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JATE

Journal of Aviation Technology and Engineering 4:2 (2015) 20–31

Comparative Analysis of Accident and Non-Accident Pilots

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Abstract

The purpose of this study was to investigate potential differences between two pilot groups; the first was a sample of individuals who have not been involved in an accident and the second was a sample of pilots from the National Transportation Safety Board (NTSB) accident database. Factors investigated included flight time, pilot flight review status, pilot certification, employment as a professional pilot, gender, and age. This study was guided by the exigent literature on aviation accidents with a primary focus on general aviation pilot accident attributes. Non-accident pilot participation was solicited through various aviation-related websites and a total of 1,829 usable cases were collected. From the NTSB database, 19,821 cases were deemed to have all of the necessary variables for analysis. Mann-Whitney U tests found significant differences in age ($U = 9377426.5$, $p < 0.001$, $r = 0.233$) and flight time ($U = 5501468.5$, $p < 0.001$, $r = 0.356$). Logistic regression was then calculated to provide improved understanding of how the variables may be used to categorize pilots in accident and non-accident groupings. The model showed a significant improvement over random assignment (χ^2 [8] = 4912.89, $p < 0.001$) and was able to successfully identify 98.9% of accident pilots and 34.9% of non-accident pilots. Significant factors that were identified included that if an individual that was employed as a professional pilot (correlation value = −.388) or as his or her age decreased (correlation value = −.522), he or she is more likely to be within the accident pilot classification. The investigated variables showed some indication of predictive value and shed some insight onto what factors may be associated with accident risk. Suggestions for future research are also included.

Keywords: aviation, accident, human factors, general aviation, aircraft

About the Author

David C. Ison has been involved in the aviation industry for over 29 years, during which he has flown as a flight instructor for both regional and major airlines. He has experience in a wide variety of aircraft from general aviation types to heavy transport aircraft. While flying for a major airline, Ison was assigned to fly missions all over the world in a Lockheed L-1011. Most recently, he flew Boeing 737–800 aircraft throughout North and Central America. His true dream was to become an aviation educator, which led him to teach at the college level, first working as an associate professor of aviation for seven years at a small college in Montana. He is currently Research Chair, College of Aeronautics, and an assistant professor of aeronautics for Embry-Riddle Aeronautical University—Worldwide. Ison has conducted extensive research concerning unmanned aerial vehicles, aviation faculty, plagiarism in dissertations, statistics in aviation research, as well as the participation of women and minorities in aviation. His previous work has been published in refereed journals and has been presented at numerous education and industry conferences. Ison also is regularly published in popular aviation publications such as *Plane & Pilot, Professional Pilot*, and *IFR Refresher* and is author of the book titled *Oral Exam Guide: Aircraft Dispatcher* produced by ASA Publications. His educational background includes a master's in aeronautical science from Embry-Riddle Aeronautical University and a Ph.D. in educational studies/higher education leadership/aviation higher education from the University of Nebraska—Lincoln. Correspondence concerning this article should be sent to isond46@erau.edu.

http://dx.doi.org/10.7771/2159-6670.1103

Introduction

Each year millions of dollars and multiple lives are lost through the occurrence of general aviation accidents. According to the Aircraft Owners and Pilots Association's *Nall Report* (AOPA, 2012), in 2010 there were 1,377 general aviation accidents yielding a rate of 5.29 mishaps per 100,000 flight hours. Among these, 420 individuals lost their lives in 245 fatal accidents. Published annually, this report outlines the trends in accident rates, causes, and numerous case studies. Preliminary data from the National Transportation Safety Board (NTSB, 2014) indicated a spike in the accident rate, increasing to 6.78 per 100,000 hours. Although the general aviation accident rate fluctuates year to year, it has been relatively stable since 2001.

Of course, a significant amount of research has been conducted to help understand accident causes with the aim to bring about a reduction in loss of aircraft and lives. The Federal Aviation Administration (FAA, 2014) continuously advocates ways to assist in this process with their most recent publication calling for a reduction in general aviation accidents by 10% over the next decade. Numerous research studies have been conducted to better understand the causes of accidents to assist in the potential for reducing the incidence thereof. To this point, however, the overwhelming majority of such research has been retrospective—looking at accident reports and statistics to see if there are trends or connections within the data (Hunter, Martinussen, Wiggins, & O'Hare, 2011; Li, Baker, & Grabowski, 2001; O'Hare, Chalmers, & Scuffham, 2006; Platenius & Wilde, 1989; Wong, Pitfield, Caves, & Appleyard, 2006). Yet to truly understand what makes accident flights and pilots unique, a comparison must be made with those that have not been involved in such events. Unfortunately, few studies have touched on this methodology (Hunter, 2001; Li et al., 2001). This study sought to identify predictive values of pilot attributes in the likelihood that they may be involved in an aviation accident. In addition, this study aimed to identify differences that may exist between the attributes of pilots involved in aviation accidents and those who have not.

Overview of the Study

Since the inception of aviation, there have been mishaps. Simultaneously, the study of how to avoid such events has followed suit. A significant amount of research has been conducted to better understand why accidents occur and how to avoid them. The methodology in such research has been multifaceted. Much attention has been paid on the attributes of pilots, which is understandable as it is well known that the primary cause of aviation accidents involves human error (AOPA, 2012). Unfortunately, the majority of analyses have been one-sided in that only pilots involved in accidents have been studied (Hunter et al., 2011; Li et al., 2001; McFadden, 1996; Platenius & Wilde, 1989; Wong et al., 2006). In some cases, pilot judgment or actions in simulated conditions, either via simulation or survey, have been evaluated (Drinkwater & Molesworth, 2010; O'Hare et al., 2006; Pauley, O'Hare, Mullen, & Wiggins, 2008; Wiggins, Hunter, O'Hare, & Martinussen, 2012). However, little inquiry into the differences between individuals who have been involved in accidents has been compared to those who have not (Hunter, 2001; Urban, 1984). This has been indicated as a flaw in currently available research (Hunter, 2001; Hunter et al., 2011; Li, 1994).

