9-2018

A Comparison of Special Category Light-Sport and Corresponding Type-Certificated Aircraft Safety

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Scholarly Commons Citation

Anderson, C., Stolzer, A., & Boyd, D. D. (2018). A Comparison of Special Category Light-Sport and Corresponding Type-Certificated Aircraft Safety. *Journal of Safety Research, 66*(). https://doi.org/10.1016/j.jsr.2018.06.004

A Comparison of Special Category Light-Sport and Corresponding Type-Certificated Aircraft Safety

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Abstract

Introduction. **The special category light sport airplane (light sport) sector of general aviation has grown ten-fold in as many years with solo operations requiring only a sports pilot's certificate. With little research on light sport airplane safety the study objective was to compare light sport and type-certificated airplane accident rates.**

Method. **Accidents were identified from the National Transportation Safety Board database. Statistics employed Poisson distribution/proportion analyses/Mann-Whitney U-tests.**

Results. **For the 2009-2015 period, the light sport airplane accident rate (fatal/non-fatal combined) was >15 fold higher than comparable type-certificated aircraft, undiminished over time. The excessive light sport airplane accident rate was associated with inferior airman experience (time-in-type, certification). Mishaps were most frequent during landing (40%) and of these nearly half were due to a deficiency in the flare. There were a dis-proportionate number of trainees involved in landing accidents compared with mishaps for other phases of operations.**

Conclusion. **Towards improving safety, additional light sport training with emphasis on landings and a focus on the flare and directional control is warranted.**

Practical application. **In the confines of the present study considering that landing mishaps, the most common accident cause, are often related to deficiencies in the flare and loss-of-directional control, instructors should ensure that airmen have mastered these aspects of landing and, for trainees, acquired the appropriate visual monocular cues.**

Keywords

Light sport aircraft; general aviation accident; SLSA, general aviation

Introduction

General aviation, classified as all civil aviation excluding paid passenger/freight transport, unfortunately accounts for 94% of civil aviation fatalities in the United States [1]. One sector of general aviation which has dramatically (10 fold) [2] expanded over the last decade is the special category light sport aircraft mainly comprised of airplanes (SLSA) but also inclusive of gliders, powered parachutes, weight-shift control aircraft and lighter-than air aircraft. This category of general aviation aircraft, introduced in 2004

[2] must meet the following specifications: maximum takeoff weight of 1,320 lbs., an airspeed in level flight not to exceed 120 kts., seat no more than two occupants (including the pilot), have a fixed landing gear and a propulsion system consisting of a single reciprocating engine with fixed pitch propeller [3]. Enthusiasm for these aircraft over the last ten years probably reflects a combination of several factors. Training requirements are lower; 20 hours to earn a sports pilot certificate compared with 40 hours for a private pilot license [4]. Finally, low fuel consumption rates coupled with a modest purchase price have also likely contributed to the gain in popularity for this general aviation sector.

As to safety of the SLSA fleet there have been no peer-reviewed studies comparing the accident rate for SLSA airplanes (exclusive of experimental builds) with the rate for 14CFR Part 23-certificated general aviation aircraft corresponding in terms of maximum take-off weight (1,321 lbs.) occupancy (2) and single powerplant. For 2016, the SLSA fleet consisted of 2,478 active airplanes flying 186,627 hours for that year [5]. By comparison, the fleet of active 14CFR Part 23-certificated general aviation aircraft comparable in occupancy and powerplant number comprised 32,044 airplanes which flew 2,105,790 hours for the same year [5].

Methods

Accident Data Source

The National Transportation Safety Board (NTSB) aviation accident Access database (March 1st, 2017 release) [6] was queried for accidents occurring over the period spanning 2009-2015 involving either SLSA (airplane category and exclusive of experimental builds) or type-certificated airplanes of 1,321 lbs. or less with a maximum of 2 seat occupancy and with one power plant all operating under 14CFR 91 regulations [7]. Experimental built airplanes were excluded from the current study since such aircraft have no FAA or industry consensus standards to meet other than those identified in the aircraft's operating limitations [8]. The database provides airman parameters such as certification, total time and time-in-type and injury severity outcome as well as the final report as to the mishap cause.

Aircraft Certification

Data were obtained from the FAA Regulation and Guidance Library [9].

