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Fatal Consequences of Safety Non-Compliance in Non-Commercial Ultralight Aviation: A Case Study

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Abstract: The popularity of ultralight planes in non-commercial aviation is on the rise; however, non-compliance with regulations and the use of faulty equipment poses significant risks. This study explores the consequences of such lapses in adherence to safety standards by thoroughly examining the conditions leading to an ultralight plane crash, focusing on data related to causative factors. The accident involved an unregistered ultralight aircraft, lacking proper inspection and the required license. The pilot's error during takeoff led to a stall, resulting in a fatal crash. Upon impact with the ground, the pilot's shoulder and lap belts were torn off, leading to immediate death. This case underscores the critical importance of compliance with safety regulations in ultralight aviation. The findings illuminate the dire consequences of non-compliance with safety regulations and the utilization of unregistered, uninspected ultralight aircraft in private aviation. The tragic accident analyzed herein underscores the pivotal role of adherence to safety standards in mitigating the risks associated with ultralight planes. The pilot's fatal error during takeoff, compounded by the absence of proper inspection and licensing, serves as a stark reminder of the potential dangers inherent in neglecting established safety protocols.

Keywords: airplane crash; accident cause analysis; ultralight aircraft

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1. Introduction

Developments in technology have led to a surge in the presence of private aircraft in the skies. Despite the continued high cost associated with aircraft usage, an increasing number of individuals are obtaining pilot certificates. In Poland, for instance, the private aircraft and helicopter fleet was 1500 units in 2022 [1]. This growing trend caters to a diverse user base, encompassing those seeking comfort, privacy, and expeditious travel, as well as affluent individuals, particularly business professionals. Flying by private plane proves advantageous in saving time, especially when reaching destinations lacking direct flights. Additionally, a notable demographic consists of hobbyist flyers who derive pleasure from aviation.

However, ownership of an aircraft entails considerable expenses, averaging around PLN 150,000 (approximately USD 35,000) annually. These costs encompass fuel, insurance, and routine maintenance, with potential for escalation in the case of major repairs. Despite the financial implications, the convenience and advantages associated with private aviation continue to attract a broad spectrum of users in Poland and beyond.

To obtain a certification for flying ultralight aircraft, a pilot does not necessarily need a Private Pilot License (PPL) [2,3]. Ultralight pilot certification typically requires less intensive training than that for a PPL(A). Ultralight pilot training includes a combination of theoretical and practical components tailored specifically to ultralight aircraft. The theoretical training covers essential topics such as air law, meteorology, navigation, and aircraft systems, usually comprising around 20 h of instruction. Practical training involves approximately 15–20 h of flight time, focusing on the unique handling characteristics of ultralights, including 5 h of solo flying. Upon successful completion of training and passing the necessary examinations, individuals are certified to operate ultralight aircraft for recreational purposes within the regulatory framework established for such aircraft.

Another way to obtain a rating to fly ultralight aircraft is by completing a course and obtaining a UACP (Ultralight Aircraft Pilot) qualification certificate [4]. Ultralight aircraft are characterized by low weight and power but have comparable flight capabilities to conventional light self-flying aircraft. The age restriction is lower than for a PPL, as you need to be at least 16 years old on the day of your first solo flight. With a UACP, you can fly aircraft that do not exceed 495 kg MTOW and carry no more than two people on board. In this case, the training consists of 60 h of lecture for pilots with no flight training and 30 h of lecture for pilots who have received flight practice credit. The theoretical training shall be completed with an internal examination to test the candidate's knowledge. A pass in the exam is a prerequisite to proceed to the practical part. To obtain an ultralight aircraft pilot certificate of competence, the applicant must have completed at least 28 h of flight time, including at least 8 h as Pilot in Command (PIC). Four hours shall be related to navigational flight. Additionally, the applicant shall have completed a flight of at least 150 km during which one full-stop landing shall be made at an aerodrome different from the aerodrome of takeoff. For overseas pilots, additional requirements must be met to convert their licenses to comply with local regulations. This often involves passing written exams and flight tests to demonstrate proficiency and understanding of local aviation laws.

