolite of Revatio, Viagra			
	Tadalafil	Tadalafil	Adcirca, Cialis			
	Tamsulosin	Tamsulosin	Flomax			
	Terazosin	Terazosin	Hytrin			
	Yohimbine	Yohimbine	Erex, Testomar, Yocon			
Sedating Antihistamines	Brompheniramine	Brompheniramine	Dimetane, Bromax, Siltane	*		
	Cetirizine	Cetirizine	Zyrtec	*		
	Chlorpheniramine	Chlorpheniramine	Chlor-Trimeton	*		
	Diphenhydramine	Diphenhydramine	Benadryl, Unisom, Nytol	*		
	Doxylamine	Doxylamine	Aldex, Unisom, NyQuil	*		
	Hydroxyzine	Hydroxyzine	Atarax, Vistaril	*		
	Orphenadrine	Orphenadrine	Norflex	*		
	Pheniramine	Pheniramine	Delhist, Theraflu	*		

Drug Category	Drug Identified by CAMI	Drug and Metabolite Equivalent	Common Brand or Trade Name(s)	Potentially Impairing	Potentially Impairing Condition	Controlled Substance
Sedating Antihistamines (continued)	Phenylpropanolamine	Phenylpropanolamine	(no longer available)	*		
	Phenyltoloxamine	Phenyltoloxamine	Momentum, Percogesic	*		
	Triprolidine	Triprolidine	Zymine, Tripohist	*		
Sedating Pain Relievers	Buprenorphine	Buprenorphine	Subutex, Subaxone	*	*	*
	Norbuprenorphine	Buprenorphine	Metabolite of Subutex, Subaxone	*	*	*
	Carisoprodol	Carisoprodol	Soma, Vanadom	*	*	*
	Cyclobenzaprine	Cyclobenzaprine	Flexeril	*	*	
	Fentanyl	Fentanyl	Sublimaze	*	*	*
	Codeine	Hydrocodone	Codeine, metabolite of morphine, similar to hydrocodone	*	*	*
	Dihydrocodeine	Hydrocodone	Metabolite of hydrocodone	*	*	*
	Hydrocodone	Hydrocodone	Lortab, Vicodin, Norco	*	*	*
	Hydromorphone	Hydrocodone	Dilaudid and metabolite of hydrocodone	*	*	*
	Morphine	Hydrocodone	Avinza, Kadian, MS Contin and related to hydrocodone	*	*	*
	Meperidine	Meperidine	Demerol	*	*	*
	Normeperidine	Meperidine	Metabolite of Demerol	*	*	*
	Oxycodone	Oxycodone	Percocet, Roxicet, Tylox	*	*	*
	Pentazocine	Pentazocine	Talwin	*	*	*
	Norpropoxyphene	propoxyphene	Metabolite of Darvon, Dolene	*	*	*
	Propoxyphene	propoxyphene	Darvon, Dolene	*	*	*
	Tramadol	Tramadol	Ultram	*	*	*

Drug Category	Drug Identified by CAMI	Drug and Metabolite Equivalent	Common Brand or Trade Name(s)	Potentially Impairing	Potentially Impairing Condition	Controlled Substance
Other Drugs	Benzoylecgonine	Cocaine[b]	Metabolite of cocaine			*
	Cocaine	Cocaine[b]	C-Topical Solution			*
	Hydroxychloroquine	Hydroxychloroquine	Placquenil	*	*	
	Quinine	Quinine	Qualaquin, Quinamm			
Other Neurologic Drugs	Amphetamine	Amphetamine	Adderall (when no evidence of methamphetamine use)	*	*	*
	D-Amphetamine	Amphetamine	Metabolite of Vyvanse (when no evidence of methamphetamine use)	*	*	*
	Donepezil	Donepezil	Aricept	*	*	
	Methylphenidate	Methylphenidate	Ritalin		*	*
	Pramipexole	Pramipexole	Mirapex	*	*	
Other Psychotropic Drugs	Buspirone	Buspirone	Buspar, Vanspar	*	*	
	Doxepin	Doxepin	Sinequan	*	*	
	Nordoxepin	Doxepin	Metabolite of Sinequan	*	*	
	Meprobamate	Meprobamate	Equanil, Miltown	*	*	*
	Olanzapine	Olanzapine	Zyprexa	*	*	
	Secobarbital	Secobarbital	Seconal Sodium	*	*	*
	Trazodone	Trazodone	Oleptro, Desyrel	*	*	
	Varenicline	Varenicline	Chantix			

[b] Cocaine has a medical use as a numbing agent for mouth and nose procedures. It is a Schedule II controlled substance.

8 Appendix B: Drug Category Definitions

Throughout this study, chemical or generic drug names are not capitalized and drug brand names are capitalized. Drug brand names are the names given by the companies that make the drugs.

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 non-medical 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.