Statistical Analyses

A generalized linear model with Poisson distribution (log-linear) was employed to determine if a change in the rate of accidents was statistically significant [10]. Fleet activities were from the general aviation annual fleet activity survey [5] using data for either SLSA aircraft or single piston-powered airplanes with 1-3 seats each summed for the indicated period. The natural log of the summed fleet activities was used as an offset [10]. Fleet activity for 2011 was derived by interpolation of data for the years 2010 and 2012.

Contingency tables employed a Pearson Chi-Square (2-sided) test to determine where there were statistical differences in proportions. If the expected minimum count was less than five the Fisher's Exact Test was used instead [11,12]. P values for cells in multinomial tables were derived from adjusted standardized residuals (Z-scores) in post-hoc testing.

Normality testing of continuous data was performed using the Kolmogorov-Smirnov test. A $p<0.05$ was indicative of non-normal distributed data [12]. Mann-Whitney tests were used to determine statistical differences in median values [12] for non-Gaussian distributed data.

All statistical analyses were performed using SPSS (v24) software. A p value of <0.05 was generally used as cut-off for statistical significance. However considering the potential for inflated alpha error rates associated with five variables in the risk factor analysis, a Bonferroni correction [12] was made. This yielded a more stringent statistical cut-off ($p <0.01$).

Results

Accident Rates for SLSA and Comparable Type-Certificated Aircraft.

First, the accident rates of SLSA airplane (hereafter, the term SLSA is restricted to those in the airplane category) and a comparator group, comprised of type-certificated airplanes corresponding in weight ($\leq$1,321 lbs.), maximum occupancy (2) and single power plant, were determined for the period spanning 2009-2015. For the initial period (2009-2010), the accident rate of SLSA was 15 fold higher (Fig 1) than that for comparable type-certificated aircraft (20.2 and 1.3 accidents/100,000 hours respectively). Although a modest decline (incident rate ratio =0.75, 95% Wald confidence intervals 0.51,1.10) in this rate was apparent for SLSA for the most recent period (2013-2014), this reduction was not statistically significant ($p=0.140$) using a Poisson probability distribution. Moreover, the SLSA accident rate was still 15 fold higher than that of type-certificated aircraft for the 2013-2014 period.

The accident fatality rate was then compared for both groups of airplanes. A fatal accident was defined as any in which one, or more, occupants perished within 30 days of the mishap from injuries incurred in the crash [13]. Over the seven year period, 12.1 and 14.1% of SLSA and comparable type-certificated airplane accidents were fatal (Fig 2). Accidents with fatal outcomes were not dis-proportionate in either group (p=0.653). Note that the total number of accidents was larger than that showed in Fig 1 as injury severity assessment included an additional year (2015).

Pilot Flight History and Certification.

The markedly elevated accident rate for SLSA operations compared with type-certificated airplanes begged the question as to why. Accordingly, a variety of parameters previously identified as accident risk factors were examined (Table 1).

Lower flight time in aircraft of the same make and model (time-in-type) [14] is a known risk factor and indeed, airmen in SLSA accidents had logged half the time-in-type compared with airmen in type-certificated aircraft. Similarly, the total flight time of pilots [15] involved in SLSA accidents was also statistically lower (p<0.001). Higher airman certification is generally associated with improved safety [16,17]. Thus, perhaps not surprisingly, SLSA pilots involved in mishaps were more likely to have lower level certificates (student (p=0.001) and sport (p=0.009)) rather than more advanced ratings. On the other hand, the finding that SLSA mishaps were over-represented in the flight instruction category was unexpected since training accident rates have previously been reported to be lower than those of non-instructional flights in fixed wing general aviation aircraft [18].

Phase of Operation.

The phases of operation for SLSA accidents were then compared with occurrences involving comparable type-certificated airplanes. Landing was the most prevalent phase of operation for both airplane categories (Table 2) and there was no difference in the proportions in the various phase of operations between both SLSA and type-certificated aircraft (p=0.865). SLSA landing mishaps accounted for 40% of all accidents in these aircraft and were over-represented (p<0.001) for student pilots (34%) compared with non-landing accidents which involved only 12% trainees.

