BRAIN. Broad Research in Artificial Intelligence and Neuroscience
e-ISSN: 2067-3957 | p-ISSN: 2068-0473
Covered in: Web of Science (ESCI); EBSCO; JERIH PLUS (hkdir.no); IndexCopernicus; Google Scholar; SHERPA/RoMEO; ArticleReach Direct; WorldCat; CrossRef; Peeref; Bridge of Knowledge (mostwiedzy.pl); abcdindex.com; Editage; Ingenta Connect Publication; OALib; scite.ai; Scholar9; Scientific and Technical Information Portal; FID Move; ADVANCED SCIENCES INDEX (European Science Evaluation Center, neredataltics.org); ivySCI; exaly.com; Journal Selector Tool (letpub.com); Citefactor.org; fatcat!; ZDB catalogue; Catalogue SUDOC (abes.fr); OpenAlex; Wikidata; The ISSN Portal; Socolar; KVK-Volltitel (kit.edu)
2025, Volume 16, Issue 1, pages: 50-70.
Submitted: October 2nd, 2024 | *Accepted for publication:* January 8th, 2025

Psychological and Neurological Tests are Required to Reduce the Risk of Injuries in Paragliding

Dan Alexandru Szabo
George Emil Palade University of Medicine, Pharmacy, Science, and Technology of Targu Mures, Gh.Marinescu str. 38, 540142 Targu Mureş, Romania.
https://orcid.org/0000-0002-7326-212X

Virgil Ene-Voiculescu
Mircea cel Batran Naval Academy, Naval Tactics and Armament Department, 900218 Constanta, Romania.
https://orcid.org/0000-0002-1451-207X

Silvia Teodorescu
Department of Doctoral Studies, National University of Physical Education and Sports, Bucharest, Romania.
https://orcid.org/0000-0002-3931-3034

Alin Larion
Ovidius University of Constanta, Faculty of Physical Education and Sport, 900470 Constanta, Romania.
https://orcid.org/0000-0001-6419-5095

George Danut Mocanu
"Dunărea de Jos" University, Faculty of Physical Education and Sports, 63-65 Gării St, Galati, Romania.
https://orcid.org/0000-0002-3534-5055

Alexandru Rares Puni
Centre of Interdisciplinary Research in Human Motricity Science, "Alexandru-Ioan Cuza" University, 700115 Iasi, Romania
https://orcid.org/0000-0001-8403-8804

Iamina-Camelia Ilea
George Emil Palade University of Medicine, Pharmacy, Science, and Technology of Targu Mures, Gh.Marinescu str. 38, 540142 Targu Mureş, Romania

Carmen Pârvu
"Dunărea de Jos" University, Faculty of Physical Education and Sports, 63-65 Gării St, Galati, Romania
https://orcid.org/0000-0002-2910-9494

Abstract: *The study's objective is to analyse and comprehend the types, frequency, and causes of paragliding pilot accidents to identify preventative and reducing measures in the future, such as a suitable physical training program designed explicitly for paragliding pilots. This study hypothesized that several factors, including the pilot's experience level, weather conditions, terrain, equipment quality, attitude toward the sport, and adherence to safety regulations, may be related to the frequency of paragliding accidents. The study's findings indicated a high accident rate since 66% of respondents had injuries while paragliding, and 67% had an occurrence that may have resulted in a pilot suffering severe injury. The analysis shows the frequent causes of accidents are primary piloting mistakes and poor decision-making as technological faults played a minor role. Equipment used for paragliding seldom malfunctions if it is routinely inspected and tested; the only exception is when it is subjected to abnormally high stresses while in flight. Oversteering of the wing or, on the other hand, inadequate reaction—specifically, inadequate pilot training in flap control and active piloting—were the leading causes of these mistakes. Poor judgments about weather and flying conditions or inadequate familiarity with the area landscape and characteristics caused some of these mistakes. In conclusion, we address the necessity to establish a standard for the ideal paraglider, conceiving psychological and neurological tests without reducing the access to this adrenaline rush sport, but increasing its safety.*

Keywords: *paragliding; injuries; prevalence; recreational sports.*

How to cite: Szabo, D.A., Ene-Voiculescu, V., Teodorescu, S., Larion, A., Mocanu, G.D., Puni, A.R., Ilea, I.C., & Pârvu, C. (2025). Psychological and neurological tests are required to reduce the risk of injuries in paragliding. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 16*(1), 50-70. https://doi.org/10.70594/brain/16.1/4

1. Introduction

The spread of bodily activities can be understood as modern man's desire to overcome challenges. In this context, adventure sports are the result of several social factors, such as the organisation of time, current work settings, the need for self-expression and change, (re)discovering nature, physical practice, contemplation, overcoming one's limits, relaxation, the ability to experience intense emotions, pleasure, freedom, health promotion and quality of life.

Terms and expressions such as adrenaline, thrill, daring, and pushing one's limits have become part of the vocabulary of those dedicated to adventure and calculated risk (Bruhns, 1997; Paixão & Tucher, 2012).

Extreme sports have gained importance for adventurous elite athletes and as a recreation for ordinary individuals (Donnelly, 2006). There is a growing appeal to the general public with the increasing popularity of adventure sports and high-risk activities in the natural environment worldwide (Tordjman, Constantini, & Hackney, 2013). Since high-altitude sports have attracted wider attention in recent years, participation in paragliding activity, an extreme branch of aerial adventure sports, has become increasingly popular worldwide. Consequently, understanding these activities' psychological and physiological effects (Tomich et al., 2023; Khurtenko et al., 2023) has gained importance for health and sports researchers (Yalcin, Kardesoglu, & Isilak, 2011; Çalık, Gürsoy, & Saruhan, 2021).

Paragliding is an extraordinarily spectacular sport with a very high development worldwide, and its practice's volume, nature, and risks continue to be poorly quantified. However, numerous associations and authorities responsible for free flight in different countries have made efforts in this direction during the last few years. The growth in paragliding over the last few decades has made it necessary to study the causes of accidents and the mechanisms by which they occur to take practical safety measures to reduce them.

Over forty years ago, mountaineers conceived paragliding as a descent instrument, but today's pilots can fly distances of hundreds of kilometres for hours. Paragliding became aviation through improvements in performance and safety.

As a small but growing discipline, the effective allocation of resources to improving safety in paragliding is perhaps even more critical than in the more "resource-rich" and established branches of aviation. This requires understanding both the accidents and the context in which they occurred. A mantra among pilots, confirmed by accident investigations, is "paragliders do not crash; pilots crash". In other words, pilot errors rather than equipment deficiencies lead to crashes. However, like other forms of aviation, paragliding is a complex activity: an interaction between skill and training, physiology and cognition, equipment, and the natural and social environment. The pilot and equipment form a system, and errors rarely occur in isolation (Reason, 2000).

Results from a UK study (Wilkes, 2020) showed that paragliding had fatality rates of 1.4 (1.1-1.9) fatalities and 20.1 (18.4-26.7) severe injuries per 100,000 flights, making this activity approximately twice as risky as general (non-commercial) aviation in the UK. This activity required low physical effort, but pilots were vulnerable to control and decision errors. When these errors resulted in accidents, pilots often failed to jettison their reserve parachutes, and the lower limbs and thoracolumbar spine junction were most at risk of injury.

A retrospective study showed that leg injuries were most common, but a large number of spinal injuries also occurred. The causes were either pilot misjudgement or the influence of weather and terrain. Improved instructor knowledge and pilot training could have prevented most accidents. Analysis of accident mechanisms and trauma modelling helps produce an effective diagnosis and treatment approach (Karakoyun & Golcuk, 2023).

The research will thoroughly analyse the epidemiological data—the frequency of accidents as a function of flying duration, weather, pilot experience, equipment type, flying method, and risk factors. The aim of this research, which is the first of its kind in Romania, is to analyse and comprehend the types, frequency, and causes of paragliding pilot accidents to identify ways to prevent and lessen their occurrence in the future. One such measure is establishing a suitable physical training program for paragliding pilots. The information will be valuable and relevant primarily for the free-flying community, particularly for training and examination centres, which can implement measures to prevent future injuries.

2. Material and Methods

2.1. Research tasks

The research tasks are:

- To collect data on paragliding accidents using the direct testimonies of paragliding pilots as a source;
- Analysing the collected data to understand the frequency and characteristics of accidents and associated risk factors;
- The data will be interpreted to understand the practical consequences and the extent to which the data support the initial hypothesis, and practical recommendations will be developed on how to increase the safety of paragliding;
- Evaluate existing safety measures and protocols in preventing accidents in paragliding and what improvements could be made;
- Develop and disseminate the report through publication in the paragliding community and relevant scientific publications.

2.2. Research Objectives

The objectives of this study are:

- To assess the frequency of accidents: to determine the rate of paragliding accidents in a sample of pilots from different geographical regions;
- To identify types of trauma and injuries: Description and categorisation of the most common types of injuries experienced by paragliding pilots and their severity;
- Analysis of risk factors: Identification and assessment of risk factors and how they may contribute to accidents;
- Evaluation of the effectiveness of safety measures: Analysis of the effectiveness of safety measures and protocols currently in place in this field to minimise the occurrence of accidents;
- Exploration of the consequences of accidents: the physical impact by assessing the recovery and functional rest of the pilots following the accidents and the social impact through hospitalisation days and sick leave;
- Proposed preventive measures: last but not least, the study aims to recommend strategies and measures to reduce the frequency and severity of paragliding accidents based on the research results.