Purpose of the Study

The purpose of this study was to investigate potential differences between the attributes of pilots involved in accidents and those who have not been involved. This required the collection of a database of pilots who have never been involved in an accident, which has previously not been conducted. This methodology has been advocated as a necessary means to identify, verify, and/or disprove differences among accident and non-accident pilots (Hunter, 2001; Hunter et al., 2011; Li, 1994).

Research Objectives and Research Questions

This study was guided by the following research questions:

1. What differences, if any, exist between the attributes of pilots involved in aviation accidents and those who have not been involved? The following attributes were selected:
   a. Flight time
   b. Pilot flight review status
   c. Pilot certificate
   d. Professional pilot employment
   e. Gender
   f. Age
2. What is the predictive value of pilot attributes in the likelihood they may be involved in an aviation accident? The following attributes were selected:
   a. Flight time
   b. Pilot flight review status
   c. Pilot certificate
   d. Professional pilot employment
   e. Gender
   f. Age

Significance of the Study

This study has the potential to provide a better understanding about pilot attributes of those who have been involved in accidents and those who have not. The majority of past research has focused only on the characteristics of pilots involved in accidents from a retrospective view. While certainly insightful, these studies lack the ability to make comparisons or predict potential traits of pilots who have been involved in accidents. As Hunter et al. (2011) noted, “there is no database of non-accident events for non-airline pilots that could be used to address” (p. 183) issues associated with studies of pilot accident involvement. Using a novel and research-based methodology of comparing non-accident and accident pilots, the study allowed for a true analysis of differences.

Review of Literature

General Aviation Accident Statistics

Between 2001 and 2010, there has been an average of 1,435 general aviation accidents. Among these, the average number of fatal events has been 277. In terms of accident rates among noncommercial fixed wing flights, the average number of accidents per 100,000 flight hours was 6.26 with a fatal rate of 1.23. For noncommercial helicopter flights, the rates were 8.44 and 1.19, respectively. In terms of trends, the total number of accidents has declined between this period, with 1,535 in 2001 and 1,259 in 2010. Among noncommercial fixed wing flights, the accident rate has increased from 5.79 to 6.30 and the noncommercial helicopter rates have decreased from 9.39 to 5.29. Fatal accident rates have remained stable with 1.13 in 2001 and 1.16 in 2010 for fixed wing types and 1.45 to 1.07, respectively, for helicopters (AOPA, 2012). The NTSB (2014) provides the most current statistics, from 2012, indicating the overall general aviation accident count as 1,471 and a total rate of 6.78. The fatal accident rate was indicated to be 1.24.

The *Nall Report* details the various causes and features of general aviation accidents. Over 70% are attributed to pilot-induced causes and 15% due to mechanical issues. More than 70% of accidents in 2010 were in single engine, fixed wing aircraft. Personal use flights accounted for 42% of flight activity yet were involved in 78% of accidents. Seventy-nine percent of fatal accidents in fixed wing aircraft were conducted for nonbusiness purposes. Only 3% of events and 6.5% of fatalities occurred on business flights. The majority (86.2%) took place in good weather (Visual Meteorological Conditions [VMC]) and during the day, whilst 8.4% took place in VMC night. In poor weather (Instrument Meteorological Conditions [IMC]), 4% occurred during the day and just over 1% took place at night. Most accidents occurred during landing (361), with take-off and climb ranking second (142). Most fatal fixed wing accidents happened while maneuvering (31). Weather-related and take-off and climb were tied in second with 28 fatal events each (AOPA, 2012).

Some pilot attributes are also reported in the *Nall Report*. Most accidents (49.1%) were conducted with individuals holding a private pilot certificate. Second in incidence were commercial pilots (28.2%), followed by Airline Transport Pilots (ATPs) (13.7%), and student pilots (5.7%) (AOPA, 2012). The distribution of accidents does not align with that of certificates held by pilots. Considering that 20% of pilots hold a student certificate, these individuals have a disproportionally low accident occurrence. Conversely, private pilots represent 30.8% of certificates held but have a much higher rate of accidents (FAA, 2012). The *Nall Report* does not detail other pilot attributes such as demographics or flight experience (AOPA, 2012).

Studies of Pilot Attributes Associated with Accident Factors

While the *Nall Report* provides insightful data about general aviation safety, it does not provide any statistical tests of comparison or relationship and only provides a cursory explanation of accident causes and the pilots involved in them. In order to better describe and understand general aviation misfortunes, a number of studies have attempted to provide more inquiry into and an explanation of such events. As pilots are at the heart of the majority of accidents, a significant amount of research has been conducted on the characteristics of such individuals. Wiegmann, Goh, and O’Hare (2002) found that pilots with higher experience (total flight time) were less likely to continue flight into deteriorating weather. In an assessment of pilot risk factors, Drinkwater and Molesworth (2010) found no significant differences in experiential and demographic descriptors among pilots. These included all types of evaluated risk measures including general flight risk, risk orientation, safety orientation, and self-confidence. Using a simulated flight event, however, there was a negative correlation between age and the willingness of a pilot to descend in deteriorating conditions, potentially increasing risk of impact with terrain. Not surprisingly, there was a positive correlation between age and flight experience (Drinkwater & Molesworth, 2010).