The surge in popularity of ultralight planes in non-commercial aviation is accompanied by significant risks due to non-compliance with regulations and faulty equipment. The increased number of flights results in a higher number of accidents [5–7], some of which are caused by technical failures (such as fuel leakage, engine failure, or control system failure) [8]. Other accidents are attributable to the aircraft operator [9,10], involving errors in piloting technique or violations of aviation regulations (such as flying below/above safe altitudes). Flights should be conducted at aerodromes equipped with appropriate equipment. Improper preparation of the runway slab can lead to potential tire damage and loss of direction during takeoff or landing. Failure to observe the wind strength limitation for the aircraft type may result in the aircraft tilting violently and losing lift, particularly dangerous during takeoff and landing phases [11], which are the most challenging parts of a flight [12].

An analysis of the causes of accidents in ultralight aviation between 1985 and 2004 is presented in [13], revealing that pilots with less than 40 flight hours on a particular aircraft model were significantly more likely to experience fatal accidents. An attempt to adapt the SHERPA (Systematic Human Error Reduction and Prediction Approach) pilot error prediction tool in aviation was made in [14]. SHERPA was initially developed to predict human error in the petrochemical industry. However, the authors have demonstrated its potential as an effective tool for identifying human error in various contexts. Simulators are utilized to analyze pilot performance and assess flight safety risks [15]. In this process, the instructor observes the decision-making and flying skills of student pilots under different flight conditions. During training, the flight conditions and parameters can be manipulated, allowing for the observation of the pilot's reactions to various situations. By combining pilot error statistics with a subjective questionnaire, it becomes possible to determine the impact of external conditions on the pilot's mental state and subsequent performance in critical flight tasks.

During the analysis of the causes of aviation accidents, various aspects related to age, experience, and training are considered. Luciani et al. indicate that older age and emotional dysregulation are associated with higher risk attitudes in pilots [16]. Ultralight pilots appear to be more risk-oriented and less self-confident than civil pilots, while more flight experience seems to favor greater self-confidence. The impact of age, gender, and experience on aviation accidents is characterized by Bazargan et al. in [17]. There is no evidence to support the likelihood of an accident caused by pilot error being related to pilot gender. Similar studies were conducted by Li et al. [18]. The prevalence and patterns of pilot error in air carrier accidents do not seem to change with pilot age. Risk perception among pilots is also studied by Drinkwater et al. [19]. The authors demonstrate a clear distinction in terms of "risk perception" between those pilots who chose to undertake the risky flight (36 participants) and those who did not (20 participants). There is also evidence of attitudinal and demographic differences between the two groups.

Ultralight aircraft accidents tend to be more severe compared to sport aviation accidents [20,21]. Unlike commercial aircraft, ultralight aircraft are not equipped with advanced rescue systems, such as catapult devices, which facilitate safe egress from the aircraft [22]. However, due to their low speed, ultralight pilots have the opportunity to perform glide flights and make controlled landings in almost any location with a level surface. These characteristics highlight the unique safety challenges and opportunities within ultralight aviation.

According to several scientific studies and accident reports, pilot error is often cited as the leading cause of ultralight aircraft accidents. However, the specific percentage or number can vary depending on the study, the geographical region, and the criteria used for classification. Pilot error is responsible for the majority of ultralight aircraft accidents. Studies have found that pilot error accounts for 60% to 80% of these accidents [23,24]. This range reflects differences in study methods, time periods, and the definitions used for pilot error. A study found that pilot error was involved in 55% of ultralight aircraft accidents in the U.S., 62.9% in Portugal and 34.13% in UK from 2000 to 2010 [20]. Research found that 75% of ultralight accidents in Australia over 10 years were due to pilot error [8]. Another study on ultralight aviation in Europe found that pilot error was responsible for approximately 65% of the accidents [25,26]. The common pilot errors identified:

- Loss of control during takeoff, flight, or landing.
- Improper maneuvering, leading to aerodynamic stalls.
- Poor decision-making, particularly related to weather conditions and aircraft capabilities.
- Inadequate training or insufficient experience, especially in emergency procedures.

Pilot error is the predominant factor in ultralight aviation accidents, with studies consistently showing that it accounts for a significant majority of these accidents. These findings underscore the importance of proper training, experience, and adherence to safety protocols in reducing accident rates in ultralight aviation.

A fatal accident involving an unregistered ultralight aircraft lacking proper inspection and licensing is examined in this study. Pilot error during takeoff resulted in a stall and fatal crash, highlighting the critical importance of safety compliance in ultralight aviation. The consequences of non-compliance, including immediate death due to torn shoulder and lap belts upon impact, emphasize the necessity of adhering to safety standards. Another aspect involves the violation of aircraft use regulations. The use of faulty equipment that has not been certified can jeopardize the life of the user. The purpose of this paper is to analyze the accident and identify the sequence of events and conditions that contributed to or caused it. Through this analysis, we aim to enhance the understanding of safety vulnerabilities in ultralight aviation and advocate for stricter compliance with safety regulations to prevent future tragedies.

