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Hot-Air Balloon Tours: Crash Epidemiology in the United States, 2000-2011

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Abstract

Introduction—Hot-air balloon tours are FAR Part 91-governed balloon rides conducted for compensation or hire. Part 91, General Aviation, in general involves the least strict federal regulations and accounts for the majority of aviation crashes and fatalities.

Methods—National Transportation Safety Board reports of hot-air balloon tour crashes in the United States from 2000 through 2011 were read and analyzed.

Results—During the 12-yr period, 78 hot-air balloon tours crashed, involving 518 occupants. There were 91 serious injuries and 5 fatalities; 83% of crashes resulted in one or more serious or fatal outcomes. Of the serious injuries characterized, 56% were lower extremity fractures. Most crashes (81%) occurred during landing; 65% involved hard landings. Fixed object collisions contributed to 50% of serious injuries and all 5 fatalities. During landing sequences, gondola dragging, tipping, bouncing, and occupant ejection were associated with poor outcomes. Of the crashes resulting in serious or fatal outcomes, 20% of balloons were significantly damaged or destroyed.

Discussion—The incidence of morbidity and mortality is high among hot-air balloon tour crashes, and the proportion of balloon crashes attributed to paid rides appears to have increased over time. In addition to examining the role of restraint systems, personal protective equipment, and power line emergency procedures in ballooning, injury prevention efforts should target factors such hard landings, object strikes, gondola instability, and occupant ejections, which are associated with balloon injuries and deaths. Crash outcomes may also improve with vehicle engineering that enables balloons themselves to absorb impact forces.

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Keywords

commercial air tours; paid ride; lighter-than-air; sightseeing; power lines

The Epidemiology of fatal and nonfatal crashes of hot-air balloon rides conducted for compensation or hire in the U.S. is investigated here for the first time. Recent data show that helicopter and fixed-wing commercial air tour operations in the U.S. have high crash rates compared with similar commercial aviation operations, and crash rates increase with decreasing regulation ([2]). The inverse relationship between crash rates and oversight raises concerns about the public health impact of less-regulated commercial air tour operations, such as paid hot-air balloon rides.

This study examines the characteristics of crashes of commercial hot-air balloon tours conducted under Part 91 of United States Federal Aviation Regulations (FARs). The majority of aviation-associated crashes, deaths, and injuries in the U.S. involve flights operated under the governance of FAR Part 91, General Aviation ([15]). However, few published studies describe the contribution of hot-air balloons to Part 91 morbidity and mortality, and none of them examines the subset of hot-air balloon crashes that occur in the setting of commercial balloon tours. This study informs hot-air balloon patrons about the risks associated with crashes that occur during this recreational activity, and it serves as a tool for operators and policy makers wishing to employ targeted prevention strategies to reduce balloon ride crashes and crash-related injuries and deaths.

METHODS

We defined commercial hot-air balloon tours, or “rides,” as flights conducted for compensation or hire in a hot-air balloon where a purpose of the flight was sightseeing. The National Transportation Safety Board (NTSB) defines an aviation “accident” 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” ([19]). A fatality occurring within 30 d of the crash is classified as a “death” ([19]). An injury that requires hospitalization for at least 48 h, results in a bony fracture other than those considered “ minor injuries, ” damages an internal organ, causes severe hemorrhage, produces second- or third-degree burns, or burns > 5% of the body’s surface, or damages a muscle, tendon, or nerve is considered a “ serious injury ” ([19]). “ Minor injuries ” include bruises, strains, sprains, and simple fractures of the fingers, toes, or nose ([19]). “ Substantial damage ” to an aircraft is defined as damage or failure requiring major component repair or replacement under normal circumstances ([19]).

In order to identify hot-air balloon crashes occurring from 2000 through 2011, the NTSB Aviation Accident Database was electronically queried by selecting “ balloon ” in the aircraft category dropdown menu on the search page. Crashes of paid hot-air balloon rides occurring from 2000 through 2011 were identified through “Yes” responses in the “Revenue Sightseeing Flight” field of the factual report and excluding all such crashes that did not occur in hot-air balloons. Two reviewers read the probable cause and factual reports from the

Board's online Aviation Accident Database and abstracted information concerning crash circumstances and outcomes ([19]). A third reviewer adjudicated cases in which the reviewers' abstracted data disagreed. Data describing the number of hot-air balloon flights and number of hours flown during the study period were not available. 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.

