Incidents and Injuries in Foot-Launched Flying Extreme Sports

Francesco Feletti; Andrea Aliverti; Maggie Henjum; Marco Tarabini; Eric Brymer

BACKGROUND: Participation rates in extreme sports have grown exponentially in the last 40 yr, often surpassing traditional sporting activities. The purpose of this study was to examine injury rates in foot-launched flying sports, i.e., sports in which a pilot foot-launches into flight with a wing already deployed.

METHODS: This paper is based on a retrospective analysis of the reports of incidents that occurred between 2000 and 2014 among the British Hang Gliding and Paragliding Association members.

RESULTS: The majority of the 1411 reported injuries were in the lower limb, followed by the upper limb. The most common lower limb injury was to the ankle and included fractures, sprains, and dislocations. The distribution of injures was different in each discipline. The calculated yearly fatality rate (fatalities/100,000 participants) was 40.4 in hang gliding, 47.1 in paragliding, 61.9 in powered hang gliding and 83.4 in powered paragliding; the overall value for foot-launched flight sports was 43.9.

DISCUSSION: Significant differences in injury rates and injury patterns were found among different sport disciplines that can be useful to steer research on safety, and adopt specific safety rules about flying, protective clothing and safety systems in each of these sports.

KEYWORDS: Adventure sports, speed flying, paragliding, powered hang gliding, paramotor, fracture, dislocations.

Feletti F, Aliverti A, Henjum M, Tarabini M, Brymer E. *Incidents and injuries in foot-launched flying extreme sports.* Aerosp Med Hum Perform. 2017; 88(11):1016–1023.

Extreme sports may be defined as sports where a likely outcome of a mistake or accident is death.[2] Participation rates in extreme sports have grown exponentially in the last 40 yr,[6,15] often surpassing traditional sporting activities such as basketball and golf.[1,24] By 2002, roughly 86 million individuals were taking up some sort of extreme sport[23] and these trends seem to be continuing.[6,22,25] As participation rates in extreme sports increase, it is likely that related incidents and injuries will also increase. The knowledge of injury epidemiology is important for rescue teams and sports medicine specialists, and to guide future preventive research to develop guidelines, protective clothing, and safety systems.[27]

The category of extreme sports includes that of flying extreme sports; the foot-launched flying extreme sports are the subgroup of flying extreme sports in which a pilot foot launches into flight with a wing already deployed. The purpose of this study was to examine injury rates in foot-launched flying extreme sports.

While foot-launched flying has existed since the dawn of heavier-than-air aviation, the modern era of foot-launched flying extreme sports arguably stems from the 1960s popularity of hang gliding.[27] Today foot-launched flying consists of hang gliding, paragliding, powered paragliding, powered hang gliding, parascending, and speedflying. While the common factor for all these aerial extreme sports is that they are foot launched, each sport has its own unique set of characteristics. For example, in hang gliding a harness suspends the pilot from a frame made from aluminum alloy, carbon fiber, and high-tech sail fabrics. Paragliders on the other hand were developed from a subset of parachutes termed ram-air canopies. Powered hang gliding, powered paragliding, and parascending originated as motorized or motor-assisted versions of these sports but then

From the Department of Electronics, Information and Bioengineering, Politecnico di Milano Unversity, Milan, Italy, and eXtremesportmed, International Scientific Association.

This manuscript was received for review in August 2016. It was accepted for publication in July 2017.

Address correspondence to: Francesco Feletti, M.D., U.O. Radiologia, S. Maria delle Croci Hospital, Viale Randi 5, Ravenna, Italy; feletti@extremesportmed.org.

DOI: https://doi.org/10.3357/AMHP.4745.2017

evolved into clearly distinct disciplines practiced in different environmental conditions (i.e., on flatlands and without thermals or wind).

The number of those who practice these sports worldwide is not known; however, foot-launched flight associations exist in many countries. The U.S. Hang Gliding and Paragliding Association (USHPA) and the British Hang Gliding and Paragliding Association (BHPA) are the largest with approximately 10,000[13] and 6729 members, respectively. Paragliding is the most popular of these sports and it is widespread, especially in Europe.[12] The USHPA has about 4500 active paraglider members.[13] The motorized versions of these sports are less popular and the U.S. Powered Paragliding Association (USPPA) in 2007 estimated about 3000 active (at least 5 flights/year) powered paragliding pilots in the U.S.

