Factors Associated With Fatalities and Injuries From Hot-Air Balloon Crashes

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Context.—Despite the increased popularity of hot-air balloon flight, data on injuries and fatalities associated with hot-air balloon crashes are limited.

Objective.—To determine factors associated with injury and death in hot-air balloon crashes.

Design.—Retrospective review of data collected from reports and investigations by the Civil Aeronautics Board and the National Transportation Safety Board.

Study Subjects.—Individuals involved in US hot-air balloon crashes from 1964 to 1995.

Main Outcome Measures.—Total number of crashes and factors associated with fatality or serious injury.

Results.—From 1964 to 1995, a total of 495 hot-air balloon crashes involving 1533 persons were reported and included 92 fatalities and 384 serious injuries. Pilot error or incapacitation was determined subjectively by crash investigators to contribute to 85.1% of the crashes. In univariate analysis, collision with the ground was the most significant predictor of a fatality or serious injury (P < .001), and power-line contact was the most significant predictor of fatality (P < .001). In multiple logistic regression, only the type of object struck by a balloon predicted a fatal crash or a fatality or serious injury.

Conclusions.—Although a number of factors likely contribute to increased severity of hot-air balloon crashes, the object struck during a crash is most predictive of fatality or serious injury. Preventive efforts are needed to decrease future injuries.

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THE SPORT OF hot-air ballooning has become more popular each year since a recreational ballooning renaissance began in the early 1960s. In 1964, only 6 balloons were registered with the Federal Aviation Administration (FAA), but by 1995, that number had increased to 7123.1 With its increasing popularity has come an influx of new pilots and balloons, as well as more crashes with associated property damage, severe injuries, and fatalities.

Consequently, the public health importance of studying hot-air balloon crashes has increased. Hundreds of commercial hot-air balloon rides are chartered each year in the United States, and mass ascensions have attracted thousands of spectators and national media attention.

Despite the increased popularity of hot-air balloon flight, published data on hot-air balloon crashes are limited.2,3 Frankenfield and Baker4 published a descriptive study of the epidemiology of injuries due to hot-air balloon crashes using 5 years of National Transportation Safety Board (NTSB) crash data (1984-1988) based on the NTSB’s 2-page abbreviated reports.

In this study, we used a national database to determine the number and characteristics of hot-air balloon crashes and to identify factors associated with crash-related injuries and fatalities.

METHODS

We reviewed the records of the 495 hot-air balloon crashes recorded by the Civil Aeronautics Board (1964-1967) and the NTSB (1967-1995), including statements recorded by passengers and pilots and medical reports filed for injured victims. The Code of Federal Regulations mandates that pilots must contact the NTSB for “any incident involving flight malfunction or failure, inability of flight crew to perform normal duties as a result of injury or illness, in-flight fires, aircraft collision in flight, damage to property estimated to exceed $25,000 for repair or fair market value (whichever is less), or if an aircraft is overdue and believed to have become involved in a crash.”5,6

The term fatality is defined as “any injury that results in death within 30 days of the crash”; the term serious injury as “any injury requiring hospitalization for more than 48 hours commencing within 7 days from the date of initial injury.” Serious injuries also include a fracture of any bone (except uncomplicated fractures of fingers, toes, or nose); severe hemorrhage; nerve, muscle, or tendon damage; internal organ injury; second- or third-degree burns; or burns affecting more than 5% of the body sur-

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face. Minor injuries include bruises, musculoskeletal strain or sprains, or simple fractures noted above.5

Descriptive statistics were calculated using the SAS/STAT version 6 statistical package (SAS Institute, Cary, NC). The 457 reported crashes occurring between 1976 and 1995 were used for risk factor identification. The unit of measurement is a balloon crash. A fatal outcome is defined as a crash that involves at least 1 fatality. A serious injury or fatality outcome occurs when a crash includes at least 1 serious injury or 1 death.

Logistic regression (EGRET software, version 1, SERC Inc, Seattle, Wash) was used to analyze each variable separately and 95% confidence intervals (CIs) of the odds ratios (ORs) as well as P values of the significance of each variable’s possible association with an adverse outcome based on the likelihood ratio test. Logistic regression also was used to create a final model containing variables that in combination best predict the outcome variable. Categorical variables having subcategories with no events recorded were analyzed by the exact Fisher-Freeman-Halton test (StatXact software, Cytel Software Corp, Boston, Mass).7

RESULTS

The distribution of crashes and injuries over the study period and the primary mechanisms of injury are summarized in Table 1.

Collision with power lines accounted for 137 crashes (27.7%), including 41 fatalities (44.6%) (Table 2). The most common serious injury was a fracture of the lower extremity (n=216, 56.3%). Head injuries accounted for only 37 serious injuries (8.6%). Sixty-six adverse events were recorded without the balloon striking an object (eg, a passenger twisted an ankle on landing).