RESULTS

During the 12-yr period from 2000 through 2011, the NTSB reported 169 hot-air balloon crashes. Of these crashes, 78 (46%) occurred during hot-air balloon tours involving 519 occupants, of which 94 (18%) suffered minor injuries, 91 (18%) sustained serious injuries, and five (1%) died. Of these 78 hot-air balloon tour crashes, 65 (83%) resulted in at least one serious or fatal injury. The NTSB's paid balloon ride crash reports characterized 43 serious injuries, the most common of which were lower extremity fractures ($N = 24$), followed by 7 upper extremity fractures, 7 injuries to the trunk, and 5 head injuries.

Among crashes of paid balloon rides, collision with fixed objects contributed to 50% of serious injuries, 85% of minor injuries, and all five fatalities. Collision with trees accounted for one fatality and 39% of all injuries; collision with the ground accounted for one fatality and 26% of all injuries; collision with power lines accounted for two fatalities and 10% of all injuries; and collision with buildings accounted for one fatality and 6% of all injuries (**Table I**). Four of the five fatalities involved the ejection of occupants from the balloon.

Ten occupants sustained serious injuries when passengers did not adhere to procedures as instructed in the preflight briefing. One of these injuries occurred during boarding and nine during landing, and most involved failure of passengers to maintain correct positioning within the balloon. In one instance, two passengers jumped out of the basket before the landing sequence was complete; the sudden and drastic decrease in weight resulted in the pilot's loss of control of the aircraft, substantial aircraft damage, and serious injury to one passenger. In another, the pilot was ejected from the basket while attempting to restrain a passenger who, against instructions, stood up during the landing sequence.

Pilot error contributed to 63 (81%) crashes and was at least a partial contributor to all 5 fatal crashes (**Table II**). Most commonly, pilots erred by descending at an excessive rate (28 cases) or failing to maintain clearance of obstacles (22 cases). The NTSB reports also cited improper fuel planning (6 cases), flying into adverse weather (5 cases), and inadequate passenger briefings (3 cases) as pilot errors that contributed to crashes. Two pilots erred by not issuing protective helmets to balloon occupants; these crashes resulted in three head injuries, including the death of one pilot from blunt force trauma to the head and neck. Helmet use was not described in the other two cases of head injury.

Excluding the single student pilot, who did not have any prior flight hours, the total flight time for pilots in command of balloon rides ranged from 78 to 24,600 h with a median total flight time of 1203 h. Time in the balloon type/model ranged from 3 to 3500 h with a median total time in type/model of 186.5 h. Flight time in the balloon type/model was unknown for 12 balloon pilots whose crashes yielded 2 fatalities, 22 serious injuries, and 17 minor injuries. Of the pilots with documented flight experience, 38% had 100 flight hours or less in type/model, and 16% had fewer than 20 flight hours in type/model.

Wind was a factor, typically the precipitating factor, in 78% of crashes, with high winds (28%) and gusts (21%) most commonly contributing to crashes. Wind speeds were 12 knots per hour or less in half of the crashes with wind cited as a factor. The majority of crashes (63, 81%) occurred during landing, with hard landings contributing to 51 crashes (65%) (**Fig. 1**).

There were 43 balloons that hit fixed objects during crashes. The most frequently struck objects were trees (15 cases) and power lines (11 cases). Likewise, the avoidance of power lines contributed to eight crashes. Fire erupted in seven balloons during flight, resulting in one death and 17 serious injuries. During landings, the wind dragged 31 balloons along the ground until they crashed into an obstruction (10 cases) or eventually came to rest (21 cases). During crash sequences, 26 balloons tipped over, ejecting occupants half the time.

Crashes were most common in the month of October (15 cases), followed by July (13 cases), May (10 cases), and August (10 cases). States with the greatest number of paid flight crashes were New Mexico (18 cases), Colorado (11 cases), Arizona (10 cases), and California (9 cases) (**Fig. 2**).