The type of study is descriptive cross-sectional, and the data source of the study is a questionnaire that was administered to a cohort of 152 paragliding pilots to determine the prevalence of their accidents, the most frequent type of injuries correlated with the time of the accidents, the experience of the pilots, the possible causes of their accidents in order to have a complete picture of the context in which they occurred. The pilot sample to which the questionnaire was applied belonged to the different flying associations in Romania (133 pilots from AZLR and Flyway Club) and 20 pilots from Switzerland from SHV (Swiss Free Flying Association). The aim is to identify the frequency and complexity of causes leading to paragliding accidents and take possible measures to prevent them.

The criteria for including pilots in the study were that they were licensed to fly Paraglider class ultralight aircraft and were active pilots at the time of the study. Their licenses had to be issued by an authority officially recognised by the Ministry of Transport. Exclusion criteria were pilots licensed to fly other classes of ultralight aircraft (e.g. hang glider, glider, balloon, parachute) or who had practised paragliding but did not hold a valid glider license issued by a nationally recognised certification authority. Another exclusion criterion was the lack of activity in paragliding in the last 5 years, which led to the expiry of the flight license.

The applied questionnaire is similar to the one that was used by Wilkes et al. (2022). Some additional questions were added to deepen the medical side of the study related to the type of injuries (12, 15, 16, 18, 19, 20, 21, 22, 23, 24). The questionnaire consists of 3 sections with a total of 25 questions, of which the first nine questions focus on each pilot's general flying experience, number of hours, types of flying, and the general conditions in which they operate. The second part of the questionnaire, which also contains nine questions, focuses on the medical part of the study related to the type of accidents that occurred or not, which parts of the body are most affected, the type and nature of injuries, possible causes and whether these incidents required specialised medical help and days of hospitalisation. The following six questions, being the last section of the questionnaire, focus on the particular conditions under which the incidents occurred, namely height above ground, time of flight, weather conditions, relief, use of reserve parachute, the last question being related to the perception of risk in paragliding by each pilot. It should be specified that the study participants completed the questionnaire using a Google Forms file.

3. Statistical processing

The statistical-mathematical analysis included Sum, Average, and Percentage. All the analyses were performed using Microsoft Office 2019 Professional Plus / Microsoft Excel, Product ID: 00414-50000-00000-AA810.

4. Results

There were 152 respondents to this questionnaire, of which 132 pilots were from Romania and 20 from Switzerland, with ages ranging from 27 to 68 years with an average age of 44 years (Fig 1). Of these, the vast majority, 89.5%, were male and 10.5% female, given the much lower presence of females in this sport (Fig 2).

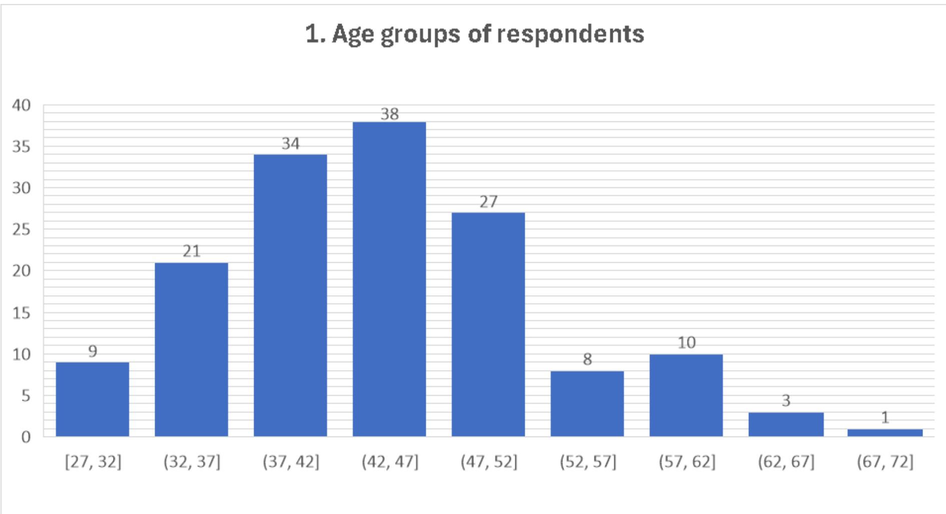


Figure 1. Age groups of respondents.

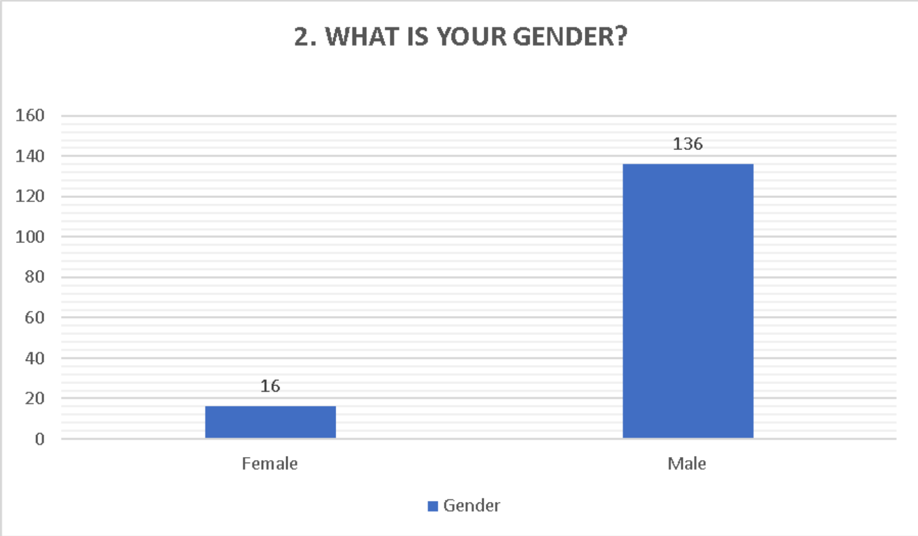


Fig. 2. Gender distribution of respondents.

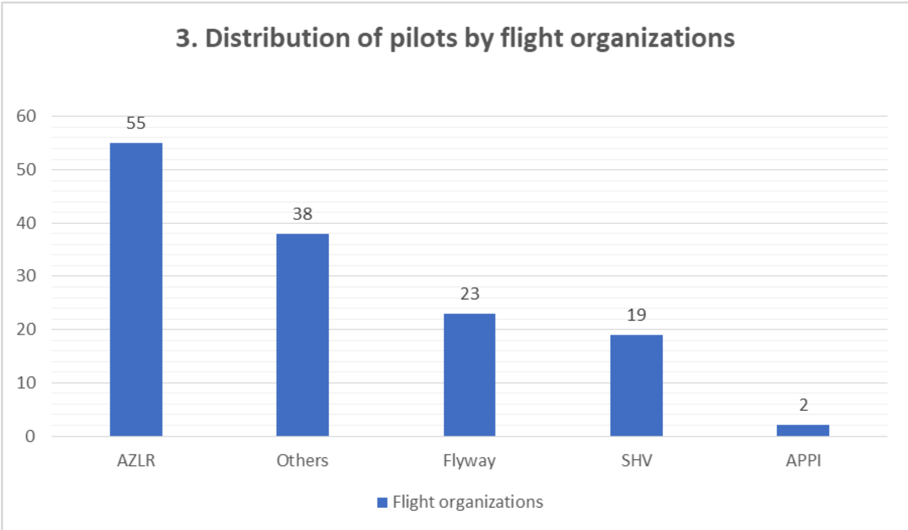


Fig. 3. Percentage distribution of pilots by flight organisations.

Of 137 respondents, 40.1% (55 pilots) are members of the Romanian Free Flight Association, and 16.8% (23 pilots) are members of the Flyway Romania Club, the two certification authorities for paragliding in Romania. 13.9% (19 pilots) belong to SHV (Swiss Free Flight Association), 1.5% (2 respondents) are members of APPI (Association of Paragliding Pilots and Instructors), and 27.7% (38 pilots) are not part of any of these organisations, they are either independent pilots or only part of local clubs (Fig.3, Table 2).

Table 2. Numerical distribution of pilots by flight organisations.

Flight organisations	Number of pilots
AZLR	55
Other	38
Flyway	23
VHS	19
APP	2

The experience of the pilots who responded to the questionnaire ranged from 1 year to 40 years of paragliding experience, with an average of 15 years of flying (Fig.4). From the point of view of flying skills, these numbers are somewhat less relevant, more relevant being the number of hours flown, the frequency of flight and the types of flight practised.

Regarding the number of hours flown, the surveyed pilots reported flight experiences varying between 6 and 9000 flight hours. 79% (112 pilots) of the respondents have an experience between 6 and 1006 flight hours, while 12% (18 pilots) have between 1006 and 2006 flight hours, and 7.8% (11 pilots) have an experience of over 2006 hours flown (Fig.5).

