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US Commercial Air Tour Crashes, 2000–2011: Burden, Fatal Risk Factors, and FIA Score Validation

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Abstract

Introduction—This study provides new public health data concerning the US commercial air tour industry. Risk factors for fatality in air tour crashes were analyzed to determine the value of the FIA score in predicting fatal outcomes.

Methods—Using the Federal Aviation Administration's (FAA) General Aviation and Air Taxi Survey and National Transportation Safety Board data, the incidence of commercial air tour crashes from 2000 through 2010 was calculated. Fatality risk factors for crashes occurring from 2000 through 2011 were analyzed using regression methods. The FIA score, Li and Baker's fatality risk index, was validated using receiver operating characteristic (ROC) curves.

Results—The industry-wide commercial air tour crash rate was 2.7 per 100,000 flight hours. The incidence rates of Part 91 and 135 commercial air tour crashes were 3.4 and 2.3 per 100,000 flight hours, respectively (relative risk [RR] 1.5, 95% confidence interval [CI] 1.1–2.1, P=0.015). Of the 152 air tour crashes that occurred from 2000 through 2011, 30 (20%) involved at least one fatality and, on average, 3.5 people died per fatal crash. Fatalities were associated with three major risk factors: fire (Adjusted odds ratio [AOR] 5.1, 95% CI 1.5–16.7, P=0.008), instrument meteorological conditions (AOR 5.4, 95% CI 1.1–26.4, P=0.038), and off-airport location (AOR 7.2, 95% CI 1.6–33.2, P=0.011). The area under the FIA Score's ROC curve was 0.79 (95% CI 0.71–0.88).

Discussion—Commercial air tour crash rates were high relative to similar commercial aviation operations. Disparities between Part 91 and 135 air tour crash rates reflect regulatory disparities that require FAA action. The FIA Score appeared to be a valid measurement of fatal risk in air tour crashes. The FIA should prioritize interventions that address the three major risk factors identified by this study.

Keywords

"commercial air tours"; "air tours"; "sightseeing"; "FIA"; "FIA score"

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INTRODUCTION

The United States Title 14 Code of Federal Regulations (CFR) defines *commercial air tours* as "flight[s] conducted for compensation or hire in an airplane or helicopter where a purpose of the flight is sightseeing."[1] Currently, air tours are conducted under CFR Part 91: General Aviation, Part 121: Domestic, Flag, and Supplemental Operations, and Part 135: Commuter and On Demand. Overall crash rates among Parts 91, 121, and 135 operators are 6.00, 0.30, and 1.06 crashes per 100,000 flight hours, respectively.[2] These figures include both air tour and non-air tour operations, as industry-wide commercial air tour-specific crash rates have not been published. However, regional data from Hawaii indicate that commercial air tour crash rates are several times higher than those of other commercial flight operations.[3]

Li and colleagues developed a simple index for measuring the risk of fatal outcomes in aviation crashes.[4] This score is called the "FIA Score" for the three risk factors it includes: ***F***ire, ***I***nstrument meteorological conditions, and being ***A***way from airport.[4] However, this score has not been validated as a risk measurement for fatal outcomes in commercial air tour crashes. This paper will describe the mortality burden of commercial air tour crashes, compare the characteristics of fatal and non-fatal crashes, and identify risk factors associated with fatal air tour crashes in the United States from 2000 through 2011. It will also assess the validity of the FIA score in measuring the risk of fatality in commercial air tour crashes that occurred from January 2000 through December 2011.

METHODS

Data Source and Primary Outcome Measures

Study data came from the National Transportation Safety Board (NTSB) aviation crash surveillance system.[5] The Board is a Congressionally charged independent Federal agency that investigates all civil aviation crashes in the United States, as well as serious mishaps that occur in other transportation modes, such as highway, railway, marine, and pipeline.[5] For each serious transportation crash, the Board undertakes an investigation to determine the probable cause of the event, and it makes recommendations to prevent crashes in the future.[5] To ensure the objectivity of its reporting and recommendations, the Board has neither regulatory nor enforcement powers.[5]

An aviation "accident" is defined by the Board as "an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage."[5] "Death" is defined as a fatality occurring within 30 days of the crash.[5] "Serious injury" is defined as an injury that requires 48 hours or more of hospitalization, causes a bony fracture (excluding simple fractures of the fingers, nose, or toes), damages any internal organ, results in severe hemorrhage, muscle, tendon, or nerve damage, causes second- or third-degree burns, or involves any burns affecting >5% of the body's surface.[5] "Substantial damage" is aircraft damage or failure requiring major component repair or replacement under normal circumstances.[5]