To ensure the safety of aviation users, the aviation safety regulator plays a crucial role in monitoring, auditing, and enforcing compliance with relevant aviation safety regulations. This includes regular inspections, audits of pilot qualifications and aircraft maintenance, and stringent enforcement of safety standards. The regulator's efforts are vital in maintaining high safety standards and preventing accidents caused by non-compliance.

2. Case Presentation

2.1. Aircraft

The Sky-Walker ultralight sport aircraft was developed at Sky-Walker Leichtflugzeug (Klaus Richter und Jürgen Osterloh, Neuenrade, Germany), with approximately 400 units produced between 1985 and 1994. A distinctive feature of the aircraft is its very short takeoff distance, making it suitable for recreational flying. It was often employed as a training aircraft due to its biplane design. The aircraft features a metal-framed powered upper wing made of aluminum tubes, equipped with ailerons and flaps. The wing is covered with Dacron, while the ailerons and flaps are covered with Ceconite. The fuselage is a dural frame, and the crew areas are open. The directional and altitude rudders are also covered with Ceconite. The aircraft has a wingspan of 10.5 m and a wing area of 26 m^2. Various engines were used as the propulsion source, including a 40 hp Hirth (Hirth, Benningen am Neckar, Germany), a 51 hp Rotax 462 (Gunskirchen, Austria), or a 65 hp Rotax 582. The propeller is push-pull. For the Rotax 582 engine, the cruising speed is approximately 100 km/h, with a minimum speed of 50–55 km/h. The minimum breakaway speed is 55 km/h.

The aircraft in use was a Sky-Walker (manufactured in 1985) owned by a member of the local flying club association. The aircraft was not officially registered (when the accident happened), and the last inspection was likely in 1992 (more than 20 years before the accident). The owner personally overhauled the aforementioned aircraft and did not undergo any technical tests to establish its airworthiness.

2.2. Descritpion of the Accident

There was an aviation association in the western part of Poland, whose members utilized a portion of the runway at the former military airfield, provided by the city authorities. The runway has a concrete surface measuring 3500 m in length and 45 m in width, although only a small section of it was actively used.

In the afternoon, the pilot initiated the takeoff procedure after completing a pre-start inspection. After reaching an altitude of approximately 15 m, there was a loss of airspeed, and the nose of the aircraft sharply tilted. The aircraft, with a descent angle estimated at about 45 degrees, collided with the concrete surface of the runway, impacting the front part of the fuselage. As a result of this collision, the front part of the keel tube, located in front of the pilot's seat and serving as a primary structural element of the fuselage (as shown in Figure 1a,b broke). During a rotation about the transverse axis, further structural damage occurred, including the fracture of the wing stays, the engine bed structure, and the rear part of the tail boom (behind the passenger seat). The aircraft came to a stop in an upright position, and the distance from the point of impact with the ground to where the aircraft halted was 11 m. Following the initial ground impact, the pilot, who was in the first seat during the flight, was ejected from pilot's seatbelt and collided with the concrete surface of the runway at a distance of 4.2 m from the initial ground contact point.