To inform where future training should be focused towards mitigating the preponderance of SLSA landing accidents, such mishaps were sub-categorized as to their cause (Table 3). Deficiency in the process of the flare (also known as round-out or level-off) where the aircraft is transitioned from a nose-down to a level attitude just above the runway surface was evident in nearly half of all SLSA landing accidents. Trainees were involved in half of these types of landing mishaps. Additionally, nearly a third of landing accidents were due to a loss of directional control and of these 38% involved trainees. In contrast, low-level aerodynamic stalls just above the runway surface were relatively rare. It should be noted that only 8% of landing accidents were related to exceeding the maximum demonstrated cross-wind component. As to hard landings, we entertain the possibility that a less robust landing gear on SLSA as a consequence of keeping the aircraft within the maximum allowable weight may make such aircraft more prone to failure.

Discussion.

Herein, we report for the first time a substantially higher SLSA accident rate in comparison with type-certificated airplanes corresponding in weight/occupancy/powerplant an occurrence rate which shows no diminution over time. This increased mishap rate was associated with less airman experience as evidenced by lower total and time-in-type flight hours and a higher proportion of airmen with less advanced pilot certification.

The finding of a higher SLSA accident rate is consistent with a recent study [19] which reported a 30 fold increased mishap rate when compared with the general aviation fleet over the period spanning 2009-2013. However, that study differed from ours since the reference group comprised the entire general aviation fleet inclusive of multi-engine, turbojets and rotorcraft aircraft rather than airplanes of comparable occupancy/maximum weight/powerplant. This difference in study design may also explain the disparate findings of a higher fatality rate for SLSA accidents [19] whereas the current study showed an unchanged fatal mishap rate referencing comparable type-certificated airplanes. Nevertheless, it should also be emphasized that the 12% fatal accident rate for SLSA is well below the 18-23% commonly cited [20,21] for general aviation 80% of which is comprised of larger aircraft [5]. In a separate report covering a study period spanning 2004-2011, Anderson [22] similarly reported a three-fold higher SLSA accident rate in comparison with type-certificated aircraft. However, for that study SLSA included experimentally-built airplanes which have no industry consensus standards to meet other than those specified in the aircraft’s operating limitations [8]. Also, like the study of Mills and DeJohn [19], the reference group was not restricted to airplanes with comparable occupancy and maximum takeoff weight.

While the current and prior studies [19,22] clearly show diminished safety for SLSA operations our research provides some possible underlying reasons. Thus, airmen involved in SLSA accidents had lower experience in terms of time-in-type and less total time and were more likely to be students. Although just speculation, it may be that such airmen gravitate to SLSA due to lower cost and the feeling of greater safety with a relatively new airplane in comparison with aging 14CFR 23-certificated aircraft. Additionally, there were a disproportionate number of SLSA accident flights involving airmen with sports pilot privileges the latter requiring only 20 hours minimum compared with 40 hours for a private pilot license [4]. A somewhat surprising finding however was the over-representation of SLSA accidents involving training. A study of general aviation flight instruction has previously shown that such flights in fixed wing aircraft have a modest (~7%) diminished risk of an accident in comparison with non-training operations [18].

The high frequency of landing accidents in SLSA merits discussion. Landing an aircraft is perhaps the most demanding (even more so for trainees) of all phases of operations due in part to a rapidly changing visual “picture” [23] (and in some cases shifting winds) and the need for timely control inputs as the aircraft is transitioned from a controlled descent to contact with the landing surface. Indeed, SLSA landing accidents were over-represented for trainees consistent with prior studies [18,24,25]. In closer analysis a flare deficiency [26] was the most frequent cause (46%) for these types of accidents. During landing, monocular visual cues (e.g. linear perspective, motion parallax, texture gradient), which generate depth perception, are used [23,27,28] to identify the point where control inputs are made to initiate the flare. However, the acquisition of monocular cues is a learned process [27,28] (in contrast with binocular vision which is an innate skill [28]) and developed during primary training [27,28]. Since trainees were dis-proportionately involved in landing accidents, this begs the question as to whether students have adequately acquired such skills. Loss of directional control was the second most common cause of landing accidents and was over-represented for students again bringing into question as to whether trainees have receive sufficient instruction.

Our study was not without limitations. First, it was a retrospective study with inherent shortcomings of such an approach. Consequently, causality cannot be absolutely established. Also, the quality (incomplete sampling) of the fleet data used for determination of accident rate has been previously debated [29]. Finally, it is possible that the small number of low-level aerodynamic stalls evident in the landing phase for SLSA aircraft represented an under-count. Thus, a subset of “hard landings” may have indeed been due to an aerodynamic stall (despite the NTSB not citing this term) rather than a consequence of a deficiency in the flare. If this was the case, such mishaps could potentially be related to less rigorous longitudinal stability characteristics required for SLSA [30] (when compared with comparable type-certificated airplanes [31]) that could lead to pilot-induced oscillation during the landing phase.