When an aviation crash occurs, the Board dispatches a field investigation team from its regional offices.[5] Crash data are collected and recorded on NTSB Form 6120.4, the Factual Report. The Factual Report details over 200 items pertaining to the crash circumstances, aircraft, and pilot.[5] Federal Aviation Administration Order 8020.11B contains detailed procedures that ensure the quality and technical depth of notification, investigation, and reporting procedures for aviation crashes.[5]

Commercial air tour crashes were identified by querying the National Transportation Safety Board's online Aviation Accident Database with the keywords "sightseeing," "sight seeing," "air tour," "airtour," and "sight." Two hundred fifty crashes were initially identified with this text search. Excluded from the study were 48 balloon crashes and 6 glider crashes because they did not meet the Federal Aviation Administration's "airplane or helicopter" requirement for classification as a commercial air tour flight. Additionally, 44 helicopter and airplane crashes were excluded because they were not conducted "for compensation or hire." A second query, performed using the National Safety Transportation Board's mainframe, returned the same cases. Unlike the publicly available query site, the internal database allows users to search for commercial air tours using a specific form-field search. Two reviewers read the probable cause and factual reports for each crash to ensure the commercial air tour crash definition was met. The 152 crashes that met the case definition were included in the analysis. The study was based on publicly available records and was exempt from review by the Johns Hopkins Bloomberg School of Public Health's institutional review board.

Total annual flight hours for Part 135 operators, Part 135 air tour operators, and Part 91 sightseeing flights were obtained from the Federal Aviation's General Aviation and Air Taxi Activity Survey for the period 2000 through 2010.[6] The Federal Aviation Administration does not collect air tour-specific flight hour data for Part 91 commercial air tour operations, so the total number of Part 91 sightseeing flight hours was used as the denominator for Part 91 crash rate calculations. Because not all Part 91 sightseeing flights are conducted for compensation or hire, using this number underestimates the industry-wide and Part 91 commercial air tour crash rates.

Statistical Analysis

Crash rates per 100,000 flight hours were calculated using numerator data from the National Transportation Safety Board's Aviation Accident Database and denominator data from the Federal Aviation Administration's General Aviation and Air Taxi Activity Survey.[5, 6] Data from the 152 commercial air tour crashes that occurred between January 1, 2000, and December 31, 2011, were analyzed in Stata version 12.0 (College Station, Texas).[7]

Fisher's exact test was used to examine fatal and non-fatal crashes for differences in binary and categorical exposures. T-tests were used to examine differences in continuous exposure measurements between fatal and non-fatal crashes. The statistical analysis for predictors of fatal crash outcomes was performed in several steps. First, the association of fatal outcomes with fire, meteorological conditions, off-airport location, loss of power, loss of flight controls, maintenance malfunction, pilot error, US region (Alaska, Hawaii, or the 48 continental states), aircraft type (helicopter versus airplane), CFR category (Part 91 versus Parts 121/135), total pilot flight hours, and time of day were examined using simple and multiple logistic regression. Total pilot flight time, time of day, aircraft type, and CFR category were considered confounders based on prior knowledge and used to adjust the regression models. Multiple linear regression analysis permitted calculation of the variance inflation factors, which were all below 2.0.

Model-wise deletion was used to exclude missing values during all analyses; cases that had missing values for any of the variables used in the analytic model were excluded. Nested models were compared using likelihood ratio tests and Aikaike's Information Criteria. When two nested models were compared using likelihood ratio tests, only the cases common to both regression models following model-wise deletion were used for comparison.

Models were selected based on a combination of knowledge of crash survivability, potential confounders, and the projected feasibility of model use in the emergency response setting.

Potential interactions were evaluated with regression models. Model fit was assessed using Pearson's and Hosmer-Lemeshow goodness of fit tests and deviance measures. Model performance was examined using the area under receiver operating characteristic (ROC) curves.

Risk Index Construction

Using the methods described by Li and colleagues, a composite score was constructed from the three well-recognized predictors of fatal outcomes from the regression model: fire, instrument meteorological conditions, and off-airport location.[4] The score was constructed with the following two assumptions: (1) the risk factors each have the same magnitude of influence on fatal outcomes, and (2) the risk factors have an additive effect on fatal outcomes that does not vary by combination of predictors.[4] Giving the fire predictor various weights, resultant differences in model performance were used to test the first assumption.[4] The second assumption was tested by comparing the rates of fatal outcomes between different combinations of predictors.[4]

The composite score was calculated for each of the 152 crashes in the study. Computed values for sensitivity, specificity, and area under the ROC curves were used to assess the validity of the score in measuring fatal outcomes. The ROC curve depicts the composite score's ability to discriminate between fatal and non-fatal crashes. The curve represents the probability that a randomly selected fatal crash is rated higher by the composite score than a non-fatal crash selected at random. In order to assess the robustness of the composite score for predicting fatal commercial air tour crashes, the analysis was replicated using two different outcome measures (fatal crash and pilot fatality).