9 Appendix C: Expanded Methodology

This study focused on exploring trends in toxicology results based on drug categories rather than individual drugs. The study methodology had to address 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 over counting 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 study methodology was developed to simplify the data and ensure that identified drugs were not over counted.

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 had occurred, not every type of fluid or tissue was available in every case; what was available varied. For this study, 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. This indicates a longer period of time had elapsed between use of the drug and the toxicology testing than if the drug was 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 in the 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 testing 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 stand-alone drug under the brand name Restoril.

For this study, in order to prevent over counting the number of drugs identified, an equivalency table was created, equating the original drugs with their identified metabolites. Any duplicates were then 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 and this production 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 prior to a fatal accident.

In an initial screen of the data in this study, over 20% of the pilots had at least one positive toxicology result for an alcohol, most of which were likely due to postmortem production. The NTSB identified ethanol use as a probable cause or contributing factor in fewer than 2% of fatal US civil aviation accidents from 1990–2012. Given the complexities of interpreting the results of postmortem ethanol testing and the fact that this study was not designed to determine impairment at the time of the accident, ethanol and other alcohol toxicology results were excluded from further analysis in this report.

Postaccident Medical Treatment

In some study 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 (such as midazolam, marketed under the brand name Versed, and atropine, marketed under the brand names Sal-Tropine, AtroPen, and Atreza) that are only available in intravenous forms and are routinely used during resuscitation attempts. 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 a number of 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 indicated postaccident treatment were also identified, we assumed that the identified morphine was part of the treatment attempt and it was removed 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 prior to 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 investigation materials were reviewed for additional information. In two cases, the pilot's fentanyl was documented to have been from transdermal use prior to the accident; in the other cases, it was part of postaccident treatment and was removed from further analysis.

Phenytoin (marketed under the brand name Dilantin) was the last drug individually reviewed for its potential use during medical care. Phenytoin is an anti-epileptic used only to prevent or treat seizures or trigeminal neuralgia (other anti-epileptics may be used to treat other neuropathic pain syndromes and a number of psychiatric diseases).[62] However, it may also be used to prevent seizures in traumatically injured patients with head injuries. Each of the seven cases where phenytoin was identified was reviewed for associated drugs suggesting postaccident treatment and the accident narratives were also reviewed. In cases where the phenytoin was identified as postaccident treatment, it 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 over-the-counter drugs suggest 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, as 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 suggests 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 which may occur with neurologic symptoms. Among the cardiovascular drugs,

[62] *Trigeminal neuralgia* is an irritation of a facial nerve, which causes severe pain often described as a stabbing sensation.

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 5 Schedules based on the degree of potential for abuse and evidence for significant medical use.[63] 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 (MDMA), and marijuana. For the purposes of this study, 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 for analysis.

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.[64] 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. For the purposes of the study, when pilots had positive findings for both drugs, the amphetamine was equated to methamphetamine and categorized as illicit. Positive findings for amphetamine alone (without also finding methamphetamine) were categorized as an "other neurologic drug" and as a controlled substance.

Methamphetamine is a Schedule II, legally available but infrequently prescribed drug marketed under the brand name Desoxyn and used to treat obesity and attention deficit hyperactivity syndrome. This study differentiated licit versus illicit methamphetamine based on the fact that the methamphetamine molecule can be turned to the left or the right (left and right stereoisomers). Because the main form of legally available methamphetamine contains only the right hand form (the dextro-isomer) of the drug and no cases were found that included only that molecule, all of the cases involving both forms of methamphetamine were considered illicit for this study. However, the left hand form of methamphetamine is available topically in an OTC product intended to treat nasal congestion (Vick's Vapor Inhaler). In two cases in this study, L-methamphetamine was found only in small amounts without association with other forms of

[63] See the definitions of controlled substances by schedule at http://www.deadiversion.usdoj.gov/schedules/index.html.

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

methamphetamine. In these two cases, the finding was classified in the "nonsedating over-the-counter" category rather than the illicit category.

The last issue with these drugs was a single case where L-methamphetamine and L-amphetamine were both present without any other evidence of methamphetamine or amphetamine use. These two drugs are active metabolites of selegiline, a drug used to treat Parkinson's disease and dementia (marketed under the brand names Anipryl and Eldepryl). For this study pilot, the results were made equivalent and placed in the category of "other neurologic drug" and as indicating a "potentially impairing condition."

Cocaine also required special consideration in this study 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. All but two cases included other illicit drugs or levels that suggested nonmedical use of the cocaine and were therefore classified as illicit and potentially impairing. The two remaining cases were classified in the controlled substance category and not as potentially impairing.

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 made 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 reassess the likelihood of pilot impairment in any of the study cases. Instead, the results are intended to assess the future risk of accidents due to pilot impairment based on the prevalence and trends in drug use by pilots.

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