Wiggins et al. (2012) studied pilots who either inadvertently or purposefully entered IMC while trying to fly visually. Looking at self-reported mean risk perception scores of 251 pilots, the study determined that there was no difference between pilots who either inadvertently or deliberately entered IMC. Yet among pilots with and without instrument ratings, there was a difference detected between inadvertent and deliberate entry of IMC conditions with those without the rating having a higher likelihood of taking part in such a risky behavior. Some reasons why pilots may continue point to perceptions about the speed at which weather conditions change or the inability to perceive changes in weather. This was noted to be likely attributable to experience with poor weather being higher among instrument rated pilots (Wiggins et al., 2012).

Li et al. (2001) studied factors associated with pilot error in crashes. The authors determined that "in contrast to the widely accepted notion that pilot error is entirely an intrinsic phenomenon of human behavior, [it was found] that extrinsic attributes [. . .] are important to pilot error as well" (p. 52). Multivariate logistic regression was used to analyze factors that may be associated with pilot error in crashes. Poor weather and airport location were found to be significant predictors. Also, pilot error decreased with higher pilot certifications, but did not vary with pilot age or gender. Among general aviation accidents, pilots with higher flight time were less likely to commit pilot error in crashes. Insignificant results in pilot error rates among major airline and other commercial operations were found in Chi-square comparisons of pilot age, flight time, and certificate level. Within general aviation occurrences, though, there were significant differences in pilot gender ($\chi^2 = 12.1$, $p < 0.001$), flight time ($\chi^2 = 480.3$, $p < 0.001$), and certificate level ($\chi^2 = 330.3$, $p < 0.001$). It is important to note that significant results due to gender from a Chi-square analysis are misleading as there are so few female pilots and therefore it is understandable that accident counts involving such pilots is significantly lower (Li et al., 2001). Female pilots were found to significantly differ from males in terms of flight time when involved in pilot error events, as females have lower experience levels ($p < 0.001$).

Pauley et al. (2008) investigated differences in pilot attributes of participants in risk and anxiety assessments related to hazardous events. Inter-correlations evaluated using the Hazardous Events Scale (HES) and the Implicit Association Test (IAT). There was a negative association of HES ($-.50$, $p < 0.05$), Risky IAT ($-.40$, $p > 0.05$), and Anxiety IAT ($-.54$, $p < 0.05$) scores and pilot age. Weak and insignificant correlations existed between flight time and HES (.12), Risky IAT ($-.17$), and Anxiety IAT (.00) (all $p > 0.05$). Thus, older pilots tended to have lower risk scores while higher flight time did not provide substantial protection from risk (Pauley et al., 2008).

In a study of pilot characteristics, risk perception, HES, and judgment, Hunter et al. (2011) utilized a 53-question survey of 364 pilots to assess attributes of those involved in no-weather, near-weather, and in-weather events. No significant difference was found among groups in terms of total pilot time ($F[2, 364] = 1.30$, $p = .27$), but there were significant findings in terms of pilot age ($F[2, 364] = 4.03$, $p = .01$). Pilots with the highest flight time indicated near-weather acceptance while the difference between in-weather and no-weather types was negligible. Younger pilots seemed more inclined to conduct risky in-weather flight. No difference existed among groups in terms of risk perception ($F[2, 329] = 0.26$, $p = .77$), but were significant for HES ($F[2, 364] = 4.51$, $p = .01$) and judgment ($F[2, 153] = 4.04$, $p = .02$). Higher judgment scores were associated with weather avoidance as were lower scores on the hazardous event acceptance scale.

Comparing Pilot Groups

Also within the literature, some comparative studies exist that attempt to identify pilot attributes that may contribute to the chance they may be involved in an accident. In O'Hare et al. (2006), the factors associated with the involvement in fatal and nonfatal accidents were evaluated. Twelve pilot variables were included in addition to aircraft characteristics and operational factors. An analysis of pilot flight time revealed that those with less than 1,000 hours had a case fatality rate of 5.1% and those with 1,000 or more hours had a rate of 16.7%. The resultant odds ratio (OR) was determined to be 3.72 (adjusted OR 1.67), meaning those with more flight time had a higher likelihood of fatal accident occurrence. The purpose of flight also showed differences in groupings with a 33.3% case injury rate for transport flights, 36.4% for nonagricultural aerial work flights, and 15.3% in other types of operations. The odds ratio was 5.00 (adjusted OR 7.46) for transport flight and 5.71 (adjusted OR 4.73) for aerial work. None of the demographic factors evaluated yielded statistically significant results other than experience (O'Hare et al., 2006).

Another comparative study involved the evaluation of differences between male and female pilots. According to McFadden (1996), "the physical, physiological, and psychological differences between males and females may affect their ability to endure the stresses of flight" (p. 443). As noted in the study, numerous reviews have investigated differences in age, recent flight time, and total flight time. In this study, it was determined that females had lower accident incidence than males. It was also noted that flight time is a confounding issue, as pilots with higher flight time have more accident exposure; thus, the conclusion that higher flight time equates with higher accident rates is not necessarily a valid correlation. This particular study controlled for age, experience, and professional occupation as a pilot. No significant differences were found between males and females, concluding neither group is safer than the other.

Platenius and Wilde (1989) studied the personal characteristics of accident histories of Canadian pilots. This study allowed for the "assessment of the degree to which self-reported personal characteristics statistically associated with past accidents can be used to predict new accidents in the future" (p. 42). The model developed in this research was able to correctly classify accident involvement with the self-reported items. Some significant items included participation in risky hobbies, life events, risk acceptance, and involvement in auto accidents. This investigation did involve a comparison between accident and non-accident pilots, thus providing an improved analysis of potential differences in mishap pilot characteristics.