The majority (91%) of crashes occurred during the 3 h after sunrise (50 cases) or the 3 h prior to sunset (21 cases). Generally, these hours are considered the safest times for ballooning since the winds are calmest at these hours, and therefore are the times when flights are most likely to have occurred. The seven crashes that occurred outside these two theoretically optimal “windows” resulted in eight serious injuries, six minor injuries, and no fatalities. Wind was a contributing factor in five of these seven crashes.

Equipment failure or malfunction played a role in 10 crashes (13%). Fuel system problems contributed to 4 of these crashes, resulting in 2 fatalities and 12 serious injuries. Envelope or vent malfunction, failure, or damage contributed to five more of these crashes, resulting in two serious injuries. In the remaining crash, two of the tether ropes in the balloon’s three-point harness system snapped after an accidental balloon launch that occurred while loading passengers in gusty wind conditions, “leaving the balloon dangling about 100 ft in the air over power lines” ([19]). The pilot stabilized the balloon and executed an emergency landing. No injuries resulted from this crash. Improper maintenance contributed to 3 of the 10 equipment-related crashes. In these three crashes, incorrect drop line rigging, incorrect deflation activation line rigging, and the installation of a non-FAA-approved fuel hose resulted in one fatal and two serious injuries, respectively.

Throughout the study period, a total of 33 balloons (42%) involved in crashes sustained damage: 14 were damaged “substantially,” 10 sustained “minor” damage, and 2 were “destroyed.” Of the 65 crashes with serious or fatal outcomes, 13 balloons (20%) sustained serious damage or were destroyed.

DISCUSSION

The frequency of paid balloon ride crashes appears to have increased over the past several decades, and the proportion of balloon crashes attributed to paid rides has increased since the year 2000. In a study of 495 balloon crashes occurring in the U.S. from 1964 to 1995, Cowl and colleagues found that paid passenger flights comprised 31% of all hot-air balloon crashes ([6]). Frankenfield and Baker reported a similar proportion (28%) of paid passenger flights in their study of 138 hot-air balloon crashes occurring from 1984 through 1988 ([9]). In our study, however, paid rides comprised nearly half (78/169, 46%) of hot-air balloon crashes occurring from 2000 through 2011.

A recent study by de Voogt and van Doorn on crashes of all categories of general aviation aircraft ([8]) permits comparison of our study results with those of all hot-air balloon crashes. De Voogt and van Doorn found that 7% of the 530 balloon crashes that took place during the 26-yr period from 1982 through 2007 resulted in fatal outcomes, but they did not report the number of serious injuries that occurred in these crashes. Whereas hard landings contributed to 35% of balloon crashes in their study, hard landings contributed to nearly twice this proportion of hot-air balloon tour crashes. The occurrence of an aircraft fire, which is highly correlated with fatality in crashes of motorized aircraft, led to a fatality in 31% of crashes of balloons, blimps, gyroplanes, and ultralight aircraft. However, only one of the seven hot-air balloon tour crashes involving fire in our study resulted in a death. Overall, de Voogt and van Doorn's study highlights the relatively low risk of fatal balloon crash outcomes, but their study did not report the burden of serious crash-associated injuries which, combined with fatalities, occurred in 83% of the balloon tour crashes in our study and may be improved by targeted interventions.

In the literature, hot-air balloon crashes involving power lines have disproportionately high death rates. From 1976 through 1983, 38% of the 231 balloon crashes that occurred in the United States involved power lines, and these crashes contributed to two-thirds of hot-air balloon crash deaths ([20]). Similarly, from 1984 through 1988, the 33% of crashes that involved power lines resulted in 83% of deaths and 30% of occupant injuries ([9]). In our study, only 7% of paid balloon ride crashes involved power lines, although these crashes resulted in two of the five deaths. This apparent decrease in the proportion of crashes involving power lines may partially explain the relatively low incidence of death and serious injury among paid ride occupants in our study; however, the small number of fatalities in our study limits this comparison. Further, although these crash reports in our study lacked detailed data for evaluation, a 3-yr study of power line collisions conducted by Aerostar International found above-the-equator envelope collisions reduced the risk of serious and fatal injuries by over half, compared with below-the-equator envelope collisions ([1]). This suggests that training pilots to impact power lines above the envelope's equator may improve crash outcomes.