RESULTS

Commercial Air Tour Morbidity and Mortality

From 2000 through 2011, 152 sightseeing aircraft crashed in the United States, resulting in 83 deaths and 315 non-fatally injured pilots and passengers. From 2000 through 2010, the estimated commercial air tour industry-wide crash rate was 2.7 crashes per 100,000 flight hours. Part 91 operators flew an average 185,875 sightseeing hours annually with an air tour crash rate of 3.3 per 100,000 flight hours. Part 135 air tour operators flew an average 326,238 hours annually with a crash rate of 2.2 per 100,000 flight hours. Compared with all Part 135 operators, Part 135 air tour operators were 2.2 times as likely to crash (95% CI 1.7–2.8, P<0.0001), and Part 91 air tour operators were 3.3 times as likely to crash (95% CI 2.5–4.2, P<0.0001). The air tour industry-wide crash rate was 2.6 times as high as the rate for all Part 135 operations (95% CI 2.1–3.1, P<0.0001). Within the air tour industry, Part 91 air tour operators were 1.5 times as likely as Part 135 air tour operators to crash (95% CI 1.1–2.1, P=0.02).

From 2000 through 2011, approximately 20% of air tour crashes resulted in at least one fatality and, among fatal crashes, an average of 3.5 people died. For both fatal and non-fatal crashes combined, the average fatality rate was 0.6 deaths per crash. The risk of injury or death was similar for pilots and passengers in air tour crashes. Of the pilots, 15% died and 28% were injured. The corresponding figures for passengers were: 14% and 24%. The differences were not statistically significant.

Crash Outcomes

Of the 152 crashes, 30 (20%) involved at least one fatality, and 122 (80%) were non-fatal (Table I). Similar proportions of helicopters and airplanes were in each outcome group. The aircraft in each outcome group also had comparable proportions of CFR Part 91 and 121/135 operators. The distribution of fatal and non-fatal crashes was similar between Alaska and the continental US. The risk that a crash would be fatal was twice as high in Hawaii relative to the continental US, although this was only borderline statistically significant (P=0.06). Fatal and non-fatal crashes occurred at roughly equal times during the day, and crash pilots were comparable in terms of total flight hours and restraint use. Both fatal and non-fatal crashes had similar proportions of crashes that were precipitated by loss of power, loss of flight control, improper maintenance, and pilot error. However, fatal crashes were more likely than non-fatal crashes to involve fire (RR 3.5, CI 2.0–6.3, P<0.001), occur during instrument meteorological conditions (RR 14.0, CI 7.0–27.8, P<0.001), and take place away from the airport (RR 5.9, CI 1.9–18.5, P<0.001).

Multiple logistic regression modeling revealed that the adjusted odds ratios for fatal outcomes were 5.0 (95% confidence interval [CI]: 1.5–16.5; P=0.008) for fire, 5.5 (95% CI: 1.1–30.0; P=0.034) for instrument meteorological conditions, and 7.2 (95% CI: 1.6–33.0, P=0.012) for off-airport location (Table II). Other variables included in the multiple logistic regression model were time of crash, pilot total flight time, type of aircraft, and CFR Part (91 versus 121/135); none of these variables had an odds ratio greater than 1.1. There were 147 unique variable patterns in the adjusted regression model; using the Hosmer-Lemeshow goodness-of-fit test, a χ^2 P-value of 0.42 was calculated. The P-value for the deviance χ^2 was 0.62. The area under the ROC curve was 0.82 (95% CI: 0.73–0.91).

Fatal crash rates increased progressively with the FIA Score (Figure 1). Overall, the fatal crash rates were 3%, 12%, 44%, and 75%, respectively, for FIA Scores 0, 1, 2, and 3 (Figure 1). The corresponding χ^2 test for trend P –value was <0.001. The specificity for fatal crash outcomes was 0.58, 0.48, 0.94, and 0.99 for FIA Scores 0, 1, 2, and 3, respectively (Table III). The sensitivity for fatal crash outcomes was 0.07, 0.43, 0.40, and 0.10 for FIA Scores 0, 1, 2, and 3, respectively. Using a cut-off of ≥1, the FIA Score had sensitivity of 0.93 and a specificity of 0.42. The area under the FIA Score ROC curve was 0.79 (95% CI: 0.71–0.88). When the FIA Score was reevaluated using pilot death as the outcome (instead of fatal crash), the area under the ROC curve was 0.78 (95% CI: 0.67–0.88).