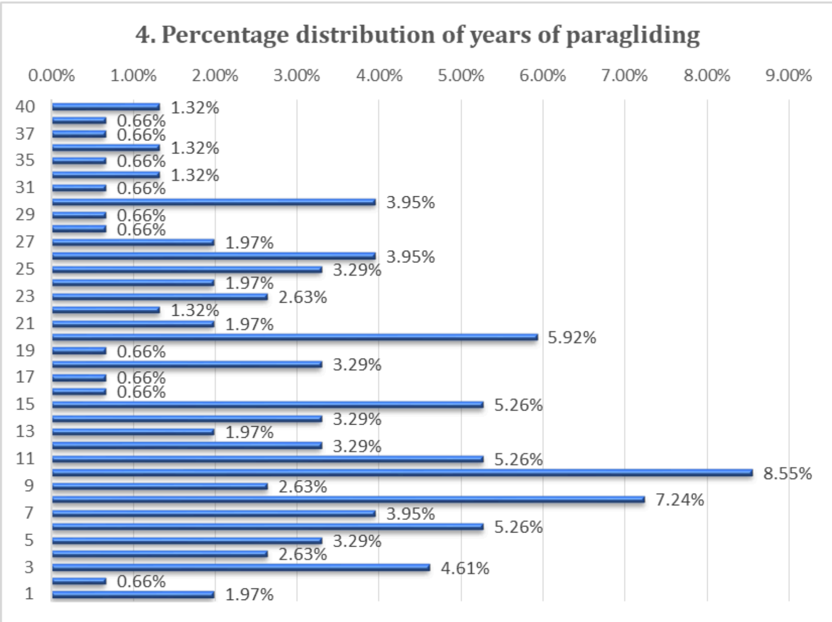


Fig. 4. Percentage distribution of years of paragliding.

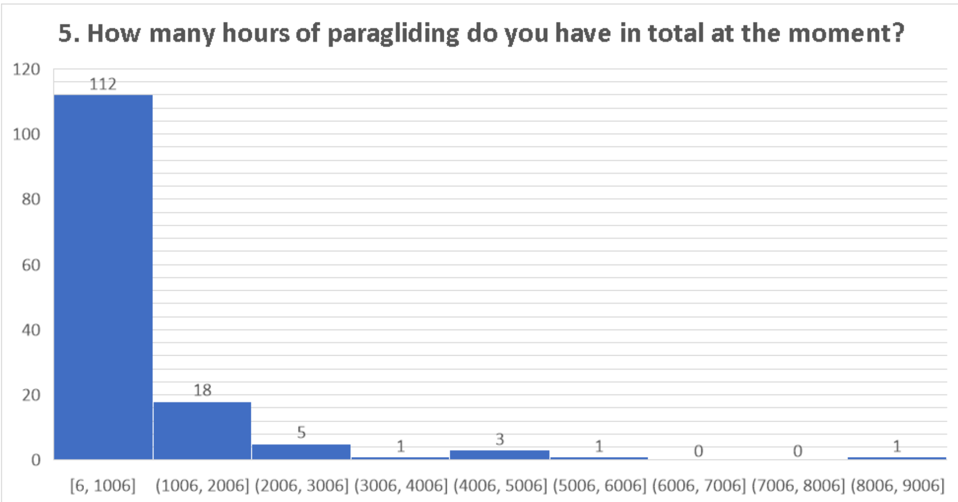


Fig. 5. Numerical distribution of pilots according to the number of hours of paragliding flight.

Table 3. Percentage distribution of wing types used.

Paraglider type	Percentage
EN-B	42.95%
EN-C	29.53%
en the	9.40%
EN-D	7.38%
Tandem	7.38%
CCC	2.01%
Other	1.34%

The most used classes of paragliders are those in the EN-B category (42.9%) and those in the EN-C category (29.5%). The EN-B class is a class of wings with higher passive safety (the wing recovers more quickly from possible developments without exact input from the pilot), and the EN-C class is the class of sports wings that require more experience and are roughly recommended at approximately 100 flight hours/year to be able to fly safely with this wing class. 9.4% of pilots use class EN-A (wings recommended for beginners), 7.3% use tandem paragliders for most flights, and quite a small number of respondents fly categories CCC (2%), EN-D (7, 3%) and others (1.3%) (these can be aerobatic wings, mini wings, single skin) (Table 3). Among the respondents, 65 fly with EN-B category wings, 45 with EN-C, 15 with EN-A, 11 with EN-D and Tandem, and only 5 with CCC category and others (Fig.6). The CCC and EN-D categories are high-performance wings that require a very high level of experience and training. They are used in high-level XC (distance flying) competitions.

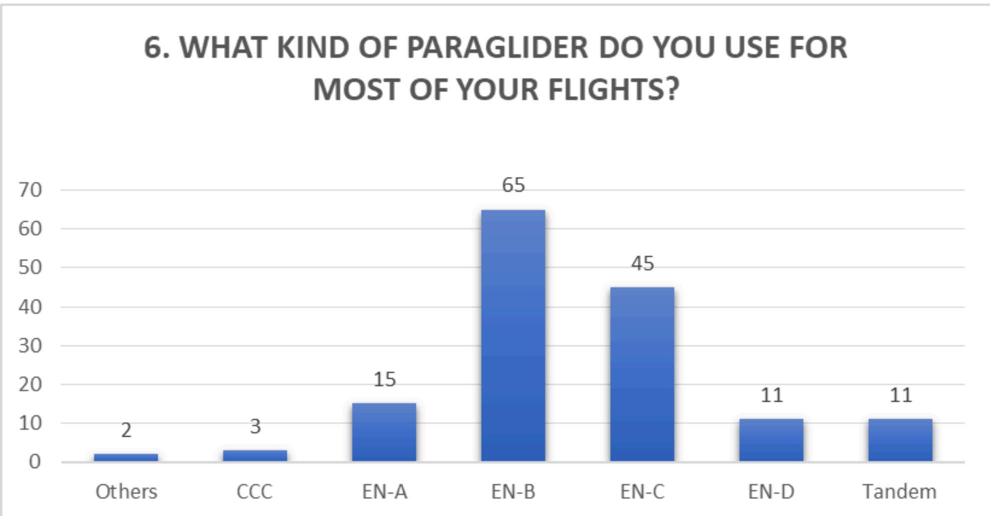


Fig. 6. Numerical distribution of wing types used.

Regarding the types of flight practised and the number of hours allocated to each type of flight, we included four types of flight in the questionnaire: Local flights, XC (long-distance) flights, Tandem flights, and Acrobatic flights and used the following percentages: 25 %, 50%, 75% and 100% to approximate the number of hours spent in each type of flight. Local flights can certainly be of many types: gliding flights, flights in the slope dynamics, hike and fly, speedily, and training flights. Nevertheless, we decided to put them in one category. So the majority of respondents (145) answered that they practice local flying as follows: 15 pilots in proportion 100%, 58 pilots in proportion 75%, 34 in proportion 50%, and 38 in proportion 25%. XC flying is practised by 121 respondents as follows: 63 of the pilots to the extent of 25%, 31 respondents fly

50% of the XC hours, 23 respondents to the extent of 75%, and 4 to the extent of 100%. A smaller number of respondents practice tandem flying and aerobatics: 26 pilots fly tandem 25% of their flying hours, 8-50%, 7-75%, while one pilot flies 100% of their hours tandem flight only. Acrobatics is practised by only 13 pilots, 11 in proportion to 25% and 2 in proportion to 50% of the hours flown. So, most hours are spent on the local flight, followed by the XC flight, tandem, and aerobatics (Table 4).

Table 4. Percentage distribution of flight hours according to flight type.

Flight types	25%	50%	75%	100%	Total
local flight	38	34	58	15	145
XC	63	31	23	4	121
tandem	26	8	7	1	42
acrobatics	11	2	0	0	13

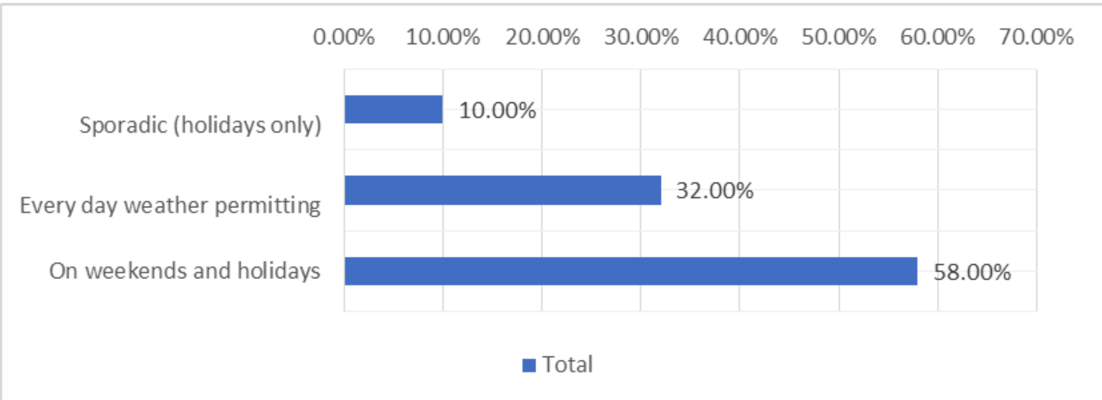
We chose three conditions to quantify the percentage of hours spent in different weather conditions: flying in still air, dynamic flight, and thermal flight. The pilots had to choose the percentage of hours spent in each of these weather conditions. The hours spent flying in still air are the least because there are no maintenance flights. Seventy pilots spend 25% of their hours flying in still air, 17 pilots 50% of their hours, nine pilots spend 75%, and only two pilots fly in still air. The flight in the slope dynamics is a type of flight, most frequent only locally, that keeps in the air for a longer time. Eighty-nine respondents spend 25% of their flight hours performing flights in slope dynamics, 28 pilots 50% of hours, 12 75% of hours, and only one pilot flies 100% dynamic. Thermal flights are the ones during which the most flight hours are executed according to the results of the questionnaire, these being maintenance flights, either local or long-distance flights. Most pilots, 65 and 58 respondents, spend 50% and 75% of their flight hours, respectively, performing thermal flights, while nine fly thermal 100% and 18 pilots only 25% (Table 5).