Although there is some research that investigates aspects of injury in some foot-launched flying extreme sports, the medical literature is partial, fragmented, and outdated.[27] For example, the most recent research on hang gliding incidents relies on data from 1991,[10] the largest study on paragliding dates back to the 1990s,[17,33] while more recent studies on paragliding have focused on spinal cord injuries.[13,25] In addition, medical literature usually groups these sports together as if they are the same activity. However, due to the different flight forms and mechanisms, equipment, and performance conditions, it is possible that each of these activities presents different challenges and injury patterns.[7] What is clear from recent research is that foot-launched flying extreme sports present incident and injury patterns which are not comparable to those associated with more popular sports such as soccer, golf, or basketball, or even air traffic incidents.[5,8,16]

METHODS

This paper reports a retrospective descriptive study of incident cases that occurred between September 2000 and September 2014 among members of the BHPA. In the UK, pilots and associations are required to report incidents within 48 h of an event through an online incident report form (IRF) that is available on the association website.[4] Reporting fatal or potentially fatal incidents to the BHPA, Air Accident Investigation Branch (AAIB), and Police is a legal requirement,[4] and as a consequence the number of nonreported incidents is expected to be very small. The data published by the BHPA were public and anonymous and their use for study and publication purposes was authorized beforehand by the association, which also provided the current membership details for the evaluation of the injury rates in the different sports. Incidents are reported by people who have either witnessed or been involved in an incident. The present study met the requirements of the ethical guidelines of the Politecnico di Milano.

The online IRF collected details about the nature of incidents, injuries, and near misses, including specification of the anatomical region of any sustained injury and details about the outcome (unhurt, injury, or fatal occurrence) of the incident. Demographic details such as age, gender, and pilot skill level (rating) were also collected, as was detailed information about environmental conditions, date, time, site where the incident took place, and a description of the equipment used. Pilot skill rating (PSR) refers to the BHPA formal training, while an Elementary Pilot (EP) award marks the successful completion of the introductory phase, and the award of Club Pilot (CP) signifies that a pilot can fly unsupervised. The qualification of Pilot (P) signifies a 'fully qualified' pilot with the skills and judgment to fly cross country outside of BHPA member facilities. Advanced Pilot (AP) rating is awarded to those with the highest skills. Both the P and AP ratings are achieved through self-learning processes under the guidance of BHPA club coaches.[29]

Prior to January 1, 2012 the survey included an extensive, detailed description of the injury type. Post January 1, 2012 only data on the severity of the injury (minor or major) and the anatomical region involved were collected. A major injury is defined as an injury that resulted in internal organ damage, fracture, dislocation, muscle rupture, nerve damage, open wound, near drowning, hemorrhage, or ligament rupture, or where hospitalization of more than 48 h was required. Injury rates were calculated as injuries/1000 participants/year based on annual membership data provided by BHPA for the period covered by the study. Fatalities were only considered a direct consequence of the incident if they occurred within 30 d following the event.[4] This work analyses the demographics and the consequences of the incidents in each sport, as well as the correlation between the consequences of the incident, the pilot status and the wind speed at the time of the incident.

Statistical Analysis

Data were manually entered into datasheets, and analyzed using descriptive statistics with Minitab 17. The correlation between the different disciplines and the injuries was evaluated using the Chi-square test of association between variables. The null hypothesis was that the injuries had the same probability of occurrence independently from the discipline.

RESULTS

The incident and injury patterns of foot-launched flying extreme sports in the UK have been determined on the basis of 1759 incidents involving 1771 people, including 12 tandem passengers, between September 2000 and September 2014. The average number of BHPA members practicing the different disciplines in the same period (**Fig. 1**) ranged between 108 (powered hang gliding) and 4525 (paragliding). Of the injured pilots, 88% were males, 9% females, and 3% did not report gender information.

The average age of the participants varied between sports and ranged between 37.2 yr (parascending) and 49.5 yr (powered paragliding) as shown in **Fig. 2**.

Pilots of all levels reported incidents (**Fig. 3**); most of them (42.3%) were classified as CP status (**Table I**). The CP group had a higher percentage of major (70.6%) and fatal (2.9%)