Comparing novice and "expert" pilots, Thomson, Onkal, Avcioglu, and Goodwin (2004) sought to identify risk perceptions in helicopter operations. Demographic, gender, and background factors were utilized to evaluate differences that were purported to "have been found to strongly correlate with risk judgments, and are likely to affect judgments of both experts and lay persons" (p. 1586). The risk perceptions of expert pilots were found to be lower than those of novices. Also, "experts' perceptions of risk are more veridical than those of novices in terms of their higher correlation with the true relative frequencies" (p. 1593). It was also found that increased flight time improved task performance, although this was also found to expert "pilots' choices toward risky alternatives, a potential result of their overconfidence based on improved task performance" (p. 1593). Novice pilots were most influenced by stress and crew coordination while expert pilots were more impacted by task-oriented factors such as controllability, altitude, night flight, and centrality. The findings of this study indicate that increased experience does not necessarily provide a protective effect from risk.

Taking a retrospective and prospective perspective, Hunter (2001) distributed a national survey of pilots to "examine the validity of measures for the prediction of aviation accidents that had occurred prior to the survey (retrospective analysis) and accidents that occurred after the survey (prospective analysis)" (p. 509). Variables included age, gender, education, attitudes toward flying, flight experience, and accident involvement. The 1999 NTSB accident database was used to identify non-accident and accident pilots as well as later (5.5 years after the survey) accident involvement. Significant results were found in pilot age ($t = -2.28$, $p < 0.05$), flight time ($t = -2.77$, $p < 0.05$), type of flying (pleasure) ($t = -2.70$, $p < 0.05$), as well as hazardous events, personal minima, opinions about flying, and hazardous attitude factors (standard t test reporting was not possible due to the presentation of the data) (Hunter, 2001). As has been reported in previous studies, "exposure, when measured any number of ways, is associated with accident involvement" (Hunter, 2001, p. 518) including age and flight time.

Although the majority of available literature has ignored the identification of non-accident pilot attributes, there were two studies that were closely aligned with this research inquiry. The first was conducted by Urban (1984) in which a comparative analysis of pilot characteristics of accident and non-accident general aviation pilots was conducted. Urban (1984) examined "the existence of possible relationships between a number of sociological concerns the incidence of general aviation accidents" (p. 308). The study utilized nonmilitary pilots who were actively flying in the Denver, Colorado metropolitan area. Urban (1984) did not report the details of the statistical findings in terms of standard reporting of results, but the text revealed some connections between pilot attributes and accident incidence. Marital status, children, religious involvement, and volunteer activity did not appear to be related to accident involvement. Pilot education revealed to have a weak positive influence on accident occurrence. Flight-related variables did have significance in the analysis. Pleasure flying and flight time did not play a noteworthy factor; however, flying for business purpose did show significance. Other significant factors were high levels of education, professional flight (flying as an occupation), high activity in nonflying aviation events, and those who have not been involved in aviation for a long period were found to be more likely to be involved in general aviation accidents.

The second was an inquiry conducted by Hunter (1995) that implemented an airman research questionnaire to identify attributes of the U.S. pilot population. The researcher used the FAA airman certification system database to identify 19,657 pilots out of the total population of 561,486 subjects to which a survey was mailed. Of the 6,808 returned surveys, 6,735 were usable. Among the respondents, 97% were not involved in an accident. The distribution of pilot certificates was 39.5% private pilot, 42.2% commercial pilot, 18.1% ATP, and 0.2% other. The sample yielded an overwhelmingly male (96.7%) response. The mean age was determined to be 50 and the average total flight time was 3,340 hours. The survey detailed various aspects of training history, employment history, involvement in hazardous events, and the types of aircraft flown. It also detailed personal minimums for risk assessment in visual flight conditions. Overall, this study appeared to provide a fairly comprehensive snapshot of the average pilot population; however, comparisons between accident and non-accident pilots were not made in this study.

Method

A correlational research methodology was utilized in order to gain insight into the potential relationships between accident and non-accident pilot characteristics. According to the Education Commission of the States (2004), this method is appropriate in identifying statistical association among variables utilizing regression techniques. Logistic regression was utilized due to the dichotomous nature of the outcome variable (accident versus non-accident cases) (University of Montana, 2010). This model was constructed through the comparison of the attributes of pilots who responded to an online survey (non-accident individuals) with those involved in accidents that were randomly collected from the National Transportation Safety Board accident database. Additional tests for differences and associations were conducted on subparts of the data using a Mann-Whitney U test.

Subject Characteristics

The non-accident pilots were solicited through *Flying* magazine, *AvWeb* aviation news website, and AOPA's website. These outlets were selected due to their willingness to assist in the research as well as the fact that they cater to the general aviation audience. A total of 2,363 respondents replied to the survey. Among these, 1,995 (84%) indicated that they have never been in an aircraft accident and 368 (16%) indicated that they were involved in an accident. From the non-accident sample, 1,829 cases had all of the necessary data for analysis. Accident cases were downloaded from the NTSB database yielding 77,863 data points. Due to incomplete records and incomprehensible coding schemes, only 19,821 cases were usable for analysis.

Sampling Procedures

All usable non-accident cases were used from the collected surveys, whilst all data points with all applicable data and usable coding were used for NTSB cases.

Sample Size/Power/Precision

Previous research in pilot attributes utilizing regression analysis were used to guide an *a priori* sample size calculation using G*Power software. Typical odds ratios were pulled from Li et al. (2001) as a guide. From this, a recommended minimum sample size of 215 was garnered for this research. The available data exceeded these requirements. While this exceeds the initial power needs of this research, it was determined that in case of odds ratios close to 1.00, as have been noted in previous research, larger number of data points should be used (Li et al., 2001). For the Mann-Whitney *U* test (assuming small effect size), a minimum total sample size of 2,652 was dictated, which was met by the sample culled for this study.

