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Nose-Over and Nose-Down Accidents in General Aviation: Tailwheels and Aging Airplanes

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Abstract: Safety in General Aviation has been a continuous concern. About 12% of all airplane accidents in General Aviation involve nose-overs and nose-down events. A total of 134 accidents reported by the National Transportation Safety Board that include nose-overs and nose-downs were analyzed for their main causes. It was found that 35% of the defining events involved a loss of control on the ground while 58% of the total dataset involved tailwheel-type aircraft. A relatively high proportion of aircraft built before 1950 were found, which are also aircraft that have tailwheel-type landing gear, and thereby a higher propensity for ground loops and nose-overs. It is shown that the high accident rate in General Aviation, especially for accidents that did not result in a fatality, was, to an important extent, explained by tailwheel and older aircraft in the US General Aviation airplane fleet struggling with controlling the aircraft on the ground. Attention to this group of aircraft in future studies may help to more effectively address the relatively high accident rates in General Aviation.

Keywords: aviation safety; landing gear; aircraft age; instruction

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1. Introduction

General Aviation safety has been a concern for several decades, during which both the frequency and seriousness of accidents have been highlighted [1,2]. Accident analyses have shown that fatal accidents in General Aviation have mostly been associated with unfavorable weather and light conditions [1–3]. However, the specificity of General Aviation aircraft and the diversity of their operations have warranted more in-depth analyses to understand possible mitigating strategies [4].

In studies focusing on airplanes, as opposed to helicopters and other aircraft, accidents in the landing phase have received particular attention due to the frequency of the accidents, which include both landings and go-arounds [5,6]. Within this group, instructional flights received particular attention, both as a starting point for training and as a purpose of flight that has a high frequency of accidents. Even though instructional flights are less frequently fatal, they are particularly numerous and often associated with landing problems [7–9].

The following study of nose-over and nose-down accidents, which are mostly associated with the landing and take-off phase, is an extension of the efforts to understand and mitigate the high number of accidents in General Aviation. Nose-over and nose-down events appear when the nose of an aircraft either hits the landing surface or the aircraft tumbles over its nose into an upside-down position. Although rarely fatal, this visually dramatic accident is relatively frequent in General Aviation accident statistics. From 1 January 2017 until 1 January 2022, there were circa 5075 accidents with General Aviation airplanes in the United States, of which 609 included nose-over or nose-down events, accounting for 12% of all General Aviation accidents with airplanes in a given year. By looking at a specific but especially frequent event, rather than a phase of flight or operation, this study aims to add a different perspective on General Aviation safety. Following previous research, both the type of aircraft, specifically the type of landing gear, and the kind of operation, mainly instructional flights, are given additional attention.

2. Materials and Methods

A total of 134 nose-overs and nose-down accidents from the period 1 January 2019 to 31 December 2019 were extracted from the U.S. National Transportation Safety Board (NTSB) online database using the CAROL (Case Analysis and Reporting Online) search query tool [10]. This interface provided by the NTSB allows the user to define search rules including the specific category of "nose-overs and nose-down" accidents. Reports were only included in the dataset if the accident report was complete, and included all accidents for this time period. Accidents were included only if they occurred in the United States and if the aircraft was a single-engine airplane or powered glider operating under Part 91 (General Aviation) flight rules.

Each accident report obtained from the NTSB database contains a factual and a probable cause statement that summarizes the findings of the NTSB investigator. It provides a narrative statement, a set of findings that includes the cause and contributing factors of the incidents, and data on the pilot, aircraft, airfield, and meteorological conditions. Additional categories specific to this type of accident, such as environmental factors, but also specific actions, such as excessive braking by the pilot and ground loops, were extracted using the narrative text; together with the other categorical data that were listed by the NTSB investigator, these were combined into a table.

Unfortunately, the Federal Aviation Administration (FAA) does not collect denominator data on tailwheel aircraft, such as the number of flight movements or flight hours or even the number of active aircraft with a tailwheel. Although older aircraft are more likely to feature a tailwheel, the introduction of the nosewheel was a gradual process [11]. As an approximation, this study uses the proportion of accidents as an indicator of risk, as suggested in a previous debate about General Aviation denominator data [12,13].

If appropriate, items were renamed or grouped together. Significant differences between expected and actual values within the dataset of categorical data were determined using Fisher's Exact Test or approximated with a Pearson's Chi-Squared analysis. Relations were considered significant if p-values were below 0.05.