In conclusion, while the limits of assigning causality pose difficulty in a retrospective study, the high rate of SLSA accidents argues for future prospective research to investigate these aforementioned cited relationships.

Practical Application

Within the confines of the present study considering the relationship between landing mishaps and a deficiency in the flare and a loss of directional control both dis-proportionately involved students, instructors should ensure that students/airmen have mastered these aspects of landing (especially considering the increased vulnerability of lighter aircraft to winds) and, for trainees, acquired the appropriate visual monocular cues.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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Figure 1 Accident Rate for SLSA and Comparable Type-Certificated Airplanes.

Accident rates are shown for SLSA and comparable (occupancy, maximum weight, single powerplant) type-certificated airplanes for the period spanning 2009-2014. Fleet activity data used as denominator were for SLSA and single piston-powered aircraft with 1-3 seats respectively. For each airplane category, fleet activity was summed for the indicated period. n, accident count. A Poisson distribution was used to determine if SLSA accident rate changed over time using the initial period as referent.

Figure 2. Proportion of Fatal Accidents for SLSA and Comparable Type-Certificated Aircraft.

A fatal accident was any in which one more occupants perished from his/her mishap-related injuries within 30 days of the event. A Pearson 2-sided Chi-Square test (n, 389, df, 1) was used to determine differences in proportions. n, accident count.

Table 1. Airman Flight History/Demographics.

Airman flight history, certification and age of those involved in accidents for the period spanning 2009-2015 are shown. A Mann-Whitney U test was used to determine whether means of these populations differed significantly. Differences in proportion for type flight and airman certification was assessed using a Pearson Chi-Square test with p values for individual cells derived from adjusted residuals. N, count; Q, quartile.

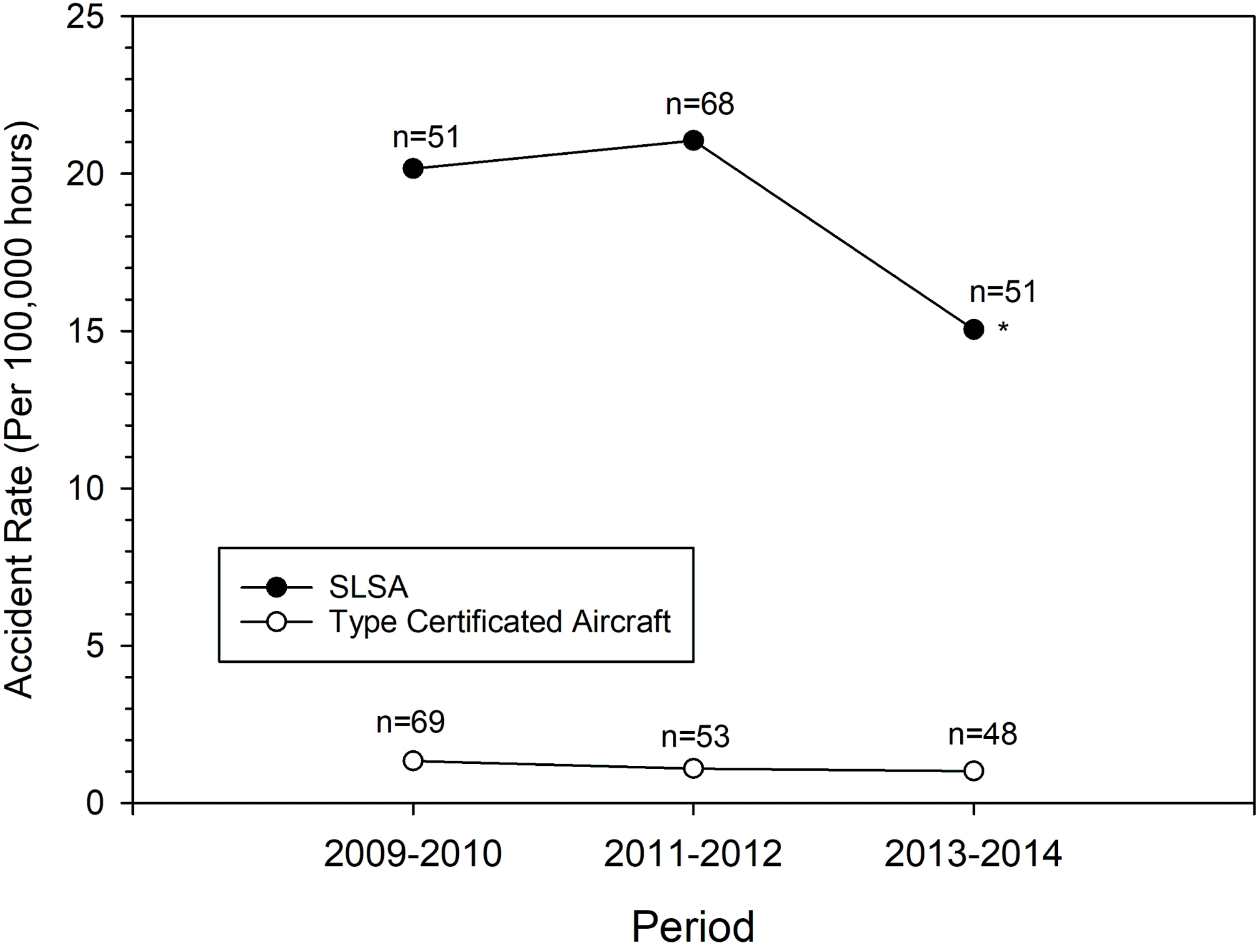
Table 2. Phase of Operation.