Measures

A survey to collect pilot attributes was designed by the researcher. Utilizing the survey design and testing process outlined by Ison (2011), it was reviewed by industry and research experts for feedback, which were incorporated in the pilot of the survey. This version was sent out to 20 nonparticipants for testing. Feedback from this process was included in the final version, which was released via Survey Monkey. The findings presented through this survey are more comprehensive than the available NTSB records. For the purposes of making this dataset available to the research community, all findings are included in summary format in the results section.

Pilot total flight time was reported in hours in both the survey and the NTSB results. If a pilot had completed a flight review (i.e., was current per the flight review guidelines in the CFR), the response was yes (coded 1) and if he or she was not current, the response was no (coded 0). Pilot certifications were coded 0 for none or student, 1 for private pilot, 2 for commercial, and 3 for ATP (Note: Due to the poor coding of the NTSB database, the researcher was unable to determine the numbers of recreational and sport pilots involved in accidents, therefore this was omitted from this research. Because these groups still form a very small percentage of the pilot population, less than 1% according to FAA records, this was deemed an acceptable practice for the purposes of this research [FAA, 2012]). Pilot primary occupation was reported as no (primary occupation was not as a pilot, coded 0) and yes (primary occupation was as a pilot, coded 1). Pilot gender was reported as male (coded 0) and female (coded 1). Age, reported in years, was utilized for analysis.

Research Design

Nonparametric analysis was used for testing of differences, as it was apparent that the data sets did not conform to the normality assumptions needed for such testing. Mann-Whitney *U* tests were conducted on pilot age and total flight time to determine if differences existed between accident and non-accident groups. Logistic regression was used to determine potential relationships among pilot attribute variables between those involved in an accident and those who have not experienced such events.

Results

Survey Results—General

The survey data was analyzed through the Survey Monkey interface, which yielded a wide range of data concerning individuals who were not involved in accidents. The average number of total flight hours among non-accident pilots was 4,139 (n = 1,995) and the average number of hours flown in the last 90 days was 31 (n = 1,995). Among responses, 1,743 (87.4%) respondents stated they had a current flight review, whilst 252 (12.6%) did not. For the distribution of highest pilot certification held, the majority of respondents held an airplane category rating (94.5%). Among the airplane class ratings held, 1,819 (96.5%) had a single engine land rating, 817 (43.3%) had a multiengine land rating, 265 (14.1%) had a single engine sea rating, and 29 (1.5%) had a multiengine sea rating (n = 1,995). A breakdown of the certifications is displayed in Table 1.

For other types of certification, 168 (8.4%) had a glider rating, 114 (5.7%) had a rotorcraft rating, 15 (0.75%) had a lighter-than-air rating, and 11 (0.55%) had additional ratings such as weight shift, powered parachute or powered lift. Almost three-fourths of respondents held an instrument rating (1,426 [71.5%]) of which 935 (65.5%) were instrument current at the time of the survey. Only a third (29.4%) had a certified flight instructor (CFI) and 531 (26.7%) held some form of aircraft type rating (n = 1,995).

Table 1
Highest pilot certificate held.

Pilot Certification	Number of Responses	Percentage of Respondents
ATP	387	19.4
Commercial	615	30.8
Private	936	46.9
Recreational	3	0.15
Sport	17	0.85
Student	32	1.6
None	5	0.30

Among respondents, 334 (16.7%) stated that their primary means of employment was working as a pilot (n = 1,995). Most pilots stated that they had received training experience conducted under Part 61 (1,757 [88%]), followed by Part 141 (682 [34.1%]), military (387 [19.3%]), and other (442 [22.1%]) (Note: Pilots can receive training under more than one set of regulations, thus the percentages do not add up to 100%) (n = 1,995).

In terms of demographics, 1,909 (95.8%) indicated they were male, 75 (3.8%) were female, and 8 (0.4%) preferred not to answer (n = 1,992). The average age reported was 55 years (n = 1,960). (Note: The sample sizes varied among groups of data based on some surveys being incomplete or missing data. Only those surveys that were completed in their entirety were utilized in the subsequent analysis).

Survey Results versus NTSB Database—General

Data from the survey and the NTSB database were analyzed to provide statistical descriptive measures. Table 2 provides the mean, median, variance, and standard deviation for hours of accident and non-accident groups. Table 3 provides the mean, median, variance, and standard deviation for ages of accident and non-accident groups.

Both Kolmogorov-Smirnov and Shapiro-Wilk tests of normality indicated non-normal distributions, although the histogram and QQ plots for ages indicated relatively normal distributions. Therefore, nonparametric analysis (Mann-Whitney U) was selected for these groups.

Cross-tabulations were conducted to evaluate the distributions of flight review status (Table 4), certification (Table 5), professional pilot occupation (Table 6), and gender (Table 7). As can be seen in Table 4, the percentage of accident pilots who had completed a flight review was higher than that of non-accident pilots. Significance of these differences is discussed later in this section. Overall, the majority of all pilots had a current flight review.

Table 2
Descriptive statistics for accident and non-accident groups—hours.

	Accident (NTSB)	Non-Accident (Survey)
Mean	790.7	4,087.9
Median	50	1,300
Variance	6,095,069.2	103,378,261.8
Std. Deviation	10,167.5	2,468.8

Table 3
Descriptive statistics for accident and non-accident groups—ages.

	Accident (NTSB)	Non-Accident (Survey)
Mean	43.2	55.1
Median	42	57
Variance	169.5	186.8
Std. Deviation	13.01	13.67

The highest percentage of accident pilots held a private pilot certificate (47%), closely followed by those that had no or a student pilot certificate (38.5%). The non-accident group had a concentration in higher certifications (e.g., commercial and ATP) than the accident groups, both groups have similar percentages of private certificated pilots, and the non-accident group had a much smaller percentage of non-student-certificated pilots. Further analysis of these findings can be found in subsequent sections.