Alternative Scoring Schemes

As presented above, the four-point composite core assumes that fire, meteorological conditions, and off-airport location contribute equally to fatal outcomes. Since fire has been shown in other studies to be more hazardous to occupants than instrument meteorological conditions or location of crash, alternative scoring methods were evaluated in which fire received more weight than the other two predictors.[4] The sensitivity, specificity, and area under the ROC curves from the models that assigned greater weight to fire were similar to those of the simpler, four-point scoring system.[4] The four-point FIA Score also assumes that the three risk factors have an additive effect on fatal outcomes.[4] In other words, the FIA Score assumes no interaction between the predictors.[4] To test this assumption, a series of logistic regression models were fitted with different combinations of two-way interaction terms.[4] This assessment revealed no interactions among the predictors.

DISCUSSION

The industry-wide commercial air tour crash rate has been documented to be 2.5 times that of all scheduled Part 135 operators.[2] Our findings indicate that within the air tour industry, Part 91 operators were 1.5 times as likely to crash as their Part 135 counterparts. One of the limitations of this study is the lack of flight hours data for Part 91 air tour operations. The FAA does not collect air tour-specific data during its General Aviation and Part 135 Activity Survey. Instead, we used the total flight hours for all Part 91 operations to approximate the total number of Part 91 air tour flight hours during this period, although this overestimates the number of total air tour flight hours and underestimates Part 91 and industry-wide crash rates.

Regulatory standards for commercial air tours differ by CFR Part categorization and reflect crash rate disparities. "Group 1" air tour operators fall under the training, operations, and maintenance specifications of CFR Parts 121 and 135, which govern commuter and on-demand operations.[1] "Group 2" operators fall under the governance of CFR Part 91 (General Aviation), but may conduct air tours with an FAA Letter of Authorization for a "25-mile exception," which authorizes air tour operations within 25 nautical miles of the departure airport.[1] "Group 3" operators also fall under the auspices of Part CFR 91 with a 25-mile exception, but may only conduct air tours for charity events.[1] Companies governed by CFR Part 91 have less stringent operations, maintenance, and training specifications than those governed by Parts 121 or 135.[8–10] Until 2007, the FAA did not require drug and alcohol screening for any Part 91 pilots and, although screening is now required of "for-profit" Part 91 pilots, it is still not required for those giving air tours for charity events.[1,8] These regulatory disparities, combined with the finding that Part 91 air tours have significantly higher crash rates compared to Part 135 air tours, suggest that the FAA should eliminate the 25-mile exception for Part 91 operators. This would mean that air tours could not be conducted under Part 91.

The results of this analysis indicate that fire, instrument meteorological conditions, and off-airport location are associated with fatal outcomes in air tour crashes. This is consistent with studies that associate post-crash fires with increases in the risk of fatality up to 8-fold among EMS,[11] occupational,[12] general aviation, [13–15] and foreign aviation crashes,[16, 17] after adjusting for crash-precipitating factors and pilot characteristics. Previous studies of helicopter and work-related aircraft crashes have also demonstrated a 7- to 9-fold increase in the odds of fatal outcomes due to adverse weather conditions.[11, 12] Several studies link adverse weather with higher fatality rates due to the obstruction of prominent terrain features by low visibility and the likelihood of impacting terrain at high velocity during instrument meteorological conditions.[15, 16] Additionally, weather-related fatalities have been associated with delayed rescue and provision of emergency care, as well as lengthy exposure to harsh environmental conditions.[15] Likewise, crash location relative to the airport is another well-documented contributor to fatal outcomes in various contexts and countries.[12, 16, 17] This is because crashes that occur on or near airports are more likely to occur at lower speeds, receive immediate emergency attention, and carry a lower risk of exposure to hazardous terrain.[15]

Although the small sample size of this study may have precluded statistical significance for Hawaii's nearly doubled risk of fatal crash outcomes relative to the continental US, this finding may be related to the unique geographic, meteorological, and regulatory environment in the Hawaiian Islands. In 1994, the Federal Aviation Administration issued Special Federal Aviation Regulation Number 71, which, among other requirements, mandated a minimum altitude requirement of 1,500 feet above ground level for all helicopter air tours conducted in the State of Hawaii.[19] The implementation of the Rule followed a 1-year period during which the number of air tour crashes escalated to 9, compared with 10 in the preceding three years.[3] After the Rule, the helicopter crash rate decreased by almost half, from 3.4 to 1.8/100,000 flight hours.[3] However, the proportion of crashes associated with inadvertent flight into instrument meteorological conditions, a risk factor for fatal outcomes, increased from 5% to 32%, as reported in a study of the 59 sightseeing helicopter crashes that occurred from 1981–2008, and the fatality rate did not change significantly.[3] The safety implications of the Rule have been a long-standing concern for the NTSB, as well as for Hawaii air tour operators, who maintain that the Rule degrades safe maneuverability in an operating environment characterized by unstable meteorological conditions.[20, 21] In order to determine the Rule's effectiveness at decreasing crash incidence and related fatalities, further investigation of the Rule's implementation, adherence, enforcement, and outcomes is needed.

