General Aviation Accidents Involving Fixed-Wing Aircraft on the Ground

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BACKGROUND: Accidents during start-up and shut-down procedures of aircraft can lead to fatalities or destroyed aircraft. Start-up procedures for propeller aircraft include the possibility of hand-propping, which may increase the occurrence of injuries from propeller strikes.

METHODS: A set of 142 accidents from a 10-yr period were selected from the U.S. National Transportation Safety Board online database. Only fixed-wing aircraft in the "standing" phase of flight were included in the dataset. The significance of differences was determined using Pearson's Chi-squared analysis.

RESULTS: The severity of the injuries sustained in the accidents were inversely related to the amount of damage to the aircraft. Hand-propping without properly securing the aircraft was more likely to result in substantial damage to the aircraft. Pilots with less than a thousand hours of flight experience were significantly more likely to use an incorrect hand-propping procedure.

CONCLUSIONS: It is recommended to make the advisory on hand-propping a regulatory article of the Federal Aviation Administration so that pilots' knowledge of this procedure is mandatory and part of their initial training, especially securing the aircraft during hand-propping. Highlighting throttle positions in both regular and hand-propping procedures may optimize checklist design and further mitigate accidents during start-up procedures.

KEYWORDS: general aviation, accident analysis, fixed-wing aircraft, hand-propping, checklist.

de Voogt AJ, Kalagher H, Burns S. *General aviation accidents involving fixed-wing aircraft on the ground*. Aerosp Med Hum Perform. 2022; 93(7):597–600.

Accidents during start-up and shut-down procedures of aircraft can lead to fatalities or a destroyed aircraft.[1,3] Human factors related to the start-up and shut-down phases of aircraft have been part of experimental studies on checklist design.[2,5] Checklists are seen as the main mitigating strategy to avoid accidents that are caused by procedural mistakes, especially when the procedures in question would benefit from a regimented approach. The possible damage to an aircraft and injury to its occupants may be gleaned from an accident analysis of aircraft standing on the ground.

In a previous study on accidents of helicopters on the ground, it was found that rotor strikes accounted for most of the fatalities and rollovers were the most frequent cause of substantially damaged aircraft.[3] For fixed-wing aircraft, propeller strikes are a likely cause of serious injury. The existence of start-up procedures that include hand-propping, also known as hand-propelling, creates additional potential for propeller strikes and injury.

Hand-propping is a start-up procedure that is used only when a regular start-up is not possible. The pilot will turn the propeller blades by hand to initiate an engine start. Hand-propping procedures commonly lack adequate checklists despite an advisory published by the Federal Aviation Administration in their *Airplane Flying Handbook* (FAA-H-8083-3A) under section 2, titled "Hand propping".[4]

In this study, we analyze the causes and factors of general aviation accidents with fixed-wing aircraft with engines running but still standing on the ground. We highlight the most common causes of accidents and propose mitigation actions for improving safety.

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This manuscript was received for review in September 2021. It was accepted for publication in March 2022.

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DOI: https://doi.org/10.3357/AMHP.6006.2022

Table I. Injury Severity Compared to Damage to Aircraft and Light Conditions.

	HIGHEST INJURY SEVERITY			
	NONE	MINOR	SERIOUS	FATAL
Damage To Aircraft				
None	0	0	11	4
Minor	7	0	3	5
Substantial	84	19	4	3
Destroyed	1	1	0	0
Light Conditions				
Day	85	17	16	11
Dusk	0	1	1	1
Night	5	1	0	0
Night/Bright	1	0	0	0
Night/Dark	1	1	1	0

METHODS

A total of 166 accidents from a 10-yr period from January 1, 2008, to December 31, 2017, were extracted from the U.S. National Transportation Safety Board online database.[6] Reports were included in the dataset if the accident occurred during the "standing" broad phase of flight and involved a fixed-wing aircraft. Of the 166, 24 were removed from further analysis because the accident did not take place during the standing broad phase of flight.

The significance of differences was determined using Pearson's Chi-squared analysis. For analyses in which the expected cell frequencies were not all above 5, a Fisher's exact test was used. Relations were considered significant if *P*-values were below 0.05.