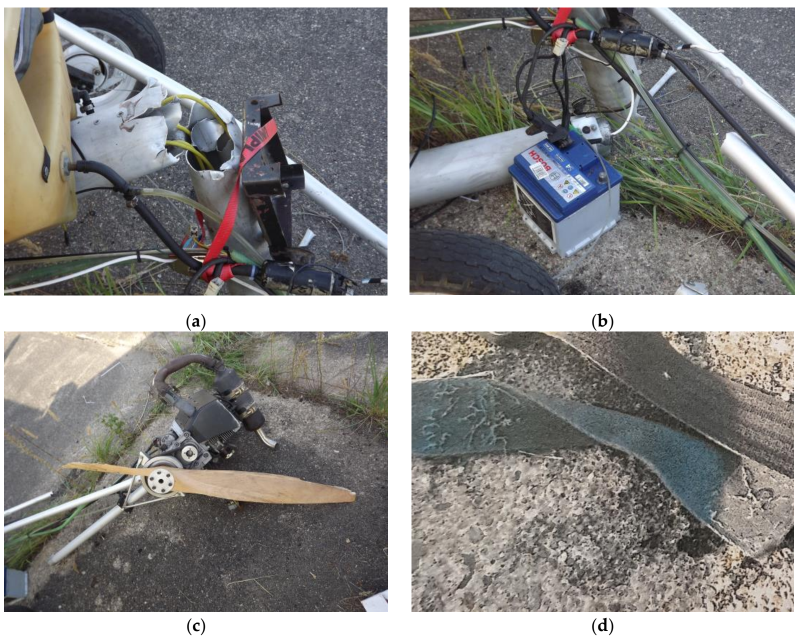

Figure 1. Damage to the front of the keel tube (**a**,**b**), propeller damage (**c**), broken shoulder straps (**d**).

The visual inspection conducted revealed that the engine was operational until the impact with the ground, as evidenced by the nature of the propeller damage (see Figure 1c). Furthermore, there was fuel in the carburetor, the fuel system was unobstructed, and there was sufficient fuel in the tank for the intended flight.

One altitude rudder drive cable, responsible for implementing downward rudder deflection, and the aileron drive cables were found to be broken. The nature of the cable breakage suggests the occurrence of a high tensile force (stranding). Notably, the pilot's seat, which also served as a fuel tank, remained undamaged.

During the flight, the pilot was wearing lap and shoulder belts and a helmet. However, the shoulder and lap belts were torn at the seams as a result of the crash (see Figure 1d).

Upon the arrival of the rescue helicopter, the pilot was pronounced dead.

The National Aircraft Accident Investigation Commission has initiated the analysis of the causes and circumstances of the accident.

2.3. Environment

On the day of the disaster, Poland was within the range of a shallow low, with its main center over Ukraine, in cool and humid polar-maritime air. An occluded front was affecting the northern part of the country. The cloud cover was extensive and high, with some overcast, and there was rainfall. At the accident site, the cloud cover was very high and complete. The sky was obscured by low-level Sc (Stratocumulus) clouds, with cloud base heights of about 600–800 m. No precipitation was recorded in the area. The air temperature was 15.5 °C. Relative humidity was approximately 78%, and visibility was 20 km. The atmospheric pressure was 1007 hPa.

At the time of takeoff, there was a crosswind from the right at 4–5 m/s in a 270° direction. Witnesses reported the presence of gusts of wind. Meteorological conditions, specifically the wind blowing from the northwest over numerous terrain obstacles at the site, may have contributed to the accident. According to pilots using this runway, the structure and shape of the greenbelt and dense trees interfere with laminar airflow.

3. Results

A post-mortem was conducted following the accident. The internal side of the cranial shell revealed the presence of an extensive hypophysis measuring 140 × 52 mm. The cranial vault exhibited multifracture fractures of the cranial vault bones with the separation of individual bone fragments. The fracture fissures extended from the vault towards the anterior cranial fossa, connecting with Le Fort fractures of types II and III. These fissures continued towards the middle cranial fossa and the calcaneal fossa, and then progressed towards the posterior cranial fossa and the occipital bone. Additionally, a fracture of the upper incisors was diagnosed, resulting in their complete prolapse from the alveoli.

There were signs of partial cerebral crushing, particularly in the anterior regions of the frontal lobes. A fracture of the L2 vertebra was identified, and the continuity of the spinal cord in this area was preserved. The distal part of the right humerus was fractured with displacement of the fragments. Both ankle joints were dislocated with significant displacement within them. Histopathological examination revealed features of subarachnoid hemorrhage, edema, and foci of contusion. Toxicological examination by gas chromatography (GC1) showed no ethanol in the blood or urine.

Abrasions to the epidermis were observed in the thoracic region. The impact of the control stick, which was pressed against the torso, was identified as the most likely cause. According to the forensic expert, the engagement of the control stick suggests the conscious action of the pilot-victim, who likely attempted to navigate out of the critical situation by firmly securing the stick against pilot's torso.

4. Discussion

The fatal accident examined in this case study resulted from a confluence of several critical factors. Primarily, the pilot's lack of the specific certification required to operate within Polish airspace was a significant contributor. Although the pilot had successfully completed the necessary examinations to operate an ultralight aircraft, they had not obtained the requisite certificate of competence from the Polish Civil Aviation Authority (CAA). Additionally, the pilot's limited experience and familiarity with this particular aircraft type were key factors; this flight was the pilot's first in this specific aircraft, which likely contributed to errors in judgment during the takeoff phase.