3. Results

All 134 accidents in the dataset were operating under Part 91 (General Aviation) flight rules. Out of a total of 134 accidents, 95 (71%) recorded no injuries or fatalities. The number of accidents per type of injury is listed in Table 1. All 134 accidents reported substantial damage (N = 134) to the aircraft. Although nose-over and nose-down accidents occurred during landing (N = 104) or take-off (N = 24), with few occurring during the taxi phase (N = 4), the cause of the accident may have started during the cruise (N = 2), so this flight phase was also reported.

Table 1. Injury severity and type of landing gear.

Landing Gear	Fatal Injury	Serious Injury	Minor Injury	No Injury
Tailwheel	2	0	11	65
Tricycle	0	5	16	28
Float/amphibian	2	0	2	3

The accidents occurred in 33 different states. The highest number of accidents was found in Alaska (N = 25, 19%), California (N = 14, 11%), and Texas (N = 12, 9%). California and Texas, however, have the highest number of General Aviation aircraft, which is more than three times the number present in Alaska [14]. All accidents took place during visual meteorological conditions and mostly took place during daylight conditions (N = 131, 97%). Out of a total of 134 accidents, 87 (65%) flights experienced environmental issues, with a total of 30 (22%) accidents occurring during unfavorable wind conditions, and 23 (17%) and 13 (10%) reported uneven or rough terrain, respectively.

The pilots involved in the accidents ranged in age from 18 to 91 years, with an average age of 53 years. Their experience in total flight hours ranged from 5 to 35,000 h, with an average of 3619 h.

Each of the aircraft in this dataset had a single engine, while most aircraft had a reciprocating engine (*N* = 129, 96%). A total of 78 (58%) aircraft were equipped with tailwheel-type landing gear, sometimes referred to as conventional landing gear or a taildragger. Most other aircraft had tricycle landing gear, which has a third wheel under the nose rather than at the tail of the aircraft. There were four amphibian and three float-equipped airplanes, of which four landed on water with a nose-over; two of these landings on water resulted in a fatality. Table 1 shows the injury severity for each type of landing gear. Accidents occurring in Alaska showed a higher proportion of aircraft with tailwheel-type landing gear as opposed to other types of landing gear (18 out of 25) than all other states combined (60 out of 109), but this difference was not significant ($p = 0.1768$). Unfortunately, it is not known how many active aircraft with tailwheel-type landing gear are active in Alaska, nor do we know the number of flight hours or movements of such aircraft compared to those in other states.

A ground loop—defined as an involuntary uncontrolled (abrupt) turn of an aircraft while moving along the ground—was reported ten times, and only one case involved an instructional flight, while all cases involved tailwheel aircraft.

The NTSB identifies one occurrence as the defining event of an accident. In this dataset, defining events included abnormal runway contact (*N* = 3), which only included tailwheel aircraft, and nose-over/nose-down (*N* = 33), which also had a significantly higher proportion of tailwheel aircraft (*N* = 27, 82%). In the list of causes mentioned in this dataset, loss of control on ground (*N* = 47) also included a high proportion (*N* = 30, 63.8%) of tailwheel aircraft compared to the rest of the dataset.

The age of the aircraft in this dataset can be compared to the number of estimated active aircraft in 2019 as provided by the Federal Aviation Administration [15]. It is shown in Table 2 that a relatively high proportion of aircraft older than 1950 is present in our dataset (20.31%). Instead, we would only presume a higher proportion of newer (2010–2019) aircraft in this dataset, as they can be expected to have made a proportionally higher number of flight hours. Although only denominator data can show this to be the case, Table 2 does indicate that aircraft older than 1950 stand out in our study.

Table 2. Active aircraft in 2019 compared to nose-over accidents in 2019 by age of aircraft.

Year Built	Active Aircraft (%) [1]	Active Fixed-Wing Piston Single-Engine Aircraft (%)	Nose-Over Accidents (%) [2]
2010–2019	25,458 (12.07%)	4956 (3.84%)	15 (11.11%)
2000–2009	35,669 (16.91%)	10,721 (8.32%)	19 (14.84%)
1990–1999	16,228 (7.69%)	5085 (3.94%)	6 (4.69%)
1980–1989	18,103 (8.58%)	9402 (7.29%)	8 (6.25%)
1970–1979	51,135 (24.24%)	41,158 (31.9%)	25 (19.53%)
1960–1969	35,734 (16.94%)	30,394 (23.47%)	20 (15.63%)
1950–1959	13,550 (6.42%)	12,568 (9.75%)	10 (7.81%)
−1949	15,102 (7.16%)	14,643 (11.36%)	26 (20.31%)

[1] Estimates provided by the Federal Aviation Administration [15]. [2] In five accidents, the age of the aircraft was not reported.