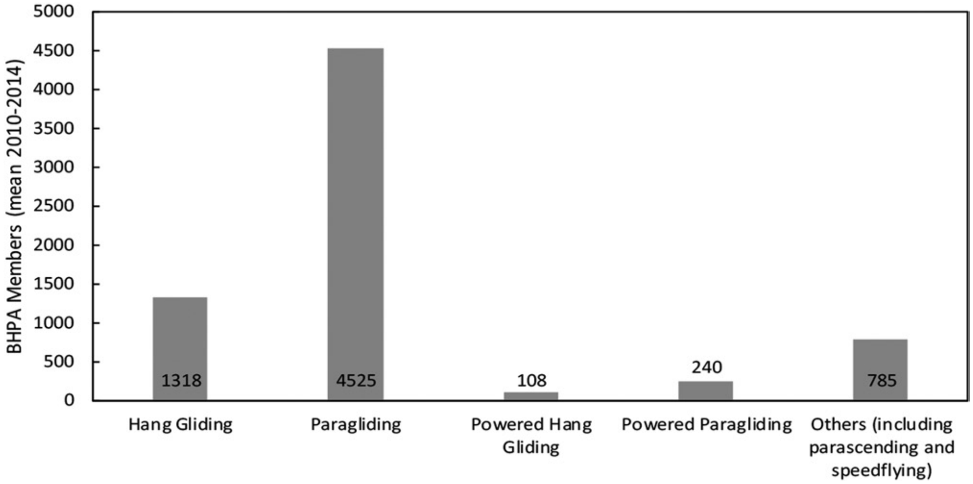


Fig. 1. Members of BHPA practicing the different disciplines (average 2010–2014).

injuries than the qualified pilot group. From the reported 1759 incidents, 427 (24.3%) did not result in injury, 46 (2.6%) were fatal, and 1130 (64.2%) resulted in injury. There were 156 (8.8%) incident reports that did not specify whether the incident had resulted in injury.

Among the incidents that resulted in injuries, 216 people sustained more than one injury, and a total number of 1411 nonfatal injuries were recorded. Paragliding produced the greatest number of reported incidents, however the percentage of injury to total number flying was only fractionally higher than recorded in hang gliding. Speed flying had the highest rate of incidents that resulted in injury and death although this resulted from a low overall number of incidents reported (**Table II**). The relationship between wind speed and incident outcome is reported in **Table III**.

The injury rate (injuries/1000 participants/year) was not adjusted for yearly fluctuations in BHPA active membership: rates were computed using the average number of BHPA members in the period 2001 – 2014. This number did not vary significantly in this period, as the ratio between the standard deviation and the mean was lower than 5%.

The injury rate (injuries/1000 participants/year) was 10.4 for hang gliding, 12.5 for paragliding, 6.2 in powered hang gliding, and 6.4 in powered paragliding. The injury rate across the whole group of examined sports was 10.8.

The highest percentage of injuries (identified from the 1411 reports including data on the anatomic distribution and descriptions) were in the lower limb, followed by the upper limb (see **Table IV** and **Fig. 4**). The most common lower limb injury was to the ankle and included fractures, sprains, and dislocations. Injuries to the leg and knee also included fractures and sprains, as well as torn ligaments. Injuries to the upper limbs were mainly in the shoulder, arm, and wrist, and included dislocations, fractures, and some nerve damage.

The relationship between the 7 disciplines and the 31 reported injury types was assessed using the Chi-squared test of association between variables. Results revealed no significant correlations (Pearson's r coefficient 0.08). Given the large discrepancy between the number of practitioners in different disciplines, the Chi-squared approximation was possibly not valid. Therefore, we decided to focus on investigating the correlation between a limited number of injuries (fracture, contusion, muscle and ligament injuries, fatal injury, soft tissue injuries, concussion, sprain, dislocation, internal organ damage, and burns) and the two sports with the highest number of participants (paragliding, hang gliding). The Pearson correlation coefficient was quite low (0.08), suggesting that in general the injury is independent from the sport.

However, when considering the distribution of specific injures separately in each discipline we found variability based on discipline requirements (Fig. 1). In particular, a total of 155 cases of spinal fracture were reported; spinal injuries were differently distributed in the various sports (χ^2, $P < 0.001$; 95% confidence); cervical fractures represented 36.4% of spine fractures in hang gliding, 0.7% in paragliding, and 16.7% in powered paragliding. All fracture cases reported in speed flying and parascending involved the lumbar tract. Lumbar fractures represented 54% of spine fractures in paragliding, 33.3% in powered paragliding, 27.3% in paragliding. Thoracic spine fractures were only reported in paragliding and