The investigative committee did not dismiss the potential impact of the prevailing weather conditions, particularly strong winds, which could have disrupted the laminar airflow around the wings, thereby exacerbating the situation. Furthermore, the aircraft involved in the accident lacked valid technical inspections and had not undergone proper maintenance, nor was it serviced by a certified mechanic. The absence of registration marks, a transponder, and maintained radio communication further complicated the investigation, making it impossible to ascertain whether the pilot encountered issues during the flight. The lack of a flight data recorder also hindered efforts to reconstruct the flight path, including critical parameters such as speed, altitude, direction, and rudder angles.

The accident occurred immediately after takeoff at a low altitude, resulting in a dynamic scenario where recovery from an aerodynamic stall was not feasible. Typically, in the event of a stall, a pilot would release the control stick, allowing the aircraft to regain airspeed; however, due to the low altitude, this recovery was not possible. The State Aircraft Accident Investigation Committee ultimately decided against further investigation, citing the aircraft's construction and operation in violation of existing regulations.

Another critical factor contributing to the accident was the aircraft's components that had deteriorated over time, particularly the seat belts, which had lost their strength properties. It is plausible that the victim might have survived the crash if the seat belts had remained intact. However, it appears that the seat belts were not replaced during the aircraft's 28 years of operation and subsequently failed during the accident. Had new belts been installed, the likelihood of serious injury could have been diminished, as the pilot would not have been ejected from the seat, preventing the fatal impact of the head with the runway. Although compensatory spinal fractures might still have occurred, the chances of surviving the crash would have been significantly higher.

In the context of non-commercial ultralight aviation, safety regulations are essential for reducing risks and safeguarding both pilots and passengers. In Poland, these regulations are primarily governed by the CAA and aligned with the guidelines set forth by the European Union Aviation Safety Agency (EASA). These regulatory frameworks mandate specific requirements for pilot licensing, aircraft maintenance, and operational protocols to minimize the inherent risks in ultralight aviation. To enhance safety further, it is suggested that the CAA introduce or emphasize regulations requiring the regular inspection and replacement of critical safety equipment as part of continuous airworthiness requirements for ultralight aircraft. This addition would ensure that safety equipment remains effective and reliable, addressing potential risks before they impact safety.

Despite these regulatory provisions, the case study reveals significant lapses in safety compliance, particularly concerning pre-flight inspections, adherence to weight and balance limitations, and the proper use of safety equipment. This accident underscores the necessity for more rigorous enforcement of current regulations, alongside the introduction of additional measures. Recommendations include mandatory recurrent training focused on safety compliance, stricter penalties for violations, and more frequent audits of ultralight aviation operations as effective deterrents to non-compliance. Additionally, public awareness campaigns could play a vital role in educating pilots, aircraft owners, and the general public about the risks associated with ultralight aviation and the importance of stringent adherence to safety regulations.

In light of the findings from this case study, it is advisable that Polish aviation authorities consider revising existing safety regulations to incorporate these suggestions [27,28]. Strengthening regulatory oversight and enforcement could markedly reduce the incidence of fatal accidents in non-commercial ultralight aviation, thereby improving overall safety in this sector.

5. Conclusions

In conclusion, a thorough examination of an ultralight aircraft accident serves as a critical exercise in understanding the vulnerabilities inherent in aviation, particularly within the realm of ultralight flying. By dissecting the contributing factors, whether they be related to human error, mechanical issues, or environmental conditions, we gain valuable insights that can significantly impact the safety measures surrounding these lightweight aircraft. It is imperative that the aviation community, encompassing pilots, manufacturers, and regulatory bodies, embraces a proactive approach to learning from mistakes. Utilizing the lessons derived from such accidents, we have the opportunity to refine training programs, enhance safety protocols, and implement technological advancements specific to ultralight aviation. Through this commitment to continuous improvement and a shared dedication to safety, we can pave the way for a future where ultralight flying is not only exhilarating but also marked by a heightened level of security and resilience against potential mishaps.