RESULTS

All 142 aircraft in the dataset were operating under Part 91 (General Aviation) flight rules. The accidents occurred in 40 different states with an additional accident in the U.S. territory of Guam. Additionally, the accidents largely occurred during visual meteorological conditions ($N = 141$, 99%) and mostly took place during daylight conditions ($N = 129$, 91%). The accidents that occurred during daylight conditions were not more likely to result in a serious injury or fatality compared to other light conditions ($P > 0.05$).

Most of the aircraft in this dataset had a single engine ($N = 122$, 86%); 19 (13%) had 2 engines and 1 aircraft had 3 engines. Single-engine aircraft were not more likely to be part of an accident with serious injury or a fatality compared to aircraft with more than one engine ($P > 0.05$).

The pilots involved in the accidents in the dataset ranged in age from 18 to 91 yr with an average of 52.9 yr. The pilots varied in their experience as defined by total flight hours accrued ranging from 1 to 31,553 h with an average of 3953 h and a median of 1390 h. Experienced pilots, as defined by accruing 1000 or more flight hours, were not significantly less likely to be involved in accidents that resulted in serious injury or fatality compared to their less experienced peers ($P > 0.05$). In 26 of the accidents, a co- or student pilot was present. We did not find a significant relationship between the presence of a copilot or student pilot and level of injury severity ($P > 0.05$).

The dataset shows a counter-intuitive inverse relationship between the damage to the aircraft and the injuries sustained. Accidents in which fatal or serious injuries were reported were significantly less likely to occur when the aircraft was damaged or destroyed (see **Table I**; $\chi^2 = 70.41$ $P < 0.00001$).

In addition to pilot and passenger injuries and fatalities, a number of people were injured who were outside of the aircraft at the time of the accident. Two people were killed, four sustained serious injuries, and two sustained minor injuries. A Fisher's exact test revealed that injuries to individuals outside of the aircraft were significantly more likely to occur when the aircraft sustained only minor or no damage (6 out of 30) compared to injuries that occurred when the aircraft was substantially damaged or destroyed (2 out of 112) ($P < 0.05$). In other words, injury severity and damage to the aircraft were inversely related in this dataset for both occupants and people injured outside the aircraft.

Table II displays the causes of the accident as determined by the NTSB investigators and the associated highest injury level as well as aircraft damage. As can be seen from the table, causes that resulted in at least one fatality included distraction from

Table II. Causes Attributed to the Accidents by NTSB Investigators and Associated Aircraft Damage and Pilot/Passenger Injury.

		AIRCRAFT DAMAGE		HIGHEST INJURY	
CAUSES	NUMBER OF OCCURRENCES	DESTROYED	SUBSTANTIAL	FATAL	SERIOUS
Distraction from Nearby Aircraft	16	0	12	1	0
Engine Fire (Undetermined Cause)	4	2	2	0	0
Failure to Shutdown Engine	4	0	1	0	3
Fuel Leak and Engine Fire	5	0	5	0	0
Incorrect Hand-Propping Procedure	43	0	36	4	7
Improper Preflight Inspection	11	0	11	1	0
Improper Engine Startup	19	0	19	1	0
Main Landing Gear Failure	2	0	2	0	0
Over-Priming Engine	5	0	5	0	0
Parking Brake Failure	8	0	5	0	0
Passenger Interference/Mistake	4	0	1	0	3
Walking into Propellor	8	0	1	3	5
Other	13	0	10	2	0

Table III. Hand-Propping Issues That Violate the FAA Handbook Advisory.

HAND-PROPPING ISSUE	NUMBER OF OCCURRENCES*
Failure to have two individuals with relevant (pilot) training	10
Attempting to start up the aircraft alone	10
Attempting start up on unstable ground	1
Ignition/magneto not on OFF	7
Failure to maintain one arm length distance	2
Failure to approach wheel chocks from behind	2
Failure to not set throttle to idle	14
Failure to properly secure aircraft	26

*More than one issue may be listed for an individual accident.

nearby aircraft, improper preflight inspection, incorrect hand-propping procedure, improper engine startup, and walking into the propeller. Two additional fatal accidents were caused by pilot incapacitation and vacuum system failure. Table II provides a clear indication that hand-propping is over-represented in ground accidents.