Table 5. Percentage distribution of flight hours according to weather conditions.

Meteo conditions	25%	50%	75%	100%	Total
Quiet air	70	17	9	2	98
Dynamic flight	89	28	12	1	130
Thermal flight	18	64	58	9	149

In terms of the distribution of flying days in a year, 58% of respondents (88 pilots) fly only on weekends and holidays, 32% (49 pilots) every day if the weather permits, and only 10% (15 respondents) sporadically. (Fig. 7)

Fig. 7. Percentage distribution of flight days.



Of the 152 respondents to the questionnaire, 101 had injuries while practising paragliding, representing 66% of the respondents. The vast majority were traumatic accidents (98% being 99 of the respondents), with only two pilots having stress trauma. Stress injuries were detailed as supraspinatus tendinitis and bicipital tendon rupture (Table 6, Fig. 8).

Table 6. Numerical distribution of the type of injuries.

The type of injury	No. Respondents
Traumatic (accident)	99
Stress (long-term overload)	2
Total respondents	101

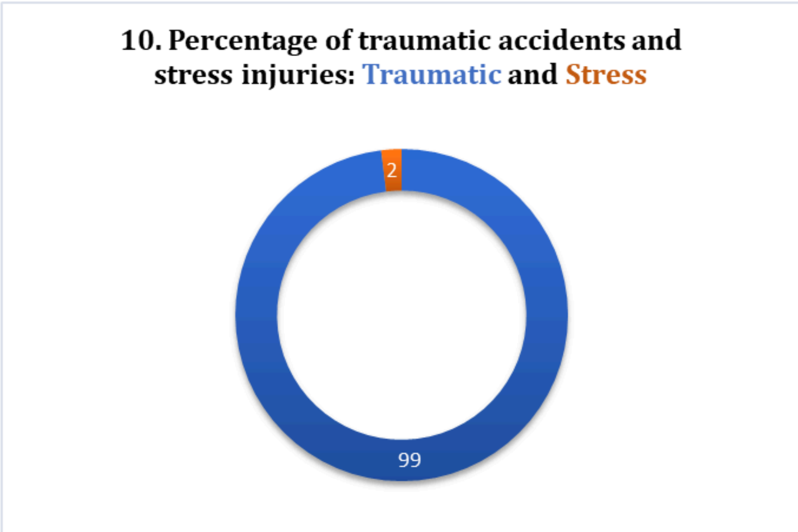


Fig. 8. Percentage distribution of the type of injuries.

Of the 152 respondents, 102 (67%) had at least 1 "quasi-incident" (defined as a flight event that had the potential to cause trauma but did not result in an injury) (Fig. 9).

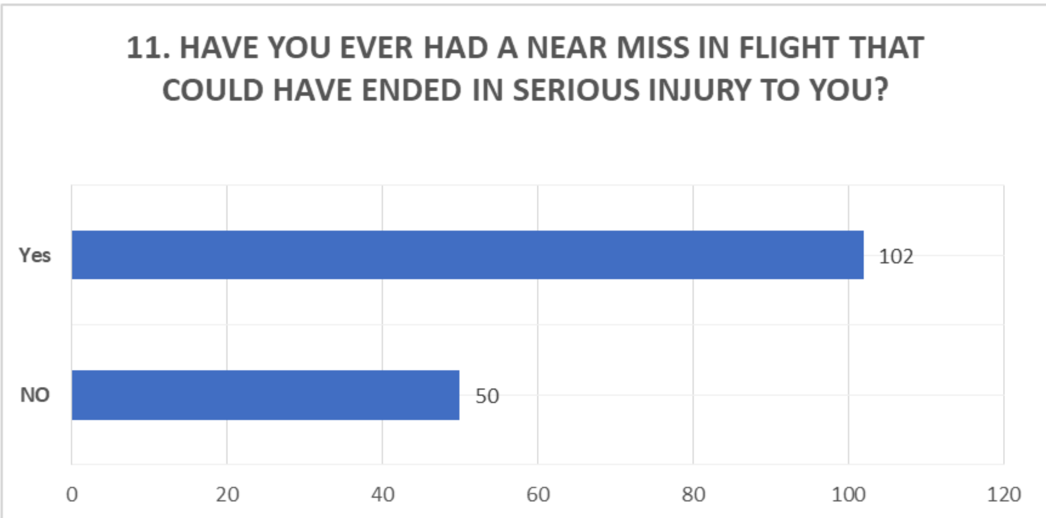


Fig. 9. Proportions of producing a "quasi-incident".

Among the potential factors that can lead to paragliding accidents, we considered four essential factors: piloting errors, equipment that is old or unsuitable for the pilot's experience level, failure to check the equipment before take-off properly, and the condition inadequate psyche. An accident in flight rarely results from only one factor; usually, it is a competition of several factors, among which we have tried to touch the most important ones. The results highlighted piloting errors as the primary cause of accidents. Forty-three of the respondents ticked 100% the weight of the piloting error factor, 16 with 75%, 34 with 50%, and 18 with 25% the weight of this factor. One hundred eleven respondents ticked the weight to some extent of the "piloting error" factor in the occurrence of their incidents.

In second place, inadequate mental state is a significant factor in incidents. A total of 51 respondents also considered this factor when their incident occurred as follows: 25 respondents considered the weight of this factor to be 25%, 17 pilots to the extent of 50%, eight respondents to the extent of 75%, while one respondent considered as 100% cause of the occurrence of his incident inadequate mental state. Inadequate equipment and failure to check equipment were minor causes of incidents. Only 18 of the respondents included inadequate equipment as the cause. Nine of the pilots were to the extent of 25%, while 7 to the extent of 50% and 2 to the extent of 100%, respectively. Failure to check the equipment before take-off was the most minor incident factor. Only 12 respondents ticked it to the extent of 25% and 2 to the extent of 75% and 100%, respectively (Table 7).

Table 7. The share of risk factors in the occurrence of incidents in flight.

Factors	25%	50%	75%	100%	Total
Pilot error	18	34	16	43	111
Inadequate equipment	9	7	0	2	18
Failure to verify the equipment	12	0	1	1	14
Inadequate mental state	25	17	8	1	51

Of 152 respondents, 97 pilots (64.8%) had no incidents requiring medical attention, hospitalisation, or sick leave days. In contrast, 55 pilots (36.1%) answered positively to this question (Fig. 10). Of the 55 pilots who responded positively, 30 were hospitalised for a period longer than 24 hours, and 25 pilots for a period shorter than 24 hours (Fig.11).

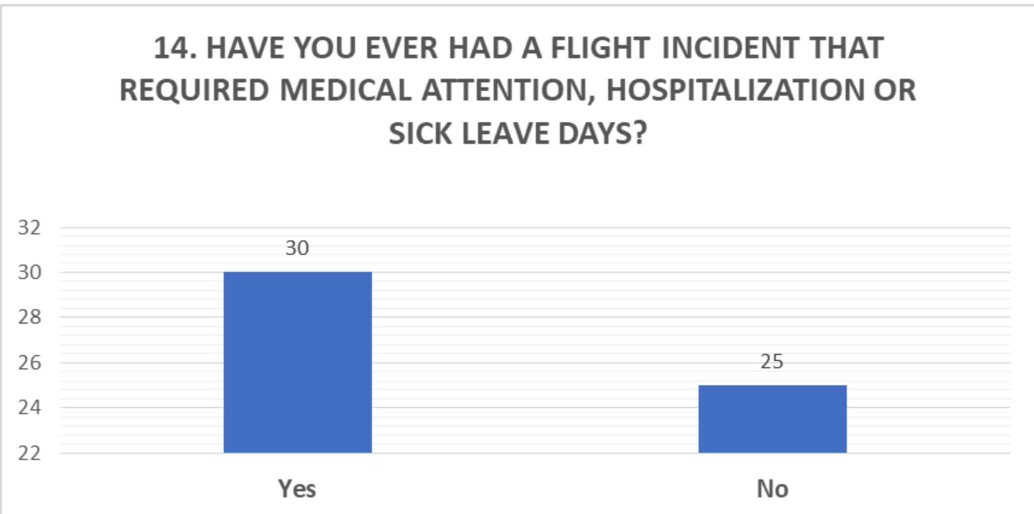


Fig. 10. Percentage distribution of pilots who had incidents that required medical aid, hospitalisation, or sick leave days.

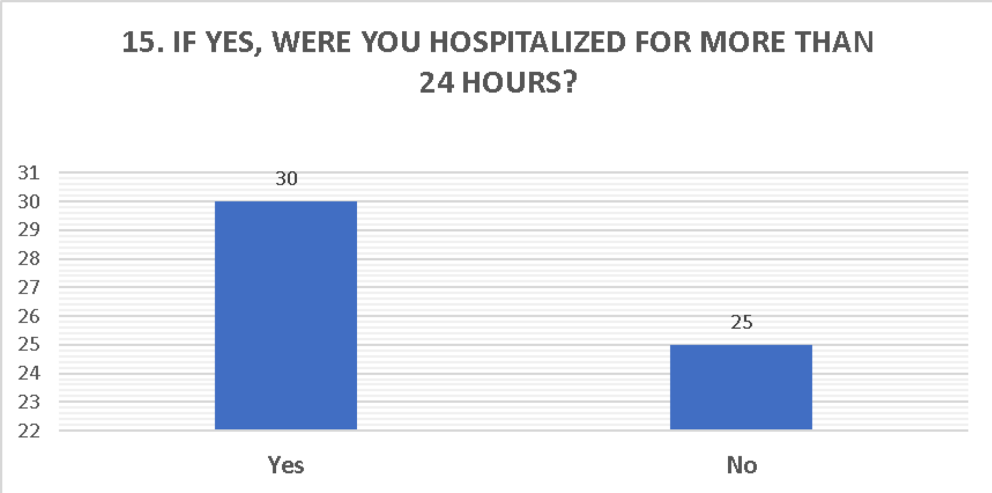


Fig. 11. Numerical distribution of pilots hospitalised for more than 24 hours.