Moving forward, regulatory bodies, aviation authorities, and operators must collaborate closely to reinforce and enforce safety measures within the ultralight aviation sector. A comprehensive approach, encompassing stringent regulations, rigorous inspections, and stringent licensing procedures, is essential for safeguarding the lives of both pilots and passengers. Specific recommendations include:

- Enhanced Pilot Training Programs: Develop specialized training modules that address common pitfalls in ultralight flying, incorporating lessons from past accidents and emphasizing emergency procedures.
- Regular Maintenance and Inspections: Implement mandatory, frequent inspections of ultralight aircraft to ensure all components meet safety standards and to identify potential mechanical issues before they lead to accidents.
- Technological Innovations: Invest in the development and integration of advanced safety technologies, such as improved restraint systems, real-time monitoring of aircraft health, and enhanced flight control systems tailored for ultralight aircraft.
- Stringent Certification Processes: Ensure that ultralight aircraft and pilots undergo rigorous certification processes that are regularly updated to reflect the latest safety research and technological advancements.

However, this analysis also highlights the need for further study in several areas to continue improving ultralight aviation safety. Future research should focus on developing advanced materials and technologies that enhance the structural integrity and reliability of ultralight aircraft. Additionally, more in-depth investigations into the psychological and physiological factors affecting pilot performance under various conditions can provide a deeper understanding of human error contributions. The continuous evolution of weather prediction models and their integration into pre-flight planning tools for ultralight pilots is another promising area of study. By pursuing these lines of inquiry, the aviation community can achieve a higher standard of safety and ensure that ultralight flying remains a safe and enjoyable pursuit for all enthusiasts.

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References

1. Statista.com. Available online: https://www.statista.com/statistics/1271993/poland-number-of-civil-aircraft-by-type/ (accessed on 2 August 2024).
2. Obwieszczenie Marszałka Sejmu Rzeczypospolitej Polskiej z dnia 04.09.2023r. w Sprawie Ogłoszenia Jednolitego Tekstu Ustawy—Prawo Lotnicze, Dz. U. Poz. 2110. Available online: https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20230002110/T/D20232110L.pdf (accessed on 25 January 2023). (In Polish)
3. Rozporządzenie Ministra Transportu, Budownictwa i Hospodarski Morskiej, Dz.U.2021.1713 z dnia 17.09.2021r. Available online: https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20210001713/O/D20211713.pdf (accessed on 27 January 2023). (In Polish)
4. Sedláčková, A.N.; Kaltman, L.; Novak, D. Proposal for Modification of the Syllabus for Ultralight Aircraft Pilot's Training. *Transp. Res. Procedia* **2023**, *75*, 288–296. [CrossRef]
5. Accidents in Civil Aviation. Available online: https://uzpln.cz/zpravy-ln?Weight=%3C2250+kg&Aircraft=Letouny&Code=&DateFrom=&DateTo=&Delegated=&OrderDate=0&Send=&incident-weight=%3C2250+kg&incident-orderDate=0&incident-pagin-page=29&do=incident-filterForm-submit (accessed on 1 May 2023).
6. Ast, F.V.; Kernbach-Wighton, G.; Kampmann, H.; Koopsc, E.; Püschel, K.; Tröger, H.D. Fatal aviation accidents in Lower Saxony from 1979 to 1996. *Forensic Sci. Int.* **2001**, *119*, 68–71. [CrossRef] [PubMed]
7. Neuhaus, C.; Dambier, M.; Glaser, E.; Schwalbe, M.; Hinkelbein, J. Probabilities for Severe and Fatal Injuries in General Aviation Accidents. *J. Aircr.* **2010**, *47*, 2017–2020. [CrossRef]
8. Lenné, M.G.; Ashby, K.; Fitzharris, M. Analysis of general aviation crashes in Australia using the human factors analysis and classification system. *Int. J. Aviat. Psychol.* **2008**, *18*, 340–352. [CrossRef]
9. Wiegmann, D.; Shappell, S.A. Human error analysis of commercial aviation accidents: Application of the human factors Analysis and Classification system (HFACS). *Aviat. Space Env. Med.* **2001**, *72*, 1006–1016. [PubMed]
10. Al-Wardi, Y.; Arabian, Y. Asian, Western: A Cross-Cultural Comparison of Aircraft Accidents from Human Factors Perspectives. *Int. J. Occup. Saf. Ergon.* **2016**, *23*, 366–373. [CrossRef] [PubMed]
11. Škvareková, I.; Pecho, P.; Kandera, B. Analysis of The Most Critical Phase of the Flight Based on HRV Measurements of Pilots Workload. In Proceedings of the 2022 New Trends in Aviation Development (NTAD), Novy Smokovec, Slovakia, 24–25 November 2022; pp. 194–200. [CrossRef]
12. Wang, Y.; Yang, L.; Korek, W.T.; Zhao, Y.; Li, W.-C. The Evaluations of the Impact of the Pilot's Visual Behaviours on the Landing Performance by Using Eye Tracking Technology. In *Engineering Psychology and Cognitive Ergonomics. HCII 2023*; Lecture Notes in Computer Science; Springer: Cham, Switzerland, 2023; Volume 14017. [CrossRef]
13. Pagan, B.; de Voogt, A.; Doorn, R.R.A. Ultralight aviation accidents factors and latent failures: A 66-case study. *Aviat. Space Environ. Med.* **2006**, *77*, 950–952. [PubMed]
14. Harris, D.; Stanton, N.A.; Marshall, A.; Young, M.S.; Demagalski, J.; Salmon, P. Using SHERPA to predict design-induced error on the flight deck. *Aerosp. Sci. Technol.* **2005**, *9*, 525–532. [CrossRef]
15. Novak, A.; Mrazova, M. Research of Physiological Factors Affecting Pilot performance in Flight Simulation training Device. *Commun.-Sci. Lett. Univ. Zilina* **2015**, *17*, 103–107. [CrossRef]
16. Luciani, F.; Veneziani, G.; Ciacchella, C.; Rocchi, G.; Reho, M.; Gennaro, A.; Lai, C. Safety at high altitude: The importance of emotional dysregulation on pilots' risk attitudes during flight. *Front. Psychol.* **2022**, *13*, 1042283. [CrossRef] [PubMed] [PubMed Central]
17. Bazargan, M.; Guzhva, V.S. Impact of gender, age and experience of pilots on general aviation accidents. *Accid. Anal. Prev.* **2011**, *43*, 962–970. [CrossRef] [PubMed]
18. Li, G.; Grabowski, J.G.; Baker, S.P.; Rebok, G.W. Pilot error in air carrier accidents: Does age matter? *Aviat. Space Environ. Med.* **2006**, *77*, 737–741. [PubMed]
19. Drinkwater, J.L.; Molesworth, B.R.C. Pilot see, pilot do: Examining the predictors of pilots' risk management behaviour. *Saf. Sci.* **2010**, *48*, 1445–1451. [CrossRef]
20. Voogt, A.D.; Chaves, F.; Harden, E.; Silvestre, M.; Gamboa, P. Ultrtalight Accidents in the US, UK, and Portugal. *Safety* **2018**, *4*, 23. [CrossRef]
21. Knecht, W.R. The "killing zone" revisited: Serial nonlinearities predict general aviation accident rates from pilot total flight hours. *Accid. Anal. Prev.* **2013**, *60*, 50–56. [CrossRef] [PubMed]