The simple risk index developed by Li and colleagues, the FIA, can be used to provide valid measures for the risk of fatal outcomes in commercial air tour crashes. Compared with the 44,828-crash evaluation of the four-point composite score performed by Li and colleagues using aviation crashes between 1983 and 2005, the composite score performed similarly in this 10-year air tour crash cohort. ROC values were 0.79 (95% CI 0.71–0.88) for air tours in this study; the confidence intervals overlapped those of 0.86 (95% CI 0.78–0.95) for major airlines, 0.83 (95% CI 0.80–0.85) for commuter and air taxi crashes, and 0.81 (95% CI 0.810.82) for general aviation crashes in Li's study.[4] The small sample size of this study results in less precision in assessing the composite score's performance; nevertheless, the FIA Score appears to be a robust measure of the risk of fatal outcomes. The high sensitivity of an FIA score of 1 or greater for predicting fatal crash outcomes makes it a good screening tool for rescue teams and emergency medical responders. Additionally, the high specificity of FIA scores of 2 and 3 highlights the importance of focusing on fire, weather, and off-airport location to reduce the risk of fatal crashes. For example, crash-resistant fuel systems have virtually eliminated post-crash fires in civil and military aircraft.[22, 23] Likewise, the risk associated with adverse weather and off-airport location could be mitigated by improving safety programs, revising criteria for permitted operations, refining emergency procedures, and upgrading aviation systems.

By knowing which questions to ask emergency callers, by being able to triage scarce resources to locations where crash victims may benefit the most, and by preventing further injuries and deaths among responders, the FIA score can be incorporated into policies and procedures that get the right person with the right equipment to the right place at the right time to save lives. The ease of assigning this highly prognostic score makes it a simple, three-question screening tool for emergency line operators to use when taking crash reports from lay callers. Given that centers may receive multiple calls that require response teams, it could also assist in triaging multiple events, thereby allocating scarce resources to locations of high potential benefit. Additionally, since this study defines "fatalities" as deaths occurring within 30 days of a crash, rather than only those that occur instantly, the FIA score helps to identify crash occupants who could survive if rescue and hospital treatment are available, such as those at high risk for thermal injury, drowning, blood loss, or air embolism due to multiple fractures. Finally, the FIA score can be used for operational risk management among emergency responders. For instance, sending a sea- or ground-based rescue team may be better than sending an air-based team to respond to an off-airport crash in instrument conditions, which may result in further fatalities.

The three major risk factors identified by this study should be used to guide federal regulations and prioritize air tour interventions. In November 1994, CFR Parts 27–30 and 29–35 were amended to required crash-resistant fuel systems for all newly certificated rotorcraft; however, previously certificated rotorcraft built after the regulation's effective date were exempt from this requirement.[23] As a result, only Bell Helicopter, which adopted crash-resistant fuel systems for all of its models produced since 1982, and a few newly certificated models from other manufacturers, deliver this equipment on standard helicopter models.[23] Regulations that allow only crash-resistant fuel system-equipped aircraft to enter the air tour fleet and other measures that facilitate the transition to crash-resistant fuel systems could reduce air tour crash fatalities.

In order to address risks associated with IMC conditions, the National Transportation Safety Board has recommended implementing Aeronautical Decision Making and "cue-based" training programs that address local weather and environmental issues, with specified schedules for initial and refresher training courses for air tour pilots.[20, 24, 25] The FAA responded to the Board's recommendations by collaborating with the National Institute for Occupational Safety and Health/Centers for Disease Control, the Medallion Foundation, and local stakeholders to develop cue-based training systems for Alaska and Hawaii.[20] The evaluation and potential scale-up of this type of intervention, aimed at improving IMC-related pilot decision making, should be prioritized in order to improve air tour crash outcomes. To further address IMC-related risks, air tour company-promulgated operational guidelines should emphasize the avoidance of IMC conditions.[3] This study serves to inform pilots and managers of the potentially fatal consequences of operating in marginal conditions, and tour operators should stress the unacceptability of intentional and inadvertent IMC flight, even if it requires tour cancellation.[3]