The majority (82.9%) of non-accident pilots were not employed professionally as pilots, while the distribution was more even among accident pilots, albeit slightly more individuals were not professional pilots (52.4%) versus those that were (47.6%). The significance of this data is analyzed in the successive results sections.

A lower percentage of accident pilots were female (2.6%) than those among the non-accident group (3.9%). A breakdown of the percentages can be found in Table 7, and the significance of the findings is described in the subsequent findings sections.

Survey Results and NTSB Database—Comparison of Cases

Differences

A comparison of pilot age between non-accident (Mdn = 57) and accident pilots (Mdn = 42) revealed a significant difference: $U = 9377426.5$, $p < 0.001$, $r = 0.233$. See Tables 8 and 9 for a summary of results.

Table 4
Cross-tabulation—flight review status.

			Group		
			Non-Accident	Accident	Total
FltRev	No	Count	228	1189	1417
		% within FltRev	16.1%	83.9%	100.0%
		% within Group	12.5%	6.0%	6.5%
		% of Total	1.1%	5.5%	6.5%
	Yes	Count	1601	18632	20233
		% within FltRev	7.9%	92.1%	100.0%
		% within Group	87.5%	94.0%	93.5%
		% of Total	7.4%	86.1%	93.5%
Total		Count	1829	19821	21650
		% within FltRev	8.4%	91.6%	100.0%
		% within Group	100.0%	100.0%	100.0%
		% of Total	8.4%	91.6%	100.0%

Table 5
Cross-tabulation—certification.

			Group		
			Non-Accident	Accident	Total
Certification	None/Student	Count	33	7632	7665
		% within Certification	0.4%	99.6%	100.0%
		% within Group	1.8%	38.5%	35.4%
		% of Total	0.2%	35.3%	35.4%
	Private	Count	880	9313	10193
		% within Certification	8.6%	91.4%	100.0%
		% within Group	48.1%	47.0%	47.1%
		% of Total	4.1%	43.0%	47.1%
	Commercial	Count	556	2211	2767
		% within Certification	20.1%	79.9%	100.0%
		% within Group	30.4%	11.2%	12.8%
		% of Total	2.6%	10.2%	12.8%
	ATP	Count	360	665	1025
		% within Certification	35.1%	64.9%	100.0%
		% within Group	19.7%	3.4%	4.7%
		% of Total	1.7%	3.1%	4.7%
Total		Count	1829	19821	21650
		% within Certification	8.4%	91.6%	100.0%
		% within Group	100.0%	100.0%	100.0%
		% of Total	8.4%	91.6%	100.0%

The comparison of pilot total flight time also yielded significant differences between the non-accident (Mdn = 1,300) and accident groups (Mdn = 50): $U = 5501468.5$, $p < 0.001$, $r = 0.356$. See Tables 10 and 11 for a summary of results.

Relationships and prediction

Logistic regression with forced entry method, as recommended by Field (2009), was calculated to determine the potential influences the factors identified in this study may have on the likelihood of accident occurrence among pilots. The initial analysis omnibus tests of model coefficients indicated significant influences ($p < 0.001$) by all variables except commercial pilot certification ($p = 0.355$). Gender was also deemed significant, but at $p = 0.001$. The model was deemed to be a significant improvement over the initial "guess" by SPSS (χ^2 [8] = 4912.89, $p < 0.001$). The initial -2 Log likelihood (-2 LL) was 12538.722, which gradually reduced with each step until step 7, where it remained the same for step 8. The final -2 Log likelihood was 7625.827. Note that -2 Log likelihood (-2 LL) is similar to aggregate sums of squares in regression. If the logistic regression model improves the ability to predict the dependent variable, the -2 LL will decrease. This reduction is then evaluated for statistical significance (University of Texas, n.d.). Although the analysis showed a significant Hosmer and Lemeshow test (χ^2 [8] = 33.474, $p < 0.001$), this was not deemed unusual in cases with large sample sizes, such as in this study, per the University of Strathclyde (2014). The Cox and Snell R^2 was 0.203 and the Nagelkerke R^2 was 0.462, the latter which is recommended by Field (2009) for interpretation purposes. The model classification

Table 6
Cross-tabulation—professional pilot occupation.

			Group		
			Non-Accident	Accident	Total
PilotOccup	No	Count	1517	10384	11901
		% within PilotOccup	12.7%	87.3%	100.0%
		% within Group	82.9%	52.4%	55.0%
		% of Total	7.0%	48.0%	55.0%
	Yes	Count	312	9437	9749
		% within PilotOccup	3.2%	96.8%	100.0%
		% within Group	17.1%	47.6%	45.0%
		% of Total	1.4%	43.6%	45.0%
Total		Count	1829	19821	21650
		% within PilotOccup	8.4%	91.6%	100.0%
		% within Group	100.0%	100.0%	100.0%
		% of Total	8.4%	91.6%	100.0%

Table 7
Cross-tabulation—gender.

			Group		
			Non-Accident	Accident	Total
Gender	Male	Count	1757	19297	21054
		% within Gender	8.3%	91.7%	100.0%
		% within Group	96.1%	97.4%	97.2%
		% of Total	8.1%	89.1%	97.2%
	Female	Count	72	524	596
		% within Gender	12.1%	87.9%	100.0%
		% within Group	3.9%	2.6%	2.8%
		% of Total	0.3%	2.4%	2.8%
Total		Count	1829	19821	21650
		% within Gender	8.4%	91.6%	100.0%
		% within Group	100.0%	100.0%	100.0%
		% of Total	8.4%	91.6%	100.0%

information is found in Table 12. The regression model was able to correctly identify 98.9% of pilots involved in accidents and 34.9% of non-accident pilots, with an overall model predictive ability of 93.5%; however, this is only a marginal improvement over the original 91.6% calculated prior to the implementation of predictive variables. The correlations among variables are displayed in Table 13.