Compared with commercial air tour crashes in motorized aircraft, hot-air balloon tour crashes resulted in a high proportion of serious or fatal injuries, but poor outcomes were not associated with balloon damage. In a study of commercial air tour crashes conducted during the same time period using the same methodology, 50/152 (32%) of helicopter or airplane crashes resulted in serious or fatal injuries ([2]) compared with 65/78 (83%) in the present study of hot-air balloon tour crashes. Of the hot-air balloon tour crashes involving serious or fatal injuries, 13/65 (20%) resulted in substantial balloon damage or destruction, whereas 48/50 (96%) of helicopter and airplane tour crashes involving serious or fatal injuries resulted in substantial aircraft damage or destruction. The rarity of concurrent occupant injury and balloon damage raises the question of whether balloons themselves can be sacrificed during crashes to better protect occupants from injury. Indeed, all eight crashes resulting in substantial balloon damage but no occupant injuries occurred during collisions with fixed objects in which destruction of the balloon envelope absorbed the impact of the collision. Two of these eight crashes involved envelope collision with power lines, which have been associated with fatal outcomes ([9], [20]).

Previous studies emphasize the high proportion of maintenance-related crashes associated with less regulated aviation operations. In Hasselquist and Baker's 1999 study on homebuilt aircraft, mechanical failure led directly to 43% of crashes and played a direct or contributory role in 63% of crashes ([12]). An estimated 15–40% of homebuilt crashes occur on "maiden" flights or after maintenance ([5]). A later study of gyroplane crashes, however, found that crashes related to mechanical problems were less likely to result in fatal outcomes than crashes not so related, and maintenance issues were associated with neither fatalities nor aircraft damage in these crashes ([21]). Likewise, a study of helicopter and airplane commercial air tour crashes found that improper maintenance was not associated with fatal outcomes in commercial air tour crashes of helicopters and airplanes ([2]). While improper maintenance contributed to 11% of commercial helicopter and airplane tour crashes, it contributed to only 4% of balloon crashes in this study. This difference may be due to the relative simplicity of balloon mechanical systems and maintenance, although it is not clear whether balloon owners and pilots are as likely to perform their own maintenance as those of other categories of aircraft.

Despite incomplete injury data, preliminary conclusions can be drawn about potential interventions to reduce balloon tour-associated mortality and morbidity. De Voogt and van Doorn reported 4 fatalities and 75 serious injuries in 86 crashes involving 408 occupants during the 5-yr period from 2000 through 2004; the most frequently reported serious injuries were lower extremity fractures (22/27) ([7]). Similarly, over half of the serious injuries characterized in our study were lower extremity fractures sustained during landings, which were the most common phase of flight in which crashes occurred. These results suggest that reducing landing forces could decrease balloon-associated injuries. This would, by definition, reduce the overall crash rate since the FAA's accident criteria include serious injury and death. Potential strategies for reducing landing forces include cushioning the bottom of the basket or employing crash-worthy auxiliary crew seats during landings.

Restraint systems endeavor to maintain occupants within a known space, thereby attenuating crash dynamics and avoiding secondary impacts with equipment and other passengers. The protective effects of restraint systems have been documented for multiple transportation modes, including aviation crashes ([14-16]). Since 80% of paid balloon ride fatalities involved ejection in this study, the data suggest that using restraint systems to prevent ejection could dramatically decrease the incidence of fatal crashes. Moreover, since most power line-related balloon fatalities result from blunt trauma from falls, rather than electrocution, restraints could be useful in mitigating the risk of this frequent contributor to balloon-related injury and death ([17], [18]).

No FAA regulations currently mandate the use of flight helmets in General Aviation, including balloon flights. However, our results suggest that this simple intervention could influence crash outcomes. Of the five serious head injuries reported in our study, three were sustained during flights in which the tour company deviated from the requirements specified in FAA-approved balloon flight manuals by failing to provide balloon ride occupants with helmets ([4], [11], [19]). Helmets can prevent head injuries or reduce their severity by distributing impact loads and preventing skull deformation. This effectively increases the skull's tolerance to linear acceleration up to 300 g ([10]). Moreover, even transient concussion avoidance could allow a balloon pilot or occupant to execute emergency procedures during a crash sequence.