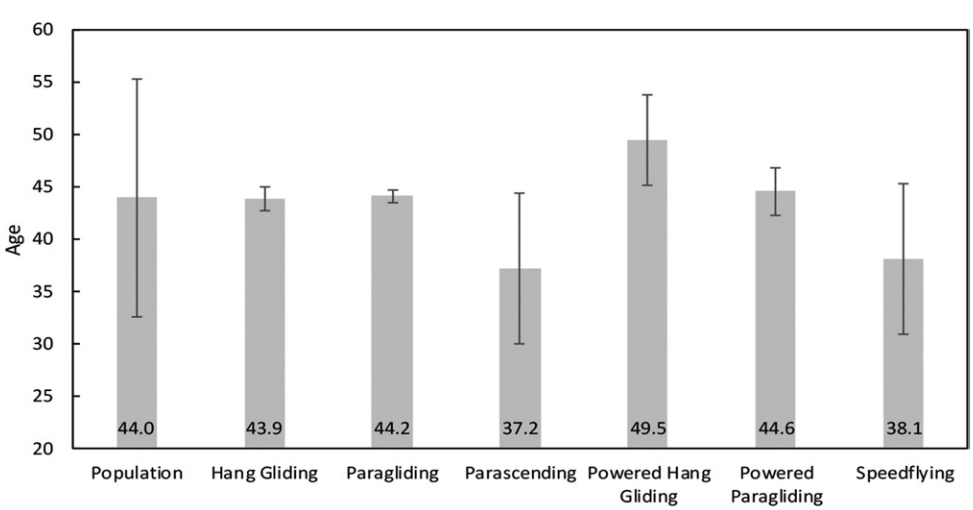
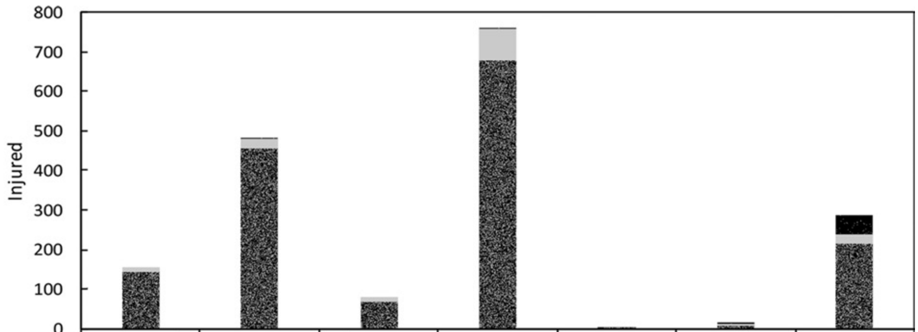


Fig. 2. Mean age of the participants of each sport (error bars indicate SD).



	Advanced Pilot	Pilot	Elementary Pilot	Club Pilot	No rating	Tandem Passenger	Unspecified
Unspecified		1		2		1	50
Females	10	25	13	81	0	2	22
Males	144	455	67	677	6	10	216

Fig. 3. Relationship between the injuries and the injured person's skill level.

represented 13.3% of vertebral fractures in this sport. Only one case of sacral fracture was reported, and that was during a paragliding incident.

The calculated yearly fatality rate (fatalities/100,000 participants) was 40.4 in hang gliding, 47.1 in paragliding, 61.9 in powered hang gliding, and 83.4 in powered paragliding; the overall value for foot-launched flight sports was 43.9.

DISCUSSION

The average age in speed flying and in parascending was lower than the average age of the entire group; conversely, the average age in powered hang gliding was higher than that of the group. There are a number of potential contributing factors for this finding including equipment cost, recreational time availability, the relative 'maturity' of the respective disciplines, and the perception of danger.

A small percentage of the reported powered paragliding and powered hang-gliding incidents occurred during strong wind conditions (Table III). This is probably due to the fact that these two disciplines are motorized, so wind and thermals are not a necessary part of participation. The percentage of incidents resulting in injuries or fatalities in paragliding and hang gliding was similar for both light and strong wind. However, in paragliding, hang gliding, powered paragliding, and speed flying there were a greater number of incidents that resulted in fatalities in strong winds. Findings in this study indicated that incidents involving fully qualified pilots were less likely to result in serious consequences than incidents involving novices. Even if the existence of hidden biases cannot be completely excluded, this figure suggests that education, training and experience may be important factors in reducing the severity of an incident outcome.

The calculated injury rates (injuries/1000 participants/year) range between 6.2 and 12.5, with an overall injury rate across all activities of 10.8. These figures compare favorably with the injury rates of 7–7.5 and 20, reported in skateboarding and in windsurfing, respectively.[11,20] Severe injuries, however, represented 16.2% of the total in skateboarding,[18] in windsurfing they represented 42% of the injuries[21] while they accounted for 66% in the present study.