The phases of operation for accident flights are tabulated. Climb/descent differ from takeoff/landing respectively by the former occurring outside the lateral limits of the aerodrome, Aircraft going-around and within the traffic pattern were included in the Maneuvering category. Accidents due to injury of occupant external to the aircraft, physical incapacitation and runaway plane due to hand-propping were all excluded. n, accident count.

Table 3. Sub-Categorization of SLSA Landing Accidents

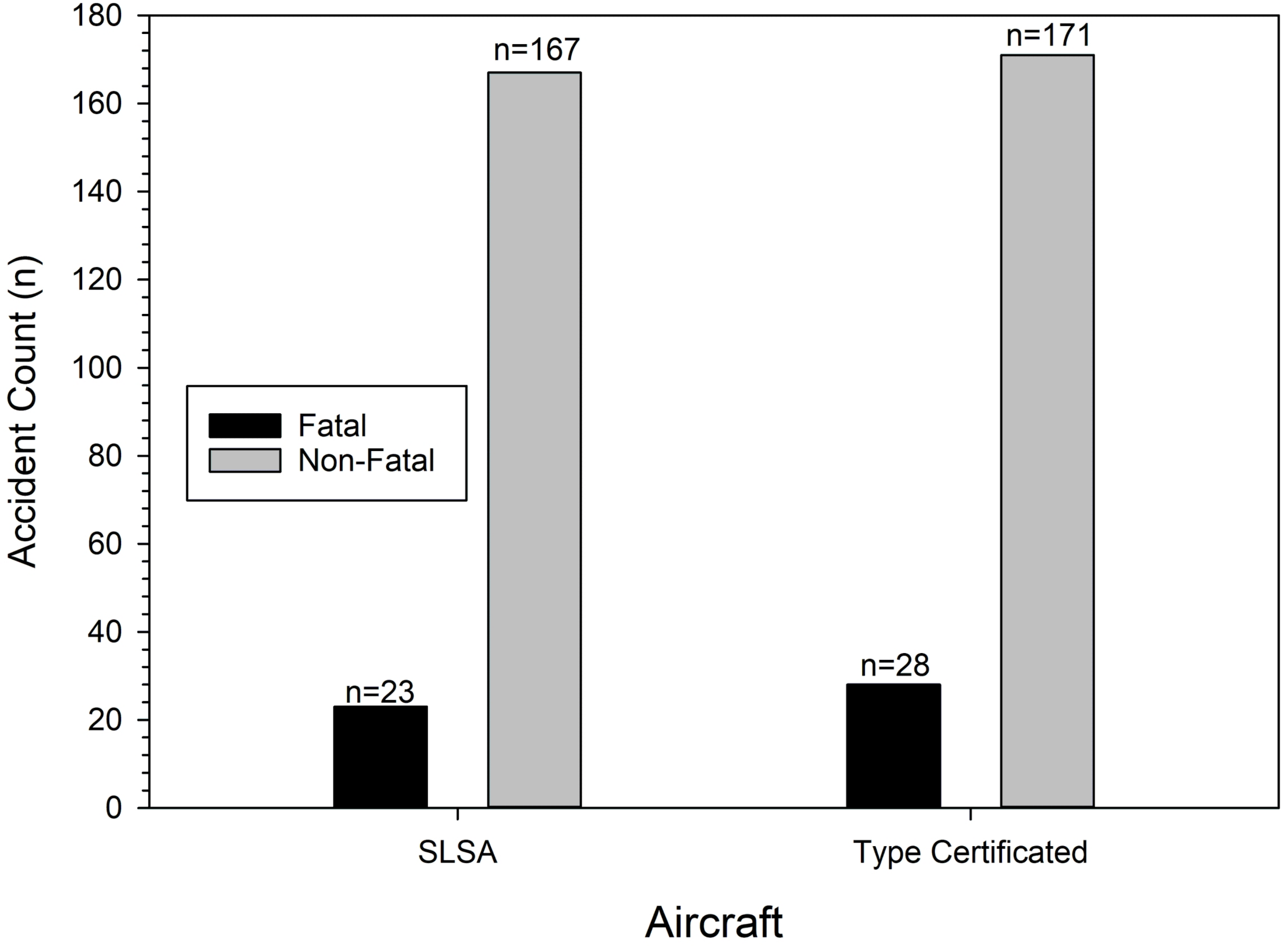
Landing accidents involving SLSA airplanes were categorized as follows. A low-level stall was defined as any landing accident in which the term “stall" was cited in the NTSB narrative cause section. Landing mishaps defined as “excess speed/energy” was any in which the airplane bounced multiple times, porpoised or over-shot the landing aiming point leading to a runway excursion from the departure end. Flare deficiency mishaps those where the terms “flare” and/or “hard” landing were cited in the narrative cause but excluded those caused by gusty winds or where an aerodynamic stall occurred. Note that some landing accidents were assigned to more than one sub-category.