A major limitation of this study is the lack of denominator data needed to calculate crash, death, and injury rates for commercial hot-air balloon tour flights. Without reliable estimates of hot air balloons in use or of the number of flight hours flown in this subset of balloon-ists, it is difficult to estimate the incidence of balloon crashes, which would provide additional context to our results. Moreover, the use of absolute figures in crash analysis has faced criticism in the past for not providing adequate denominator data to allow appropriate analysis and interpretation ([13]). However, the crash analysis performed in this study differs fundamentally from risk analysis, which is a broader approach requiring highly specific denominator data ([13]). For instance, a thorough risk analysis for hot-air balloon tours would require detailed information about each landing approach, object avoidance maneuver, and adverse wind encounter during flight. Crash analysis, while narrower in scope than risk analysis, serves as a starting point for targeting interventions to decrease the high morbidity and mortality associated with balloon tour crashes.

Another limitation to this study is the likelihood that hot-air balloon tour crashes are underreported, particularly those that do not result in passenger injuries or substantial damage to the balloon. According to current FAA regulations, occupant injuries must be reported within 10 d of a flight, and deaths must be reported within 30 d. Nevertheless, injuries of tourists may not be diagnosed until after the tourists return home, and the injuries may not be reported to air tour companies or the FAA. In our study, the NTSB discovered one crash after receiving a call from a seriously injured passenger. The pilot, who had been allowing a student to command the balloon in violation of FAA regulations, had not reported the crash.

Additionally, we could not assess the role of drugs and alcohol in balloon tour crashes since pilots apparently were not tested. Although alcohol testing of fatally injured commuter and air taxi pilots is common, such testing is rare for Part 91 pilots ([3]). Since balloon crash reporting often occurs hours to days after crashes occur, it is difficult to ascertain drug and alcohol levels at the time of the crash. In contrast to FAR Part 135 regulated airplane and helicopter air tour operators, for whom the FAA mandates drug-screening programs, Part 91 tour operators are not required to have drug-screening programs for pilots.

Finally, the data collected using standardized NTSB reports are not ideal for balloon crash analysis. Object strikes, occupant ejections, rollovers, and the use of personal protective equipment appear to play an important role in determining balloon crash outcomes. However, the NTSB forms do not standardize the reporting of this information, so data on these occurrences may be incomplete if this information is not included in the form's narrative section. Further, the lack of specific injury information recorded on the form inhibits the development of injury prevention strategies that address the risk factors faced by all individuals involved in aviation crashes.

In conclusion, the incidence of hot-air balloon tour crash-associated morbidity and mortality is high, and targeted interventions may improve crash outcomes. In addition to examining the role of restraint systems and personal protective equipment in hot-air ballooning, injury prevention efforts should address high-risk factors, such as hard landings, ejections, and object strikes, which are associated with balloon injuries and deaths. More detailed information about the nature and outcomes of balloon crashes would assist the development of targeted interventions aimed at decreasing the number and reducing the severity of balloon crash injuries.