Within the constant column/row, a negative correlation value indicates that the variable is positively associated with the accident pilot classification, while positive values indicate that the variable is negatively associated with the accident pilot classification. For example, an individual that is employed as a professional pilot (correlation value = −.388), or as his or her age decreases (correlation value = −.522), he or she is more likely to be within the accident pilot classification. Other correlation values follow conventional interpretations thereof.

Discussion

The results provide some potentially insightful findings about the differences between the non-accident and accident pilot populations. The mean number of flight hours is significantly lower among accident pilots, indicating that the lack of flight experience can have a significant negative impact on the ability to identify or avoid dangerous situations. Alternatively, it can possibly indicate the lack of skill, ability, or knowledge to deal with challenging flight conditions. This notion is further supported by the fact that a much larger percentage of accident pilots fell into the no or student pilot certification classification. This is in agreement with the findings of Li et al. (2001) in which pilot error appeared to decrease with higher certifications. However, the findings of this study are contrary to Li et al. (2001), Pauley et al. (2008), Hunter et al. (2011), and Tomson et al. (2004), which all concluded that flight time did not provide a protective effect on accident involvement or that higher flight time can be linked to lower pilot error accident rates. Also, O'Hare et al. (2006) found that fatal accidents were more likely among pilots with higher flight time. Some caution should be noted in evaluating flight time data due to the very large variance noted in both accident and non-accident groups. In particular, the accident group variance was especially large, notating a wide range of flight time values within the group.

The flight review status of accident pilots being higher than non-accident types initially appears to be counter-intuitive as one may expect that pilots who lack recent experience may be more likely to be involved in mishaps. However, this supports the notion of exposure; thus pilots who fly more often and are, therefore, more likely to have completed a flight review, and may have a higher incidence of accident occurrence. Moreover, it is likely a matter of legality. Technically, pilots who have not completed a flight review should not legally be acting as pilot in command; therefore, "law abiding" pilots would reasonably not be flying, and thus unable to be involved in an accident.

There was also a significant difference in the ages of pilot groups with the accident classification having a lower mean age. This seemingly aligns with the conclusion by Pauley et al. (2008), which described lower accident risk

Table 8
Ranks—age.

	Group	N	Mean Rank	Sum of Ranks
Age	.00	19821	10384.11	205823357.50
	1.00	1829	15608.92	28548717.50
	Total	21650		

Table 9
Test statistics—age.

	Age
Mann-Whitney U	9377426.500
Wilcoxon W	205823357.500
Z	−34.216
Asymp. Sig. (2-tailed)	.000

Table 10
Ranks—total flight time.

	Group	N	Mean Rank	Sum of Ranks
Hours	Accident	19821	10188.56	201947399.50
	Non-accident	1829	17728.09	32424675.50
	Total	21650		

scores among older pilots. As is often the case, younger pilots tend to have lower flight time and certification levels, thus the conclusion that more of these pilots may be involved in accidents. This is again supported by the data indicating the relatively large percentage of pilots that were involved in accidents fell into the no or student pilot certifications as well as the private certification level.

Interestingly, the percentage of pilots involved in accidents that were employed as professional pilots was significantly higher than those that were not involved in accidents. This could be an anomaly of the sample, as many of the pilots who may be in contact with the various means of solicitation for participation in the survey may be leisure pilots. It may also be explained by the fact that persons employed as pilots fly more often, therefore potentially exposing them to be involved in an accident. Several other studies have noted that pilots with higher flight time or that are older may have higher accident incidence simply from exposure to flying more (Hunter, 2001; Tomson et al., 2004).

There was a significant difference detected in the gender of pilots in relation to accident involvement. Data indicated that female pilots had a higher likelihood of falling within the non-accident group. Due to the low numbers of female pilots in general and within the samples, conclusions from such findings should be viewed guardedly. With this in mind, however, the findings here match those presented by McFadden (1996).

The logistic regression model developed in this study did show an improvement in accident categorization vis-à-vis to random assignment. Both the Chi square evaluating the model as well as the reduction in -2 Log likelihoods indicates that model was able to make improvements on identifying classifications. With a Nagelkerke R^2 of 0.462, it can be concluded that the amount of variance in the dependent variable explained by the model's predictor variables is 46.2%. The model was able to correctly identify 98.9% of accident pilots and 34.9% of non-accident pilots. Although the classification ability of non-accident pilots was weaker than had been hoped, the model provides some awareness as to what factors may be important indicators of accident risk among pilots through evaluating the correlation values among variables.

Table 11
Test statistics—total flight time.

	Hours
Mann-Whitney U	5501468.500
Wilcoxon W	201947399.500
Z	−49.374
Asymp. Sig. (2-tailed)	.000

Table 12
Classification percentages for the logistic regression model.

			Predicted		
			Group		Percentage Correct
Observed			Accident	Non-accident	
Step 1	Group	Accident	19601	220	98.9
		Non-accident	1190	639	34.9
	Overall Percentage				93.5

Supporting the previous discussion on age and accident involvement, there is a negative correlation of age to accident categorization—as age goes down, accident involvement may increase. The same is true, although the association is weaker, that as flight time goes down, the likelihood of accident group classification increases. Also, accident involvement may be more likely if the individual is employed as a professional pilot.

Other identified correlations appear to be logical, for example, professional pilots are more likely to have completed a flight review and to have higher flight time. Moreover, one would expect commercial pilots to report that they have achieved lower pilot certifications and higher flight time. Although these associations do not provide more discernment than might be expected, they do support the viability of the model, the survey, and the findings.