The most crashes recorded in 1 year was 33 in 1980. Ballooning crashes were most common in July (66 crashes in 31 years), followed by October (65), August (57), and September (51), representing nearly half (48%) of the crashes. This likely reflects a greater risk exposure due to the high volume of balloon flights during the warmer seasons of the year.

States with the highest frequency of crashes during the study period were New Mexico (64), California (49), Colorado (45), and Arizona (39). Twenty-three of New Mexico’s 64 crashes occurred during Albuquerque’s annual International Balloon Fiesta, the largest single congregation of balloonists worldwide.

Recreational flights (209 [42.2%]) and paid passenger flights (153 [30.9%]) were involved most frequently. Balloon rallies accounted for 75 recorded crashes (15.2%). Student pilot crashes accounted for 46 crashes (9.3% of the total), while 352 (71.2%) involved commercial pilots and 82 (16.6%) involved private pilots. Most crashes (992 [46%]) occurred during landing attempts or while approaching a landing spot (102 [20.6%]).

The NTSB determined subjectively that pilot error or incapacitation contributed to 421 crashes (88.1%). The most common errors noted in the NTSB files included inappropriate in-flight planning in 138 (27.9%), misjudgment of wind in 94 (19.0%), selection of unsuitable landing sites in 88 (18.7%), and incorrect positioning of passengers or the pilot inside the basket in 57 (11.5%).

Equipment failure or malfunction contributed to 36 crashes (7.3%) and 13 fatalities. There were 17 documented fuel-system failures, and failure of the fabric envelope was involved in only 9 crashes. The mean wind velocity for all crashes was 9.5 knots. A total of 282 crashes (57%) occurred in winds between 5 and 10 knots. Only 94 crashes (19%) occurred in winds less than 5 knots.

Aircraft damage was reported to be substantial in 218 crashes (44.0%), 162 (32.7%) had no significant damage, and 67 aircraft (13.5%) involved were destroyed. Fire occurred in 92 crashes (18.6%), the gondola was severed from the cables in 42 crashes (8.5%), and fuel tanks ruptured in 17 crashes (3.5%).

Pilot-in-command time (total hours in flight as sole operator of the balloon controls) ranged from 1 hour to 2137 hours (median, 74.5 hours). The median age of pilots involved in crashes was 38.0 years and ranged from 18 to 70 years. Table 3 shows risk factors for a balloon crash to involve a fatality. The type of object struck by a balloon during a crash was the only significant variable (P<.001). The odds of a fatality were more than 13 times greater when contacting a power line than when hitting the ground.

For crashes involving either a fatality or serious injury (Table 3), the type of flight (P<.001), the object struck during a crash (P<.001), and the experience of the pilot (P=0.1) were statistically significant. Paid passenger flights had an OR of 2.5 (95% CI, 1.5-4.1) relative to recreational flights; however, no other subcategories were statistically significant.

For the outcome of fatality and the outcome of fatality or serious injury, multiple logistic regression demonstrated that no other factor improved on

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Table 1.—Injury Severity From Hot-Air Balloon Crashes, by Year and Mechanism of Injury

<table>
<thead>
<tr>
<th>Years</th>
<th>Total No. of Crashes</th>
<th>Total Fatal Injury</th>
<th>Serious Injury</th>
<th>Minor Injury</th>
<th>Without Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>1964-1970</td>
<td>9</td>
<td>12</td>
<td>7</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>1971-1975</td>
<td>29</td>
<td>58</td>
<td>10</td>
<td>23</td>
<td>24</td>
</tr>
<tr>
<td>1976-1980</td>
<td>98</td>
<td>219</td>
<td>22</td>
<td>66</td>
<td>58</td>
</tr>
<tr>
<td>1981-1985</td>
<td>141</td>
<td>443</td>
<td>18</td>
<td>107</td>
<td>85</td>
</tr>
<tr>
<td>1986-1990</td>
<td>125</td>
<td>455</td>
<td>19</td>
<td>104</td>
<td>91</td>
</tr>
<tr>
<td>1991-1995</td>
<td>93</td>
<td>346</td>
<td>16</td>
<td>80</td>
<td>53</td>
</tr>
<tr>
<td>Total</td>
<td>495</td>
<td>1533</td>
<td>92</td>
<td>384</td>
<td>312</td>
</tr>
</tbody>
</table>

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Table 2.—Objects Initially Impacted During Hot-Air Balloon Crashes