To increase the off-airport safety of Part 135 air tours, the FAA has enhanced its oversight of operations with a risk-based surveillance approach. In 2010, the FAA mandated use of the Surveillance Priority Index, an inspector tool that more efficiently leverages FAA resources by prioritizing Part 135 surveillance based on risk. Further evaluation and development of the risk indicators used to determine a carrier's overall risk profile is needed to determine the usefulness of this tool in improving safety. Despite resistance, the FAA is also working with Hawaii operators to promote the use of Automatic Dependent Surveillance-Broadcast systems, which enhance communication and weather detection capabilities, in addition to tracking air tour routes.[20] To improve the surveillance infrastructure and maximize efficiency, the National Transportation Safety Board advocates for widespread, accelerated implementation of this system, as well as regular *en route* and ground-based operator surveillance in high-risk regions.[26, 27] Finally, despite the inherent risks within air tour operators' environment, the regulations governing the safety and oversight of the highest-risk subset, Part 91, are less rigorous than those for on-demand (air taxi) operators. The National Transportation Safety Board has recommended that the FAA eliminate the 25-mile exception that allows Part 91 operators to conduct air tours without many of the standards in place for Part 135 operators, such as an annual FAA surveillance program and pilot training programs. However, the most recent update of air tour regulations does not heed this recommendation.

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References

1. Federal Aviation Administration. 14 CFR Part 136; Commercial Air Tours And National Parks Air Tour Management. Washington, DC: FAA, DOT; Electronic Code of Federal Register; Available at: http://ecfr.gpoaccess.gov/cgi/t/text/textidx?&c=ecfr&tpl=/ecfrbrowse/Title14/14tab_02.tpl [Accessed March 12, 2012]
2. Bureau of Transportation Statistics. [Accessed March 12, 2012] Airline activity: National Summary US flights. Available at: http://www.transtats.bts.gov/
3. Haaland WL, Shanahan DF, Baker SP. Crashes of sightseeing helicopter tours in Hawaii. Aviat Space Environ Med. 2009; 80:637–42. [PubMed: 19601506]
4. Li G, Gebrekistros HT, Baker SP. FIA Score: A Simple risk index for predicting fatality in aviation crashes. J Trauma. 2008; 65(6):1278–1283. [PubMed: 19077613]
5. National Transportation Safety Board. [Accessed March 12, 2012] Aviation Accident Database. Available at: http://www.ntsb.gov/investigations/reports.html

6. Federal Aviation Administration. [Accessed September 9, 2012] General Aviation and Part 135 Activity Surveys-CY. 2010. Available at: http://www.faa.gov/data_research/aviation_data_statistics/general_aviation/CY2010/
7. StataCorp. Stata Statistical Software: Release 12. College Station, TX: StataCorp LP; 2011.
8. Federal Aviation Administration. 14 CFR Part 91; Air Traffic And General Operating Rules. Washington, DC: FAA, DOT; Electronic Code of Federal Register; Retrieved 12 March, 2012 from: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?&c=ecfr&tpl=/ecfrbrowse/Title14/14tab_02.tpl
9. Federal Aviation Administration. 14 CFR Part 121; Air Carriers And Operators For Compensation Or Hire: Certification And Operations. Washington, DC: FAA, DOT; Electronic Code of Federal Register; Retrieved 12 March, 2012 from: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?&c=ecfr&tpl=/ecfrbrowse/Title14/14tab_02.tpl
10. Federal Aviation Administration. 14 CFR Part 135; Commuter And On Demand Operations And Rules Governing Persons On Board Such Aircraft. Washington, DC: FAA, DOT; Electronic Code of Federal Register; Retrieved 12 March, 2012 from: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?&c=ecfr&tpl=/ecfrbrowse/Title14/14tab_02.tpl
11. Baker SP, Grabowski JG, Dodd RS, Shanahan DF, Lamb MW, Li GH. EMS helicopter crashes: what influences fatal outcome? Ann Emerg Med. 2006; 47:351–356. [PubMed: 16546620]
12. Bensyl DM, Moran K, Conway GA. Factors associated with pilot fatality in work-related aircraft crashes, Alaska, 1990–1999. Am J Epidemiol. 2001; 154:1037–1042. [PubMed: 11724720]
13. Li G, Baker SP. Correlates of pilot fatality in general aviation crashes. Aviat Space Environ Med. 1999; 70:303–309.
14. Rostykus PS, Cummings P, Mueller BA. Risk factors for pilot fatalities in general aviation airplane crash landings. JAMA. 1998; 280:997–999. [PubMed: 9749482]
15. Li G, Baker SP. Crash risk in general aviation. JAMA. 2007; 297:1596–1598. [PubMed: 17426280]
16. O'Hare D, Chalmers D, Scuffham P. Case-control study of risk factors for fatal and nonfatal injury in crashes in civil aircraft. Aviat Space Environ Med. 2003; 74:1061–1066. [PubMed: 14556568]
17. Ozdogan M, Tosun N, Agalar F, Eryilmaz M, Aydinuraz K. An evaluation of civilian aviation accidents in Turkey from 1955–2004. Ulus Travma Derg. 2005; 11:318–323.
18. Krebs MB, Li G, Baker SP. Factors related to pilot survival in helicopter commuter and air taxi crashes. Aviat Space Environ Med. 1995; 66:99–103. [PubMed: 7726791]
19. Federal Aviation Administration. Fed Reg. Vol. 65. Washington, DC: FAA, DOT; Sep 29. 2000 Special Federal Aviation Regulation 71: Air Tour Operators in the State of Hawaii: 14 CFR Parts 91 and 135; p. 58609-12.
20. National Transportation Safety Board. Safety recommendation A-07-18 through-26. Washington, DC: NTSB; 2007 Feb. Report No: AAR-07(03)
21. Federal Aviation Administration. Fed Reg. Vol. 68. Washington, DC: FAA, DOT; Oct 22. 2003 Notice of proposed rulemaking: National Air Tour Safety Standards; 14 CFR Parts 61, 91, 121, 135, 136; p. 60572-60591.
22. Shanahan DF, Shanahan MO. Injury in US army helicopter crashes October 1979–September 1985. J Trauma. 1989; 29:415–422. [PubMed: 2709450]
23. Hayden MS, Shanahan DF, Chen LH, Baker SP. Crash resistant fuel system effectiveness in civil helicopter crashes. Aviat Space Environ Med. 2005; 75:782–785. [PubMed: 16110696]
24. National Transportation Safety Board. Safety recommendation A-93-8 through -14. Washington, DC: NTSB; 1993 Feb. Report No: AAR-93(01)
25. National Transportation Safety Board. Safety recommendation A-95-57 through -67. Washington, DC: NTSB; 1995 Jun. Report No: SIR-95(01)
26. National Transportation Safety Board. Safety recommendation A-07-89 through -95. Washington, DC: NTSB; 2007 Feb. Report No: AAR-07(03)
27. National Transportation Safety Board. Safety recommendation A-08-59 through -62. Washington, DC: NTSB; 2008 Jul.