22. Glowinski, S.; Krzyzynski, T. Modelling of the ejection process in a symmetrical flight. *J. Theor. Appl. Mech.* **2013**, *51*, 775–785.
23. Li, G.; Baker, S.P. A retrospective analysis of general aviation pilot errors in accidents. *Aviat. Space Environ. Med.* **1999**, *70*, 710–715.
24. Goh, J.; Wiegmann, D.A. Factors influencing pilots' decisions to continue visual flight rules flight into adverse weather conditions. *Aviat. Space Environ. Med.* **2002**, *73*, 715–722.
25. Byrne, E.; Parasuraman, R. Psychoeducational approaches to the training of older pilots. *Hum. Factors* **1996**, *38*, 28–43.
26. Baker, S.P.; Lamb, M.W.; Li, G.; Dodd, R.S. Human factors in general aviation crashes involving visual flight rules flight into adverse weather conditions. *Aviat. Space Environ. Med.* **1993**, *64*, 1136–1138.
27. Regulation (EU) No 996/2010 of The European Parliament and of the Council od 20 October 2010 on the Investigation and Prevention of Accidents and Incidents in Civil Aviation and Repealing Directive 94/56/EC. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010R0996 (accessed on 12 April 2023). (In Polish).
28. Regulation art..135 ust. 6 pkt 3 Ustawy z Dnia 303.07.2002 r.—Prawo Lotnicze (Dz. U. Z 2013 r. Poz. 1393, z zm). Available online: https://lexlege.pl/prawo-lotnicze/art-135/ (accessed on 1 May 2023). (In Polish)