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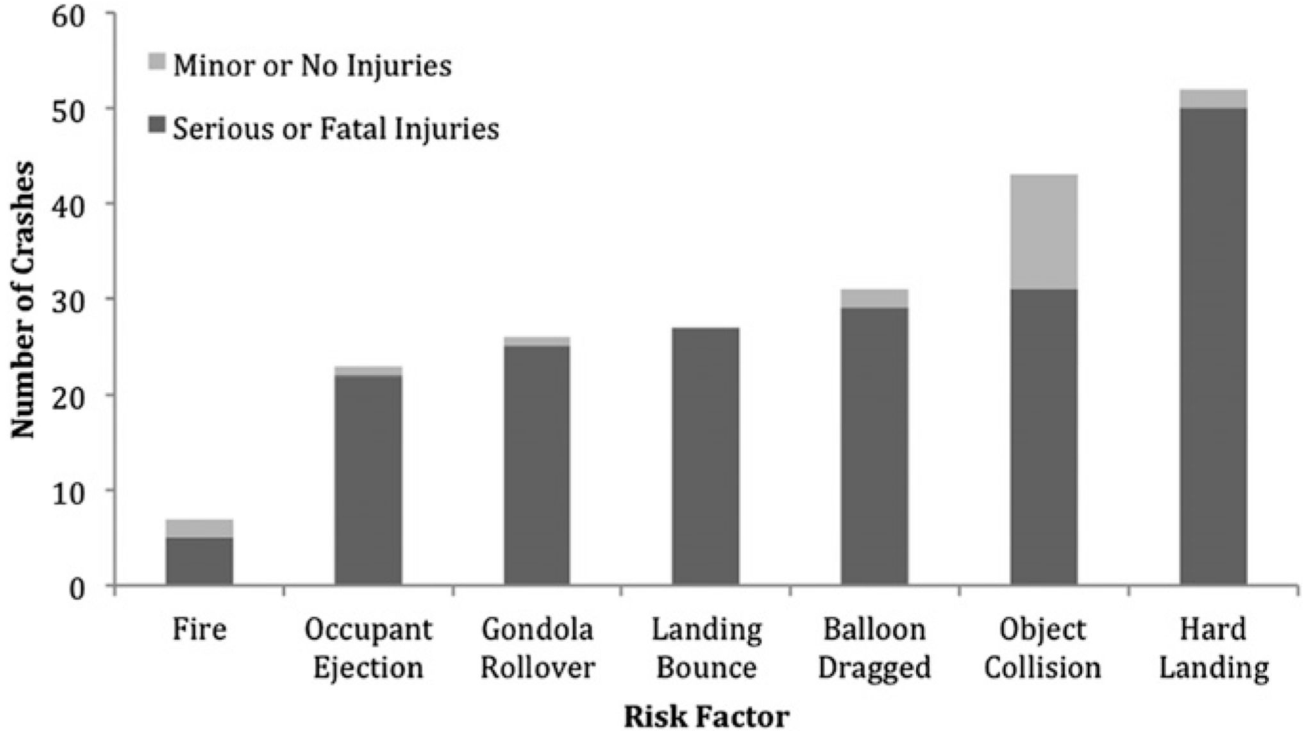

Fig. 1.

Risk factors in hot-air balloon tour crashes in relation to injury severity, United States, 2000-2011. Some crashes had multiple risk factors and are counted in each relevant group.

Fig. 2.
Paid hot-air balloon tour crashes by state, United States, 2000-2011. • = Paid hot-air balloon tour crash. (No paid hot-air balloon ride crashes occurred in Alaska or Hawaii during this time period.)

TABLE I

PAID HOT-AIR BALLOON RIDE OCCUPANT INJURY SEVERITY IN RELATION TO TYPE OF COLLISION, UNITED STATES, 2000-2011

	Injury Severity					
Collision	**Fatal**	**Serious**	**Minor**	**None**	**Total**	**%**
Tree	1	22	21	62	106	20.4
Ground	1	9	20	41	71	13.7
Multiple	0	5	13	22	40	7.7
Power line	2	5	4	26	37	7.1
Balloon	0	0	0	10	10	1.9
Building	1	2	4	0	7	1.3
Fence	0	3	1	1	5	0.1
Tower	0	0	0	3	3	0.1
No collision	0	45	31	164	240	46.2
Total	5	91	94	329	519	
%	0.1	17.5	18.1	63.4		

TABLE II
PAID HOT-AIR BALLOON RIDE OCCUPANT INJURY IN RELATION TO PRIMARY PILOT ERROR LISTED ON NTSB REPORT, UNITED STATES, 2000-2011

	Injury Severity					
Pilot Error	**Fatal**	**Serious**	**Minor**	**None**	**Total**	**%**
Excessive rate of descent	1	37	46	105	189	36.4
Failure to maintain clearance	3	20	25	59	107	20.6
Fuel planning error	0	5	4	33	42	8.1
Flight into adverse weather	1	6	0	19	26	5.0
Inadequate balloon handling	0	2	3	9	14	2.7
Distraction	0	0	0	12	12	2.3
Failure to obtain wind information	0	1	2	8	11	2.1
Inadequate passenger briefing	0	2	0	6	8	1.5
Run on landing	0	2	0	6	8	1.5
None	0	16	14	72	102	19.7
Total	5	91	94	329	519	
%	0.1	17.5	18.1	63.4		