The body segment most exposed to injuries is the leg. Since paragliding takes off and lands on and off the feet, the ankle is under intense stress. Fifty-seven respondents had the most varied injuries at this level, including contusions, sprains, dislocations, fractures, and ligament injuries. Thirty-three of the respondents reported injuries to the trunk and especially to the spine, where there were collapsed vertebral fractures, which is quite typical for injuries involving falls from a height. The hand suffered an injury in the case of 15 respondents, and 10 pilots reported injury to the shoulder (2 of which were stress injuries), 9 to the arm, 8 to the pelvis/thigh, and only 4 to the head/neck (Table. 8).

Table. 8. Numerical distribution of the number of injuries/body segment.

Body segment	Injuries no.
Foot	57
Trunk/Spine	33
Knee/Thigh	26
Hand	15
Shoulder	10
Arm	9
Pelvis/Thigh	8
Head/Neck	4

Regarding the type of injuries, 39 fractures, 33 contusions, 21 cases of tendon, cartilage, meniscus, or ligament injuries, 20 sprains, 14 dislocations, 13 muscle strains, and one internal organ rupture were reported. (Table 9).

Table 9. Numerical distribution of injury types.

Injury type	Număr
Fracture	39
Contusion	33
Injury to tendon, cartilage, meniscus, ligaments	21
Sprain	20
Dislocation	14
Muscle stretching	13
Rupture of internal organs	1

Among the 152 respondents, respectively 101 pilots who reported injuries, 41 benefited from physical therapy and medical rehabilitation following the injuries (Fig.12). So we observed a distribution of events as follows: out of 101 accidents reported, there were 55 hospitalisations, 30 hospitalisations for a period longer than 24 hours and 41 pilots who benefited from physical therapy to recover (Table 10).

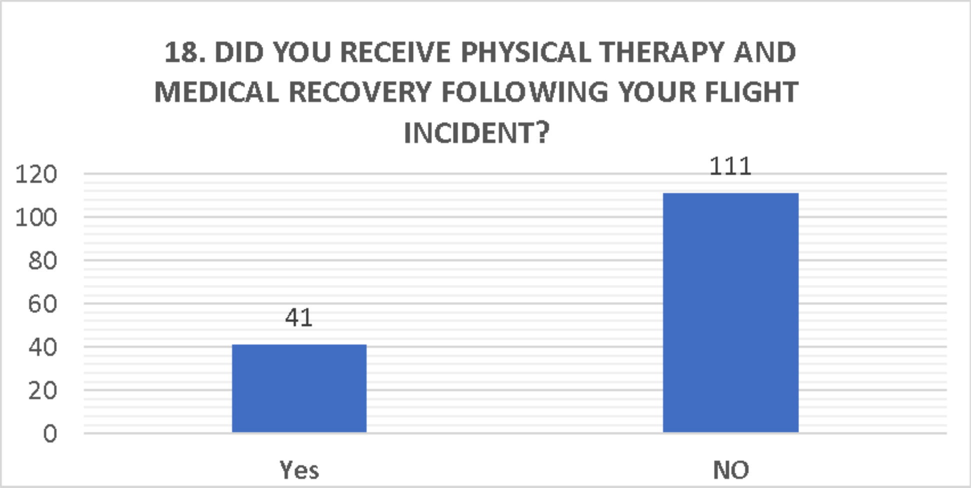


Fig. 12. Numerical distribution of pilots who benefited from physiotherapy.

Table 10. Numerical distribution of events that required medical care.

Events	Total
Injuries	101
Hospitalisation	55
Hospitalisations over 24 hours	30
Physical Therapy	41

Of the 101 respondents who reported injuries that required medical care, 72 pilots (71% of those injured) made a full recovery, 27 (26%) were left with occasional pain, and 2 pilots (1.9%) had residual functionally significant (Fig.13).

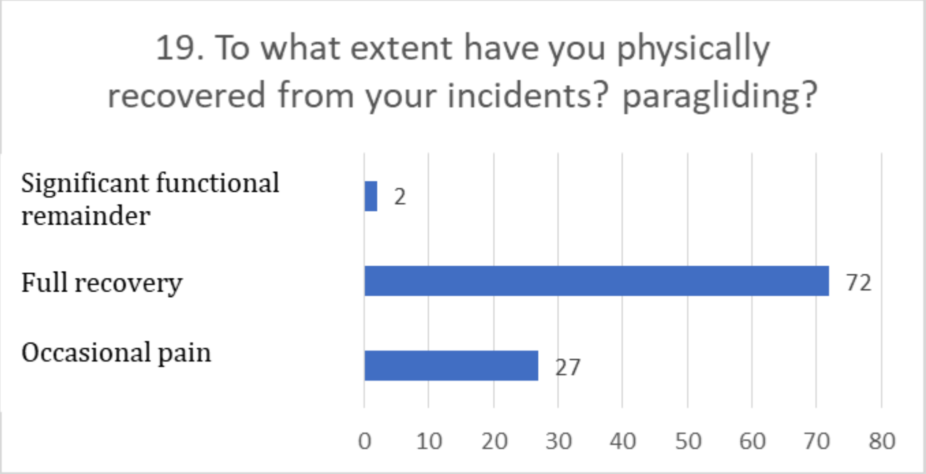


Fig. 13. Numerical distribution of post-accident rehabilitation measure.

From the point of view of the details related to the conditions in which the respondents' flight incidents occurred, the first question is related to the time of flight in which the incident occurred:

take-off or immediately after take-off, flight, or landing. One hundred twenty-eight pilots who had flight accidents or incidents answered this question: 56 incidents occurred on landing, representing 43% of the total incidents; 42 (32%) occurred during flight, and to a lesser extent, 23% of the incidents (30 in number) occurred at take-off or immediately after take-off (Fig.14).

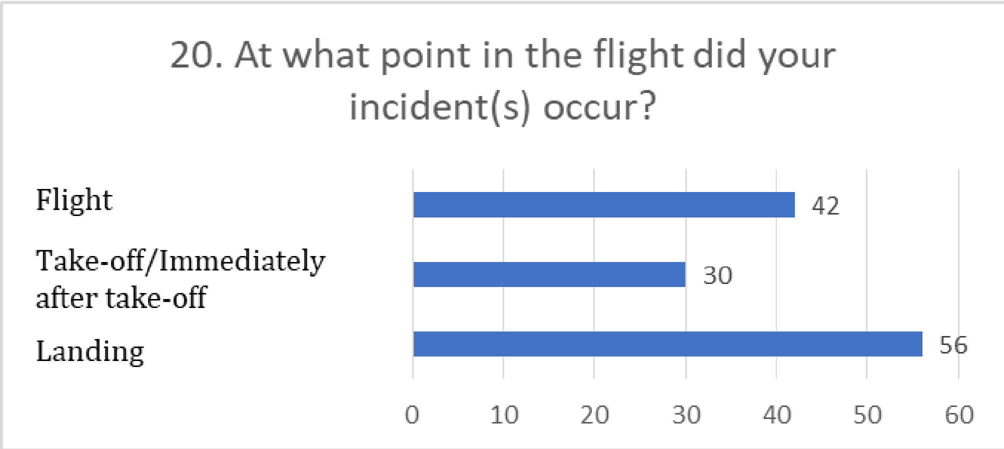


Fig. 14. Numerical distribution of times when flight incidents occurred.

More than half of the incidents (56%) happened at low heights, between 0 and 25m above the ground, and 13% (16 cases) happened at a height between 25 and 50m, so we can say that also at heights relatively small. About 18% of the incidents occurred at heights above 125m, and only 13 cases (11%) started at heights above 2000m above the ground (Fig.15).

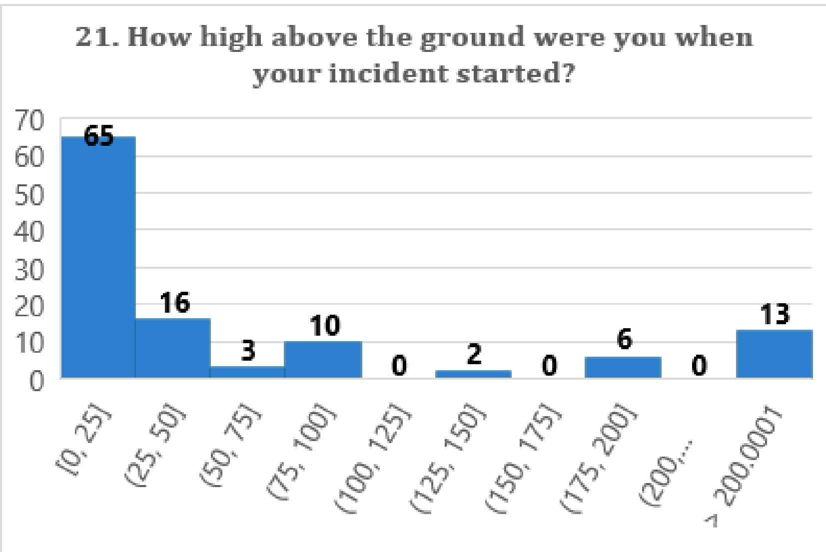


Fig. 15. Numerical distribution of altitude at which flight incidents began.