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HIGHLIGHTS

- Part 91 air tour flights were significantly more likely to crash than their Part 135 counterparts.
- Fatal air tour crashes were more likely than non-fatal crashes to involve fire, occur during instrument meteorological conditions, and take place away from the airport.
- The four-point FIA score appears to be a valid tool for measuring fatality risk in air tour crashes.

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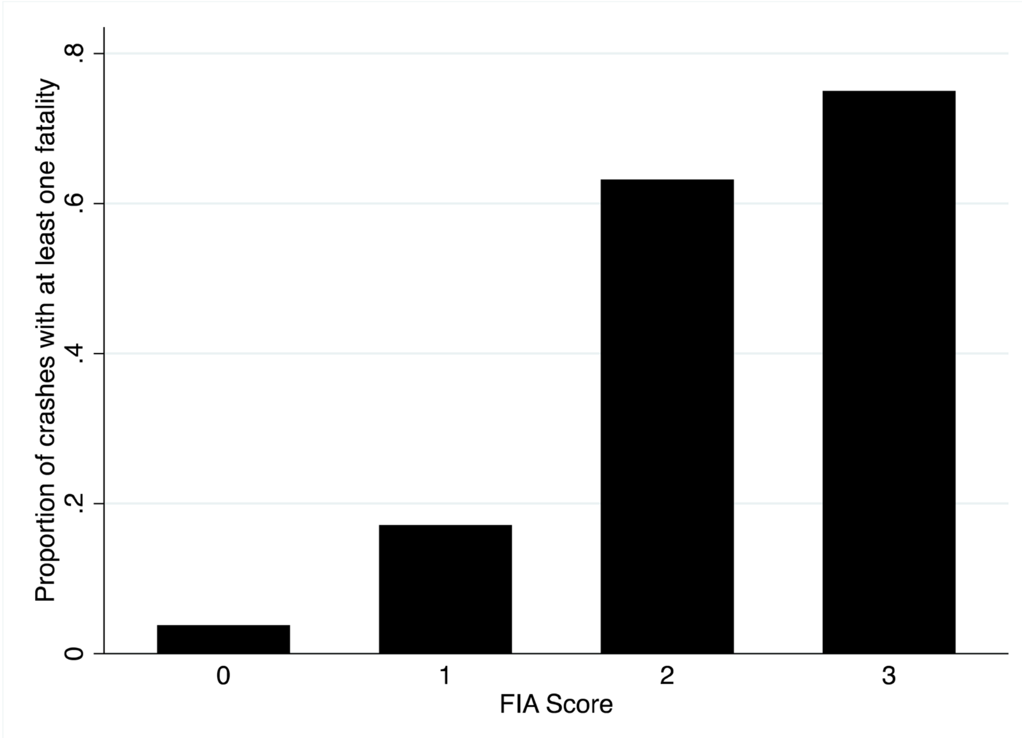

Figure 1. Commercial Air Tour Fatal Crash Outcomes by FIA Score, United States, 2000–2011.*
* Crashes receive one point for each of the following three risk factors: fire, instrument meteorological conditions, and off-airport location. The FIA score ranges from 0 (no risk factors) to 3 (all three risk factors present). χ^2 test for trend P<0.001.