Figure 1



25
20
15
10
5
0
Accident Rate (Per 100,000 hours)
n=51
n=68
n=51
*
SLSA
Type Certificated Aircraft
n=69
n=53
n=48
2009-2010
2011-2012
2013-2014
Period

Figure 2


180
160
140
120
100
80
60
40
20
0
Accident Count (n)
Fatal
Non-Fatal
n=167
n=171
n=23
n=28
SLSA
Type Certificated
Aircraft

Co-Variate		SLSA	Type Certificated Airplane	U-Value	P value	
Pilot Certification N (%)	Student	34 (18)	10 (5)		0.001	p<0.001 (df, 4)
	Sport	30 (16)	15 (8)		0.009	
	Private	60 (31)	89 (45)		0.009	
	Commercial/CFI	47 (25)	54 (27)		>0.050	
	ATP	17 (9)	30 (15)		>0.050	
Total Time (h)	Median	530 (n=182)	1,194 (n=196)	13,849	<0.001	
	Q1	104	375			
	Q3	2,313	3,000			
Time in Type (h)	Median	48 (n=171)	100 (n=176)	12,527	0.007	
	Q1	20	28			
	Q3	131	250			
Type Fly N (%)	Personal	125 (66)	168 (84)		<0.001	p<0.001 (df, 2)
	Instruction	59 (31)	25 (13)		<0.001	
	Other	6 (3)	6 (3)		>0.05	
Pilot Age (Years)	Median	60 (n=186)	61 (n=198)	17,797		p=0.571
	Q1	50	48			
	Q3	69	72			

TABLE 1

	SLSA (n=184)		Type Certificated Aircraft (n=189)	
Phase of Operation	n	%	n	%
Climb/Descent	29	16	29	15
Enroute	21	11	19	10
Landing	74	40	67	35
Maneuvering	26	14	33	17
Takeoff	28	15	33	17
Taxiing	6	3	8	4

Table 2

Table 3

	Count (n)	% Landing Accidents
Flare Deficiency	34	46
Loss Directional Control	24	32
Low-Level Aerodyanmic Stall	4	5
Excess Speed/Energy	13	18