From the point of view of the type of relief in which the incidents occurred, out of the 131 responses, the results showed that more than half of the incidents took place in mountainous relief (76 cases, which represented 58.14% of total reported cases), 44 cases occurred in hilly terrain (33.33% of cases), and 11 cases occurred in plain terrain (8.53% of cases). (Table 11, Fig. 16)

Table 11. Numerical distribution of relief types where the incidents occurred.

Relief	22What kind of relief were you in when you had the incident?
Plain	11
Hilly	44
Mountain	76
Total	131

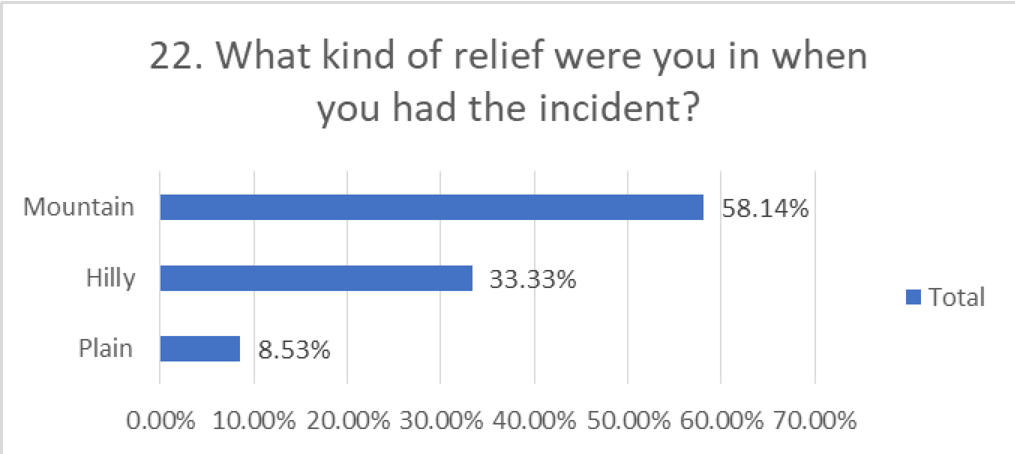


Fig. 16. The percentage distribution of the relief types where the incidents occurred.

Weather conditions at the time of the incidents were adequate in 86 cases, representing over half of the cases (67.19%), marginal in 31 cases, representing 24.22% of the total reported cases, while only 13 cases occurred in unsuitable weather conditions (8.59%) (Fig. 17).

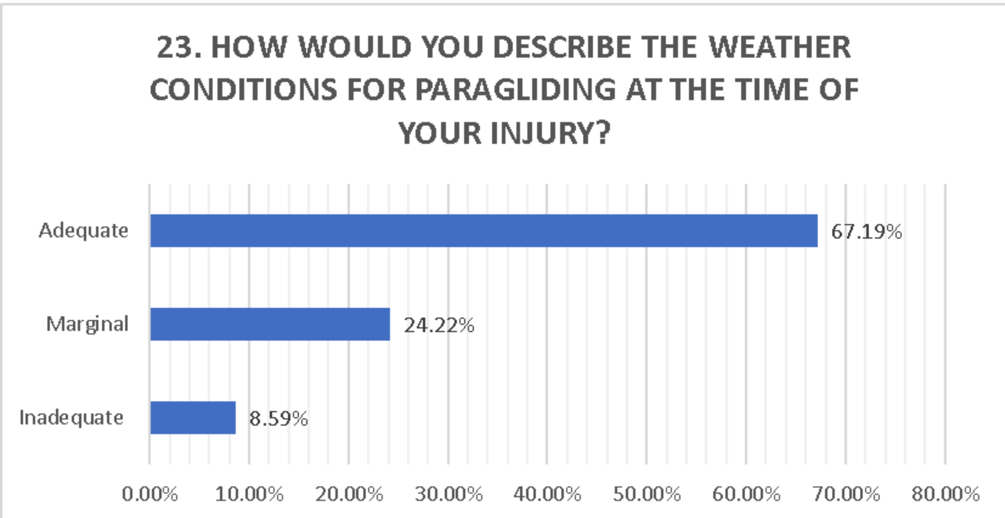


Fig. 17. Numerical distribution of the meteorological conditions causing the incidents.

Of the 142 responses related to the use of the reserve parachute to resolve an incident, most answered negatively (124 cases representing 87.9% of the total), 15 cases used the reserve parachute to resolve incidents (10.6% of the total), while 2 cases where the reserve parachute was deployed but did not open were reported (1.4% of total responses). (Fig. 18)

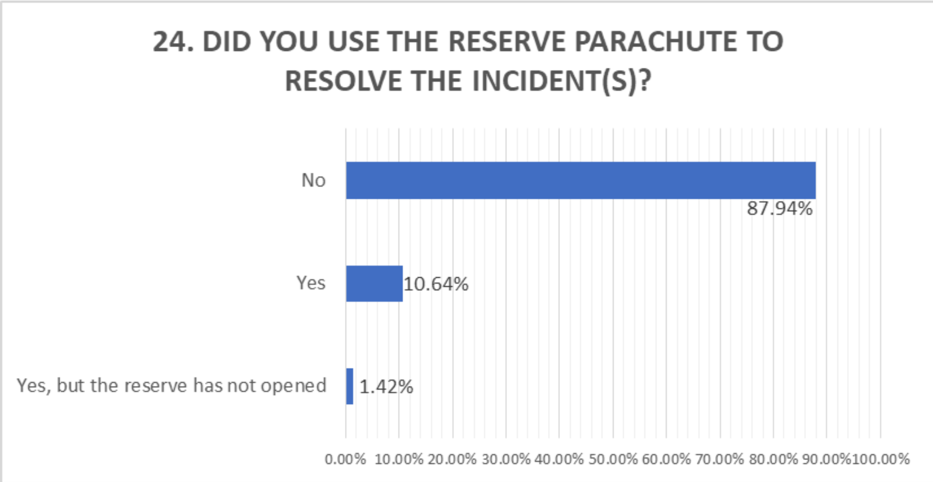


Fig. 18. Percentage distribution of reserve parachute use when solving incidents in flight.

From the point of view of the perception of risk in paragliding, there were 152 responses, of which 35.5% respectively 54 cases placed the perception of risk in the middle of the scale (at 5), with 0 representing non-existent risk and 10 maximum risk. 26 cases (17.1% of the total responses) perceive the risk at number 3 on the risk scale, 12 cases (7.9% of the total) at number 4, 15 cases (9.9%) at number 2 on the risk scale, 6 cases (3.9%) at 1, 3 cases (2%) at zero, 9 cases (5.9% of the total) at number 6 on the risk scale, 10 cases (6.6%) at number 7, 9 cases (5.9%) at number 8, 4 cases (2.6%) at number 9 and also 4 cases (2.6%) perceive maximum risk 10, of particular injury during their flight career. (Fig. 19)

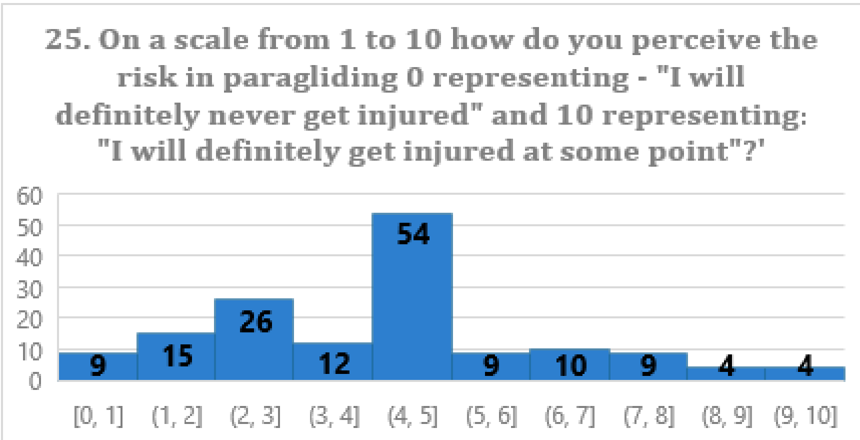


Fig. 19. Numerical distribution of risk perception in paragliding.

5. Discussions

According to the objectives of this study, we evaluated the frequency and rate of paragliding accidents on the analysed sample of pilots, and we identified the types of trauma and injuries that pilots face in this activity, namely traumatic accidents or stress injuries, the most frequent types of injuries and the most often affected body parts in accidents. We analysed risk factors, including pilots' experience (number of years and hours flown, frequency of flight), terrain, proximity to the ground at the time of the incidents, weather conditions, and time of flight when the incidents occurred. We evaluated the effectiveness of safety measures using the reserve parachute in dealing with in-flight incidents. The exploration of the consequences of the accidents was done by assessing the physical impact that the flight accidents had on the pilots, whether physical therapy was required and whether they fully or partially recovered, and the social impact of whether hospitalisation days and sick leave were required. Last but not least, we proposed preventive measures and a set of strategies to reduce the frequency and severity of paragliding accidents based on research results.

The study's results showed a high accident rate, considering that 66% of respondents had injuries during paragliding activity and 67% had an incident that could end in a severe injury to the pilot.