Table I

Baseline Commercial Air Tour Crash Characteristics by Outcome (Fatal versus Non-fatal), United States 2000–2011.

	Fatal (n = 30)	Non-fatal (n = 122)	Relative Risk (95% CI)	*P*-Value* (2-sided)
Flight Operating Characteristics				
Aircraft platform				
Airplane, No. (%)†	15 (50)	58 (38)		
Helicopter, No. (%)	15 (50)	64 (52)	1.1 (0.6–2.1)	0.841
Code of Federal Regulations Part				
Part 91, No. (%)†	12 (40)	59 (48)		
Part 121/135, No. (%)	18 (60)	63 (52)	0.8 (0.4–1.5)	0.541
U.S. Region				
Continental States,† No. (%)	17 (57)	84 (69)		
Alaska, No. (%)	4 (13)	20 (16)	1.0 (0.4–2.7)	1.000
Hawaii, No. (%)	9 (30)	18 (15)	2.0 (1.0–3.9)	0.063
Time of day, Mean (SD)‡	12:58 (3:15)	13:40 (3:07)	n/a	0.302
Risk Factors§				
Aircraft fire, No. (%)	10 (33)	9 (7)	3.5 (2.0–6.3)	<0.001
Instrument meteorological, No. (%)	22 (73)	3 (2)	14.0 (7.0–27.8)	<0.001
Away from airport crash, No. (%)	27 (90)	65 (53)	5.9 (1.9–18.5)	<0.001
Pilot Characteristics				
Total pilot flight hours, Mean (SE)	7190 (1912)	6782 (647)	n/a	0.841
Pilot shoulder harness used, No. (%)	17 (57)	104 (85)	0.8 (0.3–2.6)	0.725
Crash Precipitating Factors§				
Loss of Power, No. (%)	5 (17)	34 (28)	0.6 (0.3–1.5)	0.342
Loss of Flight Control, No. (%)	3 (10)	11 (9)	1.2 (0.4–3.3)	0.729
Improper Maintenance, No. (%)	2 (7)	14 (11)	0.6 (0.2–2.2)	0.527
Pilot Error, No. (%)	23 (76)	77 (63)	1.7 (0.8–3.9)	0.261

Abbreviations: No. = number of crashes, CI = Confidence interval, SD = standard deviation, n/a = not applicable, SE = standard error

Note: Of the 152 crashes in this study, 5 crash reports (3%) lacked total pilot flight hour data; 13 (9%) lacked pilot shoulder harness data; 5 (3%) lacked loss of power data; 4 (3%) lacked loss of flight control data; 9 (6%) lacked maintenance data, and 7 (5%) lacked pilot error data

* *P*-values were calculated using the t-test with Satterthwaite's degrees of freedom for continuous variables and the 2-sided Fisher's exact test for binary variables

† Reference group

‡ Time calculated with a 24:00 clock

§ Total not 100% because some crashes had multiple risk and/or precipitating factors

Table II

Results of Logistic Regression Analyses of Commercial Air Tour Risk Factor Variables with Fatal Crash as the Outcome Variable, United States 2000–2011.

	Crude			Adjusted*		
Risk Factor	**OR†**	**95% CI**	***P*-value**	**AOR**	**95% CI**	***P*-value**
Fire						
Relative to no fire	7.3	(2.7–19.9)	<0.001	5.1	(1.5–16.7)	0.008
Instrument meteorological conditions						
Relative to visual conditions	12.1	(2.9–50.2)	<0.001	5.4	(1.1–26.4)	0.038
Away from airport location						
Relative to on-airport location	11.1	(2.5–48.8)	<0.001	7.2	(1.6–33.2)	0.011

*Adjusted model included fire, meteorological conditions, location relative to airport, total pilot flight hours, time of day, aircraft type (helicopter versus airplane), and Code of Federal Regulations part (Part 91 versus Parts 121/135).

† Abbreviations: OR=Odds Ratio, AOR=Adjusted Odds Ratio, CI = Confidence interval

Table III

Sensitivity and Specificity of the FIA Score when Predicting Fatal Crash Outcomes Among Commercial Air Tour Crashes, United States, 2000–2011.

FIA Score	Sensitivity	Specificity
0	0.07	0.58
1	0.43	0.48
2	0.40	0.94
3	0.10	0.99
≥ 1	0.93	0.42