Propellor strikes were part of more accidents than those involving hand-propping. In a total of 53 accidents, a person came in physical contact with the airplane's propeller by either rotating the propeller by hand ($N = 33$, 62%), or by being struck by the propeller ($N = 13$, 25%), and there were 7 (13%) instances in which the person rotating the propeller by hand was ultimately also struck by the propeller. Rotating the propeller by hand was significantly more likely to result in a destroyed aircraft or substantial damage (33 out of 39) compared to accidents in which a propeller struck an individual but did not involve hand-rotation (1 out of 14), as determined by a Fisher's exact test ($P < 0.05$). We did not find a significant relationship between experience and accidents that involved a person getting struck by a propeller ($P > 0.05$). In the majority of the propeller strike accidents, the pilot was the individual who was struck ($N = 13$, 65%), which included one flight instructor (nonfatal) and two student pilots (one fatal). In six of the accidents involving a pilot, the pilot also sustained fatal injuries. In the remaining seven accidents, there were five passengers (one fatal), one crewmember (fatal), and one bystander (nonfatal) struck by the propeller.

Start-up related causes included improper engine startup, over-priming, incorrect hand-propping, or hand-propelling without securing, making a total of 67 (47%) accidents, which include 5 (42%) of the fatal accidents. A Fisher exact test revealed that hand-propping without properly securing the aircraft was more likely to result in substantial damage to the aircraft (26 out of 110) as opposed to minor or no damage (0 out of 30) compared to all other causes combined ($P < 0.05$). Unfortunately, no information was available about pilots' awareness of correct hand-propping procedures. Hand-propping was not more likely to result in serious or fatal injury compared to all other causes combined ($P > 0.05$).

The specific hand-propping startup issues are displayed in **Table III**. In 15 of the 43 hand-propping issue reports, more than one cause was listed. In the total dataset, 63 pilots had accrued less than 1000 flight hours. These pilots were significantly more likely to use an incorrect hand-propping procedure (25 out 63) compared to their more experienced peers (18 out of 79) ($\chi^2 = 4.74$, $P < 0.05$). However, we did not find a similar significant relationship between experience and improper engine startup.

DISCUSSION

As with helicopter accidents on the ground, the damage to the aircraft and the severity of the injuries were inversely related.[3] As a result, mitigation strategies that assist in reducing injuries do not necessarily reduce aircraft damage. For instance, rotor strikes for helicopters on the ground are similarly dangerous as propeller strikes for fixed-wing aircraft and present the most common cause of a fatal and severe injury, but rarely damage the aircraft. In this study, it was found that improper hand-propping resulted in both damaged aircraft as well as in injuries from propellor strikes, but not necessarily at the same time. This may also explain why less experienced pilots were more likely to be involved in an incorrect hand-propping procedure, but equally likely to be seriously injured.

Unlike accidents involving helicopters, accidents on the ground with fixed-wing aircraft show a high proportion of accidents that relate to start-up procedures. Hand-propping stands out as a particularly dangerous element, a procedure that is only used if an airplane propeller engine does not start following the standard start-up procedure. The Federal Aviation Administration (FAA) explains in detail how a hand-propping operation is supposed to be conducted in their *Airplane Flying Handbook* (FAA-H-8083-3A) under section 2, titled "Hand propping".[4] However, this handbook is not part of FAA regulations and pilots are not necessarily aware of this advisory. A significant relationship between experience of the pilot and accidents involving hand-propping was found that suggests that knowledge of the advisory or experience with the handbook hand-propping checklist may have been lacking.

This research points to at least two possible mitigation strategies that may reduce future accidents with airplanes standing on the ground. The first is making the advisory on hand-propping a regulatory article of the FAA so that pilots' knowledge of this procedure is mandatory and part of their initial training. Since not all airplanes allow for a hand-propping procedure, at a minimum it should be a mandatory part of training before a pilot operate aircraft that allow hand-propping. Second, the hand-propping checklist requires pilots to monitor the throttle settings and conduct several checks almost simultaneously. Checklist experiments have shown that dynamic checks in which pilots need to monitor as well as conduct additional checks have a higher chance of human error.[5] In addition to raising awareness about the proper hand propping procedure, performing the checklist correctly may benefit from practice rather than just taking note of an FAA advisory.

ACKNOWLEDGMENTS

Financial Disclosure Statement: The authors have no competing interests to declare.

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