Given the high number of accidents (66% of respondents) and near misses (67% of respondents) reported by pilots, why are there so many accidents in this sport, and what can we do in the future to prevent them? Paragliding is a very accessible form of aeronautical sport, and for this reason, many pilots have been self-taught, especially in the early days when the sport was starting to establish itself. Aviation legislation is not yet designed to apply to this young sport, but efforts are being made.

According to Wilkes et al. (2022), there was and still is an idea that pilots who fly regularly, have many hours of flight time, and are aware of the risks involved, are less prone to accidents than pilots who fly occasionally and perceive paragliding as very safe. However, the data do not suggest this. The more hours a pilot is exposed to paragliding, the more likely he or she is to report an accident. Even pilots with many flight hours and experience have had incidents in flight. This is primarily because no matter what level the pilots are at, they are always trying to push the limits further and further, achieving unprecedented flight numbers and aiming for higher and higher performance. Another aspect is the emergence of an extensive range of sub-disciplines in paragliding, such as speed-flying, speed-riding, and hike and fly, with risks associated with higher flight speeds and high approach to the terrain.

Schulze et al. (2002), on the other hand, concluded that novice pilots were the pilots with the most accidents. In this category, the number of take-off and landing accidents and accidents due to over-piloting was above average.

Most incidents were related to pilot error and inadequate mental state, and far fewer were related to equipment. Technical malfunctions due to equipment were a minimal factor in accidents and flight incidents, which has also been concluded by other studies (Schulze et al., 2002; Soldati, Jackowski, & Schön , 2022). However, the quality, certification, and safety of flight equipment has been reported to be essential for paraglider pilots (Paixão & Tucher, 2012). Uncontrolled collapses significantly cause accidents with predominantly DHV classes 2 and 3 wings. These wings are known to have demanding control and flight characteristics, unlike beginner or intermediate wings, and pilots have to fly very actively to control them.

Consequently, recreational pilots should not fly such wings. We recommend gradual staged training to get pilots to fly such canopies safely. A pilot switching to another wing in the same category but of a newer generation should be trained in how to fly these. We have shown that human error is mainly responsible for accidents, particularly over-piloting. The trend towards flight safety and performance is reflected in the growing acceptance that much practice is needed. Flight preparation should include assessing general and local weather conditions, discovering the local peculiarities of an area, and inspecting take-off and landing.

If flight equipment is tested and approved, it will likely fail during flight. It is gratifying that our study showed that most pilots fly EN-B and even A-category wings, which have the highest passive safety (do not require prompt pilot intervention in the event of evolution in flight). Only a few pilots reported using CCC category wings, which are much more difficult to control. This contrasts with the early days of paragliding when many more pilots were flying wings that were beyond their level of experience and proficiency. However, over the last few years, there has been a growing awareness of the risk and the need to fly with a wing appropriate to the pilot's proficiency level or even below that level to increase the margin of safety. However, more thorough training of pilots in case of emergencies is required in flight schools or special SIV courses simulating incidents in flight.

The distribution of injuries was quite specific and reflected the energy and orientation involved in a possible impact on the ground. The pilot, suspended in the harness with a likelihood of impacting the ground in a vertical position or with the lower limbs below, would experience forces transmitted upward through the lower limbs, pelvis, and spine, resulting in fractures at biomechanically vulnerable points. So, most of the injuries reported were at the level of the lower body (contusions, sprains, fractures at the level of the lower limbs) and the level of the spine (slumps, fractures at the spine level). This was confirmed by a similar study (Cevik et al., 2016), where similar results emerged regarding the types of trauma and the most frequently affected body parts. This study concluded that the most common injuries were to the soft tissues and ligaments, and over half were to the lower extremities. Interestingly, this study (Cevik et al., 2016) assessed the rate of injury, hospitalisation, and surgery as low, while we considered it high, with a percentage of more than 50% of hospitalisations based on the number of accidents reported. A similar distribution of trauma was also noted in the study by Canbek et al. (2015), with the predominance of injuries to the lower limbs and the spine, especially at the lumbar level.

Injuries to the upper limbs were less in number, results that are also found in other studies (Feletti et al., 2017; Bigdon et al., 2022); however, the presence of stress injuries at the shoulder level in the case of professional pilots is noted. Being with the arms raised for many hours during the flight and the stress at this level during take-offs is felt over time in the form of stress wear. As a result, it is necessary to use harnesses with approved protection to ensure maximum safety in case of a more complex impact and the future development of more adequate protection devices. Thorough physical training of pilots is also required through special physical training programs dedicated to paraglider pilots that emphasise the development of the lower body muscles, back, and shoulders. Equally important is the mental preparation of pilots, considering that most accidents are a combination of factors that very often involve the pilot's inadequate mental state.

Most flight incidents occurred close to the ground, either on take-off or landing, necessitating continuous practice of ground inflation wing ground control exercises, either in flight schools or later, throughout the entire career of a pilot. These exercises teach pilot wing control in flight and active piloting, respectively, and prepare the pilot to react appropriately to possible incidents in flight.

A frequent cause of accidents is insufficiently structured landing. Our study showed that 43% of incidents occurred on landing (Schulze et al., 2002). Flight path planning is often too late; the remaining alternatives leave room for too slight landing variation. In these cases, it is impossible to make corrections for wind direction and intensity on landing, ground activity, obstacles, or other pilots falling in on landing, which can quickly lead to extreme situations.

Some of the pilots flew in unsuitable or marginal weather conditions, and their incidents were primarily due to this aspect. Strong wind, over 30km/h, overdevelopment of clouds, showers, and overdevelopment near the flight area are conditions in which paragliding is extremely dangerous and take-off is contraindicated. Niedermeier et al. (2019) listed the main risk factors in the occurrence of paragliding accidents: strong wind, lack of piloting skills, the collapse of the paraglider, and incorrect use of controls (over- or under-piloting of the wing), which also emerges from our results. In many cases, pilots overestimate their flying skills, especially since each pilot makes these decisions individually. Because the assessment of flight conditions is subjective and made by each pilot, this is the frequent cause of assessment errors and injuries. That is why it is necessary to have a thorough knowledge of meteorology to study the METAR information from the meteorological stations in the area and the local flight characteristics of the area where the flight is to be carried out. To prepare for the flight, it is essential to know the weather forecasts and anticipate the weather evolution during the day the flight is to take place.

The mountainous relief is where most accidents and incidents have occurred. It is also technically much more complicated for paragliding. Schulze et al. (2002). Generally, the thermal flight conditions are more robust, so the air is generally more turbulent, and there are downwind and the possibility of getting behind tubing obstacles. That is why it is recommended to fly with caution in these areas and to study the terrain on which the flight is to be carried out in advance.

The relatively low rate of reserve parachute deployment (only 10.6% of cases) may be due to insufficient training in opening the reserve parachute (training that makes pulling the reserve parachute a reflex gesture). Also, the low height from the ground (less than 100m) led to the difficulty of opening the reserve parachute, its opening time being very short. The same aspect was noted in another study (Soldati, Jackowski, & Schön, 2022). The practice sessions of reserve parachute openings are essential in conclusion. The reported cases of it not opening were either because the pilot was not high enough or because the parachute was not folded properly. The annual folding of reserve parachutes is therefore required by specialised personnel instructors who have the necessary training or are under their supervision. It is also recommended that a sufficiently large safety distance from the ground be maintained to allow the opening of the reserve parachute and room for maneuver in case of uncontrolled evolutions of the paraglider.

6. Limitations of the study

The study's limitations include a relatively low response rate, subjectivity, and limited generalizability. We assessed the response rate as low, considering that there are over 2000 pilots in Romania (of which maybe 1000 are active), and they all had access to this questionnaire. This may have been due to a lack of interest or the perceived irrelevance of the study. Also, pilots who gave up paragliding following accidents or those who had fatal accidents could not be included in the study because there was no accessible database to determine these aspects.

The databases of the flight associations in Romania are incomplete, and the majority of flight incidents are not being reported at all; therefore, this study needed to rely exclusively on each pilot's personal reporting. However, this type of reporting is problematic in adventure sports, given the complex dynamics of the environment in which it takes place. Pilots may not be aware of all the factors that contributed to their incidents, misinterpret the causes, or not remember what happened. Terminological confusion was another limiting factor.

As one of the last limitations of the study, we want to emphasise that we used Microsoft Excel tools over more specialised statistical software.

Finally, the results may not be generalisable to the entire pilot community. The respondents to the questionnaire were a cohort who were more engaged and motivated in sport; as a result, they were interested in responding to this study. At the same time, there was no definition of the "average pilot" as a term of comparison. For these reasons, the study's results should be treated with caution and refined through future studies.

7. Conclusions

The main factors in incidents were piloting errors and incorrect decision-making; in conclusion, the human factor and, to a minimal extent, technical failures. If checked and tested regularly, paragliding equipment rarely fails, only if exposed to unusually high forces during flight. Most of these errors were due to oversteering of the wing or, conversely, to a lack of adequate reaction, namely poor pilots' training in flap control and active piloting. Some of these errors were related to wrong decisions regarding the assessment of flight conditions and weather conditions or not knowing the terrain and local features well enough. Given that over half of the incidents occurred at low altitudes, during take-off or landing, we can conclude that the pilots either did not correctly assess the take-off or landing conditions, were surprised by the landing conditions, or did not prepare their correct framing in time.

So, we considered the most common errors based on lack of skills. This high number of decision errors reflects the greater responsibility of pilots, as opposed to other more regulated aviation disciplines, in choosing when, where, and how to fly.