Comparing the injury rates of the present study with previous data relating to the same sports was not possible due to the scarcity of data available in the literature. The exception was paragliding, where an annual percentage of 0.32–0.5% for severe injuries has been previously reported.[30]

With regard to the anatomic distribution of injuries, existing studies on hang gliding showed that upper limbs injuries are twice as likely to occur than lower limbs injuries.[10] Upper limb injuries appear to be more common in hang gliders, while lower limbs injuries are common both in hang gliding and paragliding.[24] This study provides a clearer picture of this difference with injuries to the upper limbs predominating in hang gliding, and those to the lower limbs (feet and ankles in particular) in paragliding. This may be due to the fact that in hang gliding the pilot is in a prone position in the harness (https://www.bhpa.co.uk/sport/hang_glider/),[4] making upper limbs the most liable to injury in the event of impact, while in paragliding the pilot is in a standing or sitting position (https://www.bhpa.co.uk/sport/paraglider/),[4] directly exposing the lower limbs to injury in the event of a fall.[27] The distribution of injuries in paragliding is similar to that reported in the study on skydiving by Westman et al., in which most of the injuries (51%; $N = 160$) were to the lower limbs, affecting the leg, the ankle, and the foot in particular.[32] The high percentage of back injuries in paragliding observed in this study (18.7%; $N = 195$) is also consistent with results from previous studies.[14,26,28] The prevalence of spinal injuries in paragliding, in particular vertebral body compression fractures that

Table I. Injuries, Fatalities, and Pilot Ratings.*

			PILOT RATING (%)							
			EP	CP	P	AP	NONE	TP	UNS	TOTAL (CASES)
Incident outcome	Unhurt		3	32	35	14	-	1	14	432
	Unknown		-	32	27	6	-	-	35	156
	Injuries	Unspecified severity	-	40	-	20	-	-	40	10
		Minor	7	45	24	7	1	1	16	373
		Major	4.9	49	25	7	-	0.1	14	754
	Fatalities		7	48	22	7	2	-	16	46
Total			5	42	27	9	-	1	16	1771

* Pilot Ratings: EP: Elementary pilot; CP: Club Pilot; P: Pilot; AP: Advanced Pilot; TP: Tandem Passenger; Uns: Unspecified). Aggregate of paragliding, hang gliding, powered paragliding and powered hang gliding.

Table II. Consequences of Incidents in Different Sports.

SPORTS	NUMBER OF INCIDENTS	INCIDENTS RESULTING IN INJURIES % (*N*)	INCIDENTS WITH UNHURT PARTICIPANTS % (*N*)	UNKNOWN OUTCOME % (*N*)	INCIDENTS RESULTING IN FATALITIES % (*N*)
Hang gliding	316	65.5 (207)	20.2(64)	11.7 (37)	2.5 (8)
Paragliding	1244	68.3 (850)	22.6 (281)	6.5 (81)	2.5 (32)
Parascending	38	65.7 (25)	34.2 (13)	-	-
Powered hang gliding	24	41.7 (10)	29.2 (7)	25 (6)	4.1 (1)
Powered paragliding	60	38.3 (23)	48.3 (29)	8.3 (5)	5 (3)
Speedflying	7	85.7 (6)	-	-	14.3 (1)
Other/Unknown	70	12.9 (9)	47.1 (33)	38.6 (27)	1.4 (1)
Total	1759	64.2 (1130)	24.3 (427)	8.8 (156)	2.6 (46)

were more often located in the lower thoracic or upper lumbar regions, may be due to the pilot seating position. Pilot positions for hang gliding and paragliding are the same as for previous studies. These results reinforce the importance of spine protector systems and shock absorbing footwear to protect the spine in paragliding and the use of protective gloves in hang gliding.[27] Injury patterns for upper and lower limbs in the motorized sports were markedly different from those found in paragliding and hang gliding, confirming what has been reported in works already published.[7,8]

In hang gliding, upper limbs are the most common body region affected by injuries, while in powered hang gliding the head is most commonly injured. However, in powered paragliding the upper limbs, in particular wrists and hands, were more frequently injured. This may be due to the position of the engine (see also https://www.bhpa.co.uk/sport/power/paramotor/),[4] which potentially exposes the upper limbs to a risk of propeller contact.[7] The difference between powered hang gliding and powered paragliding might be explained by the fact that the propeller in powered hang gliding is installed on the bottom of the frame, far from the pilot body (See also https://www.bhpa.co.uk/sport/power/powered_hang_glider/).[4] Results from this study suggest support for general safety approaches that could be recommended. In particular, the use of protective gloves, in order to protect the hands against injuries in hang gliding and powered hang gliding and the use of a protective shroud (safety ring) to the engine cage for reducing severe injuries (such as the amputation of the fingers).[7]

In our study, concussion accounted for 5.2% ($N = 21$) of all injuries in hang gliding and for 1% in paragliding. These rates are less than half those reported in previous studies: 11.5%[19] and 2.2–2.5%[17,33] in the two sports, respectively. This reduction in the proportion of concussions is reflected in both paragliding and hang gliding. These results could reflect the mandatory requirement for helmets to be used by all participants in these sports. Also insurance provided by BHPA to participants is only valid if pilots wear a safety helmet while flying.[4] However, the application of safety regulations in foot-launched flying sports might be difficult to actuate. Typically, in many extreme sports, there are no regulations requiring protective gears and athletes show a certain hostility in following safety rules.