Limitations and Delimitations

There are several limitations to the study that must be identified. The sample in this study may not have been able to develop a representative picture of the non-accident population. Considering there is currently no database of the "average" pilot, it is difficult to ascertain how well the sample fits the general pilot population. The demographic and other factors collected by this study were limited to those who were exposed for the call for participation, thus the individuals must have been active on the various websites used to introduce the study. It is also assumed that the individuals answered honestly and accurately. Failure to do so would clearly skew the results of this study. The ability of the survey instrument to collect the necessary data was thoroughly evaluated during the research design process, but there still could have been limitations to its ability to capture the requisite data. Lastly, the survey window was approximately three months, which may not have been long enough to collect a representative sample from the available population.

The study was unable to reach the entire pilot population; however, a reasonable effort was made to collect an ample number of respondents to capture a realistic snapshot of the average, non-accident pilot group. Considering the

Table 13
Correlation values among variables.

		Const.	Age	Current Review	Private	Comm	ATP	Prof Pilot	Male	Hours
Step 1	Constant	1.000	−.522	−.158	−.115	−.281	−.277	−.388	−.631	−.191
	Age	−.522	1.000	.065	−.078	−.125	−.080	.267	−.115	.003
	Current Review	−.158	.065	1.000	−.068	−.066	−.028	.242	.033	.072
	Private	−.115	−.078	−.068	1.000	.406	.372	−.129	.030	−.032
	Comm	−.281	−.125	−.066	.406	1.000	.781	−.202	.034	.183
	ATP	−.277	−.080	−.028	.372	.781	1.000	−.141	.008	.163
	Prof Pilot	−.388	.267	.242	−.129	−.202	−.141	1.000	−.022	.191
	Male	−.631	−.115	.033	.030	.034	.008	−.022	1.000	−.010
	Hours	−.191	.003	.072	−.032	.183	.163	.191	−.010	1.000

ubiquitous nature of internet access today, it was assumed that it would be reasonable that pilots would have an online presence. Moreover, the FAA has moved to a more online presence through the required use of the internet for medical and pilot certification processes; therefore, it was also assumed that these individuals would be comfortable in the basic functions of the online environment and may access it regularly.

With all of these factors in mind, the findings of this study may not be generalizable to the entire pilot population as not all members may be active online or access the sites on which the survey used in this study was presented. Such individuals may have different certification, experience, or other factors than those of pilots who do not access these sites.

Conclusions

This study sought to identify potential differences between accident and non-accident pilots as well as associations of various factors on the incidence of accidents. Initial reflection on the survey sample is that it contained a more experienced group (e.g., higher certifications, higher flight time, higher ages) than was found among accident pilots. It is unclear if this is a valid indicator of differences between non-accident and accident pilots, although these findings do align with various previous studies on the subject. It also logical that younger, less experienced pilots may be more inclined to make mistakes or mishandle situations that may lead to an accident. The nature of the relationship between age and experience, in terms of both flight time and certification, also reinforces the findings of this and previous studies, specifically that younger pilots tend to have less experience.

Three factors that were identified as different between the two pilot groups, flight review status, professional pilot occupation, and gender, provided further insight into accident incidence, albeit most likely due to exposure issues. For example, a pilot who has a current flight review is likely to be more actively flying while those without such achievement may not be regularly flying. Thus, a pilot who is flying more frequently is more likely to be exposed to accident incidence. It also possibly supports the FAA regulation construct that noncurrent pilots are not flying when they are not legal to do so, and are, therefore, not involved in accidents. This finding also indicates that the non-accident sample may be less frequent in their flying and less likely to be current. In terms of professional pilot occupation, those who fly professionally are also expected to fly more than leisure pilots, thus raising their exposure to accident potential. The sample appeared to be less "professional" in nature and may have lower accident exposure probability. Along with the aforementioned, due to the lower numbers of female pilots, their overall contact with flight time would be lower, and, therefore, could explain the lower incidence of accidents. Although this does align with the findings of at least one prior study, further investigation would be necessary to make conclusions on whether gender is a significant factor in accident incidence.

The logistic regression model did provide improved prediction over random assignment. For accident cases, the model was able to successfully classify 98.9% of cases; for non-accident cases, the value was 34.9%. While the model was not as strong as was hoped, it did provide utility to the identification of factors that may be a factor in accident incidence. The correlations of a variety of influences such as flight time, pilot occupation, age, and gender seem to support the other findings in this study. Further investigation is warranted on the independent variables to evaluate their relationship to accident causation.

In sum, it appears that pilot experience based on several measures (e.g., age, flight time, certification, currency, and profession) is related to accident occurrence. Increased levels of capability do seem to provide a protective effect. Conversely, with increased experience comes elevated accident exposure risk. These two facts are supported by this study and the findings in previous studies. As is the case in this current study, the factors of age, flight time, and certification are the most positive potential defenses against accident occurrence. One can surmise that maturity, experience, practice, and currency all play a role in why this apparently is true. These findings can support pilot experience requirements for a variety of roles and cost factors, such as insurance purposes. The findings of this study, coupled with those of previous studies, provide a clearer picture as to what factors and influences may be related to the involvement of pilots in aviation accidents.

Suggestions for Future Research

The findings of this study indicate the following suggestions for future research:

1. Replication of the current study with a wider sample to capture a larger volume of "average" pilots who have not been involved in an accident.
2. Make comparisons between captured accident and non-accident pilots from the study sample.
3. Attempt to broaden the evaluation of accident/non-accident factors beyond those examined in this study to potentially include judgment and risk-taking attributes of pilots.
4. Conduct an additional study to compare pilots involved in accidents and incidents. Additionally, these groups could then be compared to those who have not been involved in accidents.
5. Conduct an additional study to account for potential differences among pilots involved in fatal accidents, nonfatal accidents, and incidents.

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