Another aspect I noticed is the specific distribution of injuries. Considering the rider's position in the harness, the possibility that the impact with the ground is made from the bottom up (from the level of the lower limbs, pelvis, and spine) is the highest, except for the rarer cases when the rider impacts the ground or an obstacle with the side of the body. Injuries to the lower limbs were the most common. Of 162 injuries totalling all parts of the body, 51.2% were in the lower limbs, 25% in the trunk, spine, and pelvis/thigh, and to a lesser extent in the upper limbs and cephalic extremity. Fractures and contusions predominated among the types of injuries. Pilots who required hospitalisation following paragliding accidents represented quite a large number, 54% of all pilots who reported injuries, meaning that over half of the injuries were substantial. Of the respondents, only 2 reported significant functional impairment, but here comes one of the limitations of the study, namely the fact that we could not include people who left the sport as a result of a debilitating injury; therefore, we cannot know this aspect accurately.

The type of relief that raised the most problems was the mountain; here, more than half of the paragliding incidents occurred (58.14%). We attribute this to the fact that ridge and valley systems are technically the most difficult to fly with many topoclimate changes, to the fact that mountain ridges act as obstacles behind which turbulence (rotor) forms and valleys accelerate the wind (Venturi effect). So, the pilots did not recognise situations such as solid valley winds, rotors, wind accelerations in passes or gorges, overdevelopment of clouds on mountain ridges, and mountain or valley breeze. These aspects are more easily predictable on flat terrain without obstacles. In conclusion, we can also attribute the fact that the pilots were insufficiently trained to recognise the meteorological and terrain peculiarities of the mountainous areas to human error and decision mistakes.

The use of the reserve parachute was relatively small compared to the number of accidents (only 15 cases where the reserve parachute was successfully used were reported, representing 15.1% of the accidents). There were 2 cases where the parachute did not open, most likely due to the low altitude, but some accidents, which we can assume could have been solved by using the reserve parachute in time. Below the height of 30m, the reserve parachute does not have enough time to open, but a prompt opening of the reserve at a higher height can be lifesaving. Therefore, we can conclude that the pilots had poor training regarding dropping the reserve parachute; they hesitated because they panicked or tried to recover the wing from the evolution, losing time and height to open the reserve parachute effectively.

Regarding risk perception, we believe that most pilots have an adequate attitude because risk perception influences the pilot’s attitude toward flying. A pilot who perceives no risk at all will most likely fly carelessly or ignore essential aspects that will eventually lead to injury, and a pilot who perceives maximum risk will fly timidly, which will hinder his development in the sport; it makes him panic when his quick reaction is needed, and it will affect his concentration. However, most pilots placed the perception of risk in the middle on our scale (60% of pilots placed the risk between 2 and 5), which we considered a positive aspect. Most pilots are aware of the risks; in conclusion, they will prepare adequately for the flight, but not to the extent that it hinders their performance or concentration during the flight.

8. Proposals and Recommendations

Paragliding is a fascinating sport where each pilot’s sense of responsibility largely determines the degree of risk. The proposals and recommendations of this study refer to the observed aspects that can lead to the improvement of the degree of safety in this sport, namely, to avoid injuries:

- More thorough training of pilots in wing ground control, inflation exercises, and flight simulation courses is required, even after initial training in flight schools. At the level of flight schools, it is recommended to implement new training programs that include more hours dedicated to learning active piloting, meteorology, evaluating flight conditions at different flight sites, performing flights at different take-off sites in varied flight conditions, learning different take-off techniques in different wind intensities. In addition to the existing specific training programs, the pilots’ mental training and special physical training programs dedicated to the paraglider pilots, along with the development of the musculature in the lower body, back, and shoulders, are necessary.

- The new generation EN A and B wings, with their passive safety features and good performance, offer stress-free flying in higher safety conditions
- Interventions on the safety line regarding the equipment should be made at the back protection level of the harnesses by developing new materials and technologies, considering the number of accidents at the spine level. The constant use of certified paragliding helmets, high ankle boots, gloves, and appropriate flight clothing provides added safety in flight.
- A rigorous analysis of the flight location (take-off, landing) and general and local weather conditions is required, and it is recommended that local paraglider pilots be contacted for additional information related to local peculiarities before engaging in flight over unfamiliar terrain. We also studied aeronautical charts and learned about restricted or prohibited flight areas.
- Another important aspect that is required is the annual organisation of additional and opening sessions of the reserve parachute to prevent possible errors in opening the reserve and to train the pilots to open it promptly in case of need.

Conflict of interests

Nothing to declare.

References

Bigdon, S.F., Hecht, V., Fairhurst, P.G., Deml, MC., Exadaktylos, A.K., & Albers, C.E. (2022). Injuries in alpine summer sports - types, frequency and prevention: a systematic review. *BMC Sports Sci Med Rehabil, 14*(1), 79. https://doi.org/10.1186/s13102-022-00468-4

Bruhns, H. T. (1997). Lazer e meio ambiente: corpos buscando o verde e a aventura. [Leisure and the environment: Bodies seeking greenery and adventure.] *Revista Brasileira de Ciências do Esporte* [Brazilian Journal of Sport Sciences], *18*(2): 86-91.

Çalık, D.S., Gürsoy, R., & Saruhan, E. (2021). Evaluation of the Psychological and Hormonal Parameters in Paragliding. *Central European Journal of Sport Sciences and Medicine, 2*(34), 15–23. https://doi.org/10.18276/cej.2021.2-02

Canbek, U., İmerci, A., Akgün, U., Yeşil, M., Aydin, A., & Balci, Y. (2015). Characteristics of injuries caused by paragliding accidents: A cross-sectional study. *World J Emerg Med. 6*(3), 221-224. https://doi.org/10.5847/wjem.j.1920-8642.2015.03.011

Cevik, A.A., Kaya, F.B., Acar, N., Sahin, A., & Ozakin, E. (2016). Injury, hospitalisation, and operation rates are low in aerial sports. *Turk J Emerg Med. 17*(3), 81-84. https://doi.org/10.1016/j.tjem.2016.11.004

Donnelly, M. (2006). Studying Extreme Sports: Beyond the Core Participants. *Journal of Sport and Social Issues, 30*(2):219-224, https://dx.doi.org/10.1177/0193723506287187

Feletti, F., Aliverti, A., Henjum, M., Tarabini, M., & Brymer, E. (2017). Incidents and Injuries in Foot-Launched Flying Extreme Sports. *Aerosp Med Hum Perform. 88*(11), 1016-1023. https://doi.org/10.3357/AMHP.4745.2017

Karakoyun Ö.F., & Golcuk Y (2023). Accidents and injuries related to paragliding on mount Babadağ, Turkey: A cross-sectional study. *Turk J Emerg Med, 23*(4), 232-237. https://doi.org/10.4103/tjem.tjem_67_23

Khurtenko, O., Tomich, L., Drahunov, D., Hancheva, K., Lytvyn-Zhmurko, T., & Radchuk, H. (2023). Neuroscientific View on Making Urgent Decisions, Responding to Unusual Situations in Sports and the Role of Emotions. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 14*(1), 370-386. https://doi.org/10.18662/brain/14.1/425

Niedermeier, M., Gatterer, H., Pocecco, E., et al. (2019). Mortality in Different Mountain Sports Activities Primarily Practiced in the Winter Season-A Narrative Review. *Int J Environ Res Public Health, 17*(1), 259. https://doi.org/10.3390/ijerph17010259

Paixão, J. A. Da, & Tucher, G. (2012). Risk perception for paragliding practitioners. *International Journal of Sports Science, 2*(2), 6-10.

Reason, J. (2000). Human error: models and management. *BMJ. 320*(7237), 768-770. https://doi.org/10.1136/bmj.320.7237.768

Schulze, W., Richter, J., Schulze, B., Esenwein, S.A., & Büttner-Janz, K. (2002). Injury prophylaxis in paragliding, *Br J SportsMed, 36,* 365-369. https://doi.org/10.1136/bjsm.36.5.365

Soldati, F.O., Jackowski, C., & Schön, C.A. (2022). Foot-Launched Flying Sport Fatalities in the Canton of Berne, Switzerland. *Wilderness & Environmental Medicine. 33*(1), 50-58. https://doi.org/10.1016/j.wem.2021.11.004

Tomich, L., Levchenko, A., Girchenko, O., Sikorska, L., Nazarov O., & Perelygina, L. (2023). Psychological Counseling as a Means of Developing the Athlete's Personality. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience, 14*(1), 647-661. https://doi.org/10.18662/brain/14.1/439

Tordjman. K., Constantini, N., & Hackney, A.C. (2013). Endocrine aspects and responses to extreme sports. Adventure and Extreme Sports Injuries, 315–324, http://dx.doi.org/10.1007/978-1-4471-4363-5_15

Wilkes M.R. (2020) PhD Thesis Accidents in context: the relative contributions of pilot, equipment and environmental stress to paragliding incidents, University of Portsmouth, 3.

Wilkes, M., Long G., Massey H., Eglin C., & Tipton M. (2022). Quantifying Risk in Air Sports: Flying Activity and Incident Rates in Paragliding. *Wilderness Environ Med, 33*(1), 66-74. https://doi.org/10.1016/j.wem.2021.11.011

Yalcin, M., Kardesoglu, E., & Isilak Z. (2011). High altitude and Heart. *TAF Preventive Medicine Bulletin, 10*(2), 211–222,