This study found that fatal outcomes accounted for 2.5% of both hang gliding and paragliding incidents. Previous studies reported that fatality outcomes accounted for 3.5%[10] of hang gliding incidents and between 0.69% and 6.1% (0.69%,[26] 0.9%,[17] 1.16%,[28] and 6.1%[30]) of paragliding incidents. In the two motorized sports, the fatality rate and the percentage of incidents resulting in fatalities (Table II) are higher than in non-motorized

Table III. Relationship Between Wind Speed* and Incident Outcome in Different Sports.

			INCIDENTS OUTCOME				
SPORT	WIND SPEED	TOTAL NUMBER	FATAL (%)	MAJOR INJURIES (%)	MINOR INJURIES (%)	UNHURT (%)	UNSPECIFIED (%)
Paragliding	Low	940	1.3	48.6	22.6	21.4	5.8
	High	215	4.1	49.7	17.6	21.3	6.9
Hang gliding	Low	201	1.9	40.7	26.8	19.9	10.4
	High	96	2.0	47.9	18.7	18.7	12.5
Powered paragliding	Low	46	-	30.4	10.8	54.3	4.3
	High	3	33.3	-	66.6	-	-
Powered hang gliding	Low	20	5.0	15.0	20.0	30.0	30.0
	High	1	-	-	100	-	-
Speedflying	Low	1	-	100	-	-	-
	High	6	16.7	50	33.3	-	-
Parascending	Low	30	-	20	36.6	43.3	-
	High	7	-	42.8	57.1	-	-
Other/unspecified		70	1.4	8.5	4.2	47.1	38.5

* Wind speed: Low: mean value ≤ 0–24 km/h; High: mean value > 24 km/h. The values partially overlap because the source data was expressed as speed ranges. Wind speed was unspecified in 19 hang gliding incidents, in 89 paragliding incidents, in 1 parascending incident, in 3 powered hang gliding incidents and in 11 powered paragliding incidents. When considering the whole sample, the percentage of incidents resulting in fatalities and major injuries was higher with high wind speed, while the percentage of incidents resulting in minor injuries and with unhurt pilot was higher with low wind speed (χ^2, $P = 0.028$).

Table IV. Anatomic Distribution and Description of 1411 Injuries.