Most accidents showed the purpose of flight as personal (*N* = 97, 72%) or instructional (*N* = 28, 21%). In addition, there were four positioning flights, two agricultural flights, two flight tests, and one aerial observation. Instructional flights showed several significant differences with other flight purposes in this dataset. Eleven accidents with an instructional purpose reported wind conditions as a cause, which was significantly higher than for all other flights combined, which only reported 18 cases out of 106 with wind conditions as a cause ($p = 0.0185$). Additionally, a significantly higher proportion of aircraft with tricycle landing gear were involved in instructional flights (16 out of 50) compared to those with other landing gear (10 out of 84), (p = 0.0064). Not surprisingly, student pilots more often had fewer flight hours, with 19 out of 28 instructional flight accidents reporting that the Pilot in Command had less than 500 h, as opposed to 28 out of 106 for the remainder of the accidents, with three cases of non-instructional accidents in which flight experience was not recorded (p = 0.0001). Directional control was identified as part of the cause in 39 accidents and, again, instructional flights with 13 out of 28 accidents reporting directional control problems showed a higher proportion than personal flights with 26 out of 106 accidents (p = 0.0342). Among the instructional accidents, seven reported brake-related issues but this was not significantly more than in flights with a different purpose (p = 1).

4. Discussion

Previous research on General Aviation showed that 20% of accidents were fatal [2], while landing accidents had 17% fatal accidents but only 7% if there was no evidence of deficient airspeed management [6]. For instructional flights, only 4% of fatal accidents were reported for students flying solo [9], for instance, suggesting that the landing phase and instructional operations may be, but are not necessarily, more dangerous. Events with nose-overs and nose-downs in this study only reported 3% with a fatality, which is particularly low in General Aviation accident analysis, and at least partially explained by the landing phase in which most accidents took place. Addressing nose-overs and nose-downs is, however, especially relevant for understanding and mitigating the overall number of General Aviation accidents as opposed to the fatal ones since, in 2019 alone, 12% of all General Aviation accidents reported nose-overs or nose-downs.

Several studies have found a significant portion of accidents taking place in Alaska, even though California, Texas, and Florida have more General Aviation activity [16–18]. The dangers of the Alaska environment also appear to affect nose-over and nose-down accidents, but this finding was not significant.

There are no denominator data about the number of tailwheel-type airplanes in the US, but 58% of the aircraft in our accident dataset on nose-overs and nose-downs had tailwheel landing gear. They are mostly associated with older planes, with a significant number of aircraft in our dataset built before 1950. Only in 1956 did Cessna fit its Cessna 172 with "new landing gear" that "replaced the tail dragging design, which could cause inexperienced pilots to ground loop on landing" [11] (p. 124).

More importantly, nose-over and nose-down as a defining event included significantly more tailwheel aircraft, while the overall dataset already has a majority of aircraft with tailwheel landing gear. This suggests that an important proportion of non-fatal General Aviation accidents relates to tailwheel aircraft, an observation that can only be further corroborated if future research includes the type of landing gear in the accident analysis.

Nose-overs and nose-down accidents, to an important extent, had environmental causes that include wind and terrain issues. Causes attributed to the pilot included directional control and, together with wind problems, they disproportionally affected instructional flights. Aircraft with tricycle landing gear were more often associated with instructional flights in relation to nose-overs and nose-downs. In other words, both airplanes with tailwheel and tricycle landing gear configurations may experience nose-overs and nose-downs, but the dominant circumstances in which these occur vary between the two categories. The FAA requires tailwheel certification that includes separate training under CFR 14, Part 61.31, and a subsequent endorsement by an instructor [19]. Future research may determine, for instance, whether a higher proportion of tailwheel-type airplanes are also associated with other types of accidents in General Aviation, which could inform the tailwheel certification process.

While the additional training for tailwheel certification is shown to be particularly necessary, the FAA could assist in recording the number of flight movements or flight hours of tailwheel aircraft allowing future studies to determine the risk of accidents. Accordingly, improved training and, for instance, additional limitations on flying under certain wind and terrain conditions for tailwheel aircraft specifically, may assist in reducing the proportion of accidents for this category of aircraft in General Aviation.

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