<table>
<thead>
<tr>
<th>Objects</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground</td>
<td>152 (30.7)</td>
</tr>
<tr>
<td>Power lines</td>
<td>137 (27.7)</td>
</tr>
<tr>
<td>No collision</td>
<td>66 (13.3)</td>
</tr>
<tr>
<td>Tree</td>
<td>46 (9.3)</td>
</tr>
<tr>
<td>Building or fixed structure</td>
<td>31 (6.2)</td>
</tr>
<tr>
<td>Vertical terrain</td>
<td>19 (3.8)</td>
</tr>
<tr>
<td>Another balloon</td>
<td>17 (3.4)</td>
</tr>
<tr>
<td>Fence</td>
<td>16 (3.2)</td>
</tr>
<tr>
<td>Water</td>
<td>5 (1.0)</td>
</tr>
<tr>
<td>Motor vehicle</td>
<td>2 (0.5)</td>
</tr>
<tr>
<td>Total</td>
<td>495 (100)</td>
</tr>
</tbody>
</table>
COMMENT

The NTSB was established in 1967 as an independent federal agency to investigate all civil aviation accidents, maintain a national database of crash data, and issue safety recommendations aimed at preventing future mishaps. In April 1995, the NTSB was granted additional power to mandate detailed reporting of aircraft crashes, making our data relatively free from differential case ascertainment over time.

Our review of 31 years of NTSB data showed that power-line strikes contributed to a large portion of hot-air balloon crashes. Contact with power lines caused the basket to overturn while airborne in some cases or, worse, created electrical arcing that severed the load cables from the basket, causing pilots and passengers to fall to their deaths. Of the 40 individuals involved in crashes in which power lines arced, 24 people were electrocuted, resulting in 8 deaths, 8 serious injuries, and 8 minor injuries.

The univariate data analysis indicates that if a balloon crash occurs, there is a 1.4% chance (2/141) of a fatality when the ground is contacted first compared with a 16.1% chance (92/572) of a fatality if initial contact is made with a power line (OR, 13.4; 95% CI, 3.1-58.4) (Table 3). In the univariate analysis for fatality or serious injury, contact with a power line first, there is a 53% chance (43 collisions with trees, 35% resulted in serious injuries or fatality. However, the OR of a serious injury or fatality from striking a tree relative to striking the ground is 0.06 (95% CI, 0.03-0.15), which may be attributable in part to underreporting of crashes with the ground that resulted in nonserious injuries.

Changing weather conditions were noted by the NTSB in 35 crashes (7.1%), and the odds of a fatality or serious injury appear to increase with greater wind velocity (although this result is not statistically significant [P=.07]). Measurement error may have played a role in this calculation since wind data are often collected from the pilot involved in the crash or from nearby locations where...
wind speed may vary from the value at the crash site. The major limitation of our study is the lack of exposure or denominator data for estimating the incidence of injury and fatality. The number of balloons registered with the FAA is relatively accurate since all airworthy aircraft must be enrolled. Unfortunately, there are no reliable estimates of the number of balloons actually in use, the number of active balloon pilots, or the number of hours flown annually per balloon or per pilot. Given these major limitations, we did not attempt to analyze incidence data.

In addition, it is likely that some pilots did not report crashes with only minor structural damage to the balloon and no significant injuries to the passengers. Current FAA regulations require pilots to report all crashes that cause structural damage to the aircraft or injury to the occupants and require a report to be filed within 10 days of the incident. Despite this, we discovered several crash reports in the NTSB database that were filed weeks or months after the crash and only after NTSB officials demanded that the pilot file a report or risk prosecution.

Further, the findings in this study are subject to misclassification error. Because NTSB officials add information to their database by transferring information from individual crash reports, individuals not familiar with balloon flight may incorrectly label certain factors involved in balloon crashes. For example, data collection forms used by the NTSB are designed for motorized aircraft; thus, many variables in the standardized collection form are not applicable to balloon flight. Consequently, some of the data entered into the NTSB database for hot-air balloon crashes are extracted from the pilot narrative and are subject to recall bias.

Finally, blood alcohol levels and urine drug-screening results were not available for all pilots involved in crashes. The FAA regulations allow for a maximum blood alcohol level of 0.09 mmol/L (0.4% by weight) to operate a balloon, and no alcoholic beverage may be consumed within 8 hours of flying. However, since crash reports can be filed several days after the occurrence, routine drug and alcohol screening has been impractical.

In conclusion, our data demonstrate that the number of fatalities from hot-air balloon crashes has decreased, but the percentage of crashes with either serious injury or death has increased. The type of object struck during a crash is the best predictor of adverse outcome. Collision with the ground is the most significant predictor of a fatality or serious injury, whereas power-line contact is the most significant predictor of fatality.

Improper weather interpretation, incorrect management of rapid descents, and contact with equipment inside the basket during landings are associated with significant morbidity. The incidence of hot-air balloon serious injuries and fatalities is difficult to estimate because of the lack of accurate denominator data.

Continued preventive efforts, such as mandatory attendance of educational programs that emphasize avoidance of power lines and increased awareness of other potential risk factors for crashes, and further safety improvements by balloon manufacturers may help to decrease future injuries and deaths.

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References
6. 49 CFR §830, subpart A.