BODY REGION (TOTAL; %)	BODY PART (*N*)	DESCRIPTION OF INJURIES (N)
Head/Neck (118; 8.4)	Head (50)	Concussion (40)
	Face (28)	Fracture [17, of which: skull (3), cheekbone (4) nose (2) teeth (6), cervical spine (2)]
	Eye (6)	Soft tissue injuries* (50)
	Neck (17)	Muscle strain, torn ligament/tendon (8). Minor not specified (3)
	Not specified (3)	
Upper Limb (341; 24.2)	Shoulder (75)	Dislocation [46, of which: shoulder (35), elbow (11), wrist (1)]
	Arm (84)	Fracture and dislocation (5, of which: shoulder (2), elbow (1), hand (2))
	Elbow (38)	Fracture [171, of which: shoulder (17), humerus (60), wrist (50), elbow (15), forearm (9) hand (20, including two amputations due to contact with propeller in PPG)]
	Forearm (9)	Sprain [11, of which: shoulder (10), elbow (1)]
	Wrist (60)	Soft tissue injuries* (46)
	Hand (30)	Burns (4). Muscle strain/torn ligament/tendon (9)
	Not specified (45)	Damaged nerve (2 including a palsy radial and a medial nerve injury)
		Unspecified (47): major (35); minor (10); unclassified (2)
Lower Limb (453; 32.1%)	Hip (4)	Fracture [220, of which: hip (2), femur (15), knee (7), leg (99), ankle (65), feet (32, including 14 heel fractures)]
	Thigh (22)	Dislocation [18, of which: knee (6, one resulting in meniscus torn), ankle (9), foot (3)). Sprain (61, of which knee (12), ankle (49)]
	Knee (54)	Soft tissue injuries* (63)
	Leg (135)	Muscle strain/torn ligament/tendon [23, of which: thigh (2), knee (12), leg (6), ankle (3)]
	Ankle (134)	Unspecified [68; of which: major (45); minor (18), unclassified (5)]
	Feet (41)	
	Not specified (63)	
Back (222; 15.7)	Spine (139)	Spinal fracture (138). Spinal dislocation (1)
	Soft tissues (42)	Soft tissue injuries* (25)
	Not specified (41)	Muscle strain (11). Burns (1)
		Not specified [46, of which major (31), minor (10)]
Thorax (112;7.9)	Chest wall (95)	Fracture [84, of which: rib (59), clavicle (17), sternum (4), scapula (4)]
	Lung (16)	Soft tissue injuries* (10)
	Not specified (1)	Pneumothorax (14). Lung contusion/bruising (2)
		Muscle strain (1). Minor not specified (1)
Pelvic Region (52; 3.7)	Bony pelvis (36)	Fracture (36)
	Soft tissues (8)	Bruising (7); damaged nerve (1)
	Not specified (8)	Not specified [8, of which: major (6), minor (2)]
Unspecified (79; 5.6)		Bruising (19), cuts (5), fracture (3), muscle strain (3), grazes (1), major not specified (34), minor not specified (13) nerve damage (1)
Abdomen (12; 0.9)	Internal injuries (7)	Bladder rupture (2). Liver rupture (2). Spleen rupture (1).
	Wall of the abdomen (5)	Kidney rupture (1)
		Bruising (5). Electrical burns (1)
Generalized (5; 0.4)		Near drowning (1). Psychological shock (2). Contusions (1). Bruising (1)

* Namely: contusions, bruising, lacerations, cuts.

hang gliding and paragliding; this possibly results from the higher impact energy due to the engine thrust and equipment weight which may aggravate the dynamics of trauma.[7] Injuries in powered paragliding and powered hang gliding are less common but more severe than paragliding and hang gliding. This observation suggests benefit in measures to cushion the high-energy impact in case of incidents. The particular characteristics of impacts in the motorized disciplines also point to the need for more research on the biomechanics of traumatic brain injuries. Powered paragliding is widely believed to be safer than paragliding, as reported on the internet site of the major flight associations (BHPA, USPPA). However, our analysis showed a lower injury rate, but a higher percentage of fatal incidents in powered paragliding; we found that of 5.8% of powered paragliding incidents were fatal, which is just slightly lower than that of 6% as was previously found in this sport.[7]

The small amount of available data about parascending and speed flying was such that only limited analysis was possible. Parascending recorded 40% ($N = 10$) of major injuries, while speed flying presented the worse incident outcome compared to other disciplines when considering the higher percentage of incidents resulting in injuries and fatalities (Table II). Speed flying may be considered a subdiscipline of paragliding which involves fast riding in close proximity to steep ropes, with incidents that often result in severe injuries. Speed flying, however, has experienced a dramatic increase in popularity over the last years, and new air foils continue to be developed. This evolution might affect the homogeneity of the dataset: this was not an issue in the other foot-launched flying disciplines as the equipment had not evolved considerably over the period covered by this study. Nevertheless, we cannot entirely rule out the possibility of other selection processes influencing these data.

Finally, we compared foot-launched flying annual fatality rate (43.9/100,000 participants) with other extreme sports and we found an intermediate value between skydiving (28/100,000)[31] and BASE jumping (900/100,000).[3,9]

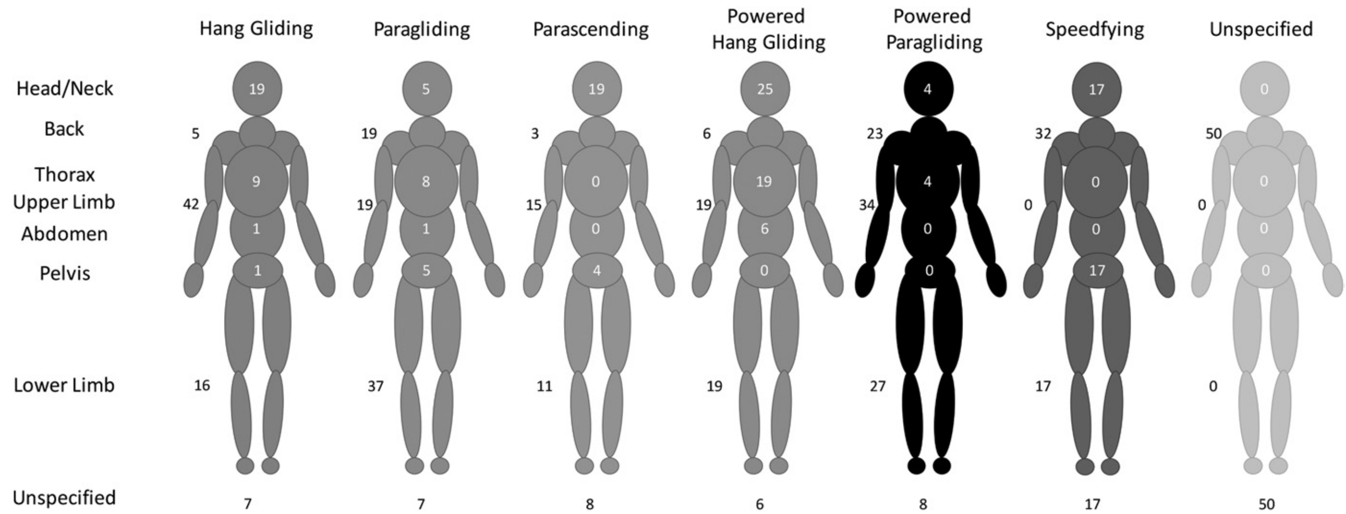


Fig. 4. Percentage of injuries occurring to different body parts in each sport.

Since formal training programs seem to be effective preventive measures, our epidemiological data are not necessarily generalizable to foot-launched flying as a whole, but they reasonably represent the lower boundary that can be achieved in other countries adopting similar training programs.

The self-reported nature of the data is a major limitation of this study. Self-reported injuries are prone to recall bias, potentially leading to incorrect conclusions about epidemiology. Self-reporting is also influenced by a range of other factors, including secondary gain perceptions of the reporter (related, for instance to the possibility of compensation from insurance funding). The bias, however, is expected to be limited, given the lack of any gain in reporting injuries with an increased severity.

Another limit of the study is the reporting of data by non-medical personnel, however the establishment of a different system to collect medical data in these sports is particularly problematic due to the large number of intermittent participants, their practice in many different locations, and only in specific weather conditions. Finally, despite the fact that it is a legal requirement, and also a duty for BHPA members, to report air incidents we cannot completely exclude the existence of unreported incidents or fatalities.

In conclusion, this research reviews the incidence and patterns of injuries suffered by pilots and passengers engaging in several different foot-launched flying sports. Differences were observed in the injury rates and injury distribution between the different sports. Those differences may be useful for steering future safety research and to allow participants and governing bodies to develop relevant sport-specific safety policies concerning training, flying techniques, protective clothing, aircraft design, and other safety systems. Many of these suggestions, for example the use of protective helmets or propeller shrouds, are already well established in other areas of aviation safety. While that may be true, many of the participants in these extreme sports do not have a prior aviation background and are in-part attracted to the thrill-seeking aspects of those sports. This results in a delicate balance between safety efforts, thrills, and the very real dangers. On the one hand, safety measures are desirable to prevent injury and death, yet on the other hand those very measures may be perceived to reduce the attractiveness of the activity to participants. By understanding the sport-specific injury rates and patterns it may be possible for participants and governing bodies to steer safety efforts where the greatest community benefit can be achieved, without unnecessarily undermining the attraction of the extreme sports.

ACKNOWLEDGMENTS

We would like to thank the British Hang Gliding & Paragliding Association (BHPA) for providing the data and permission to use the data for the study.

Authors and affiliations: Francesco Feletti, M.D., Local Health Authority of Romagna, Department of Diagnostic Imaging, S. Maria delle Croci Hospital, Ravenna, Italy; Francesco Feletti, M.D., and Andrea Aliverti, Ph.D., Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milan, Italy; Maggie Henjum, PT, DPT, OCS, FAAOMPT, Motion, St. Paul, MN, and University of Minnesota, Minneapolis, MN; Marco Tarabini, Ph.D., Department of Mechanical Enginering, Politecnico di Milano, Lecco, Italy; and Eric Brymer, Ph.D., Institute of Sport Physical Activity and Leisure, Leeds Beckett University, UK.

REFERENCES

1. American Sports Data. Generation Y" drives increasingly popular "extreme" sports. Sector Analysis Report. Available from: http://archive.li/Xozvj. [Accessed on November 2002].
2. Brymer E, Schweitzer R. Phenomenology and the extreme sports experience. London (UK): Routledge; 2017.
3. BASE Fatality List-BLiNC Magazine. Available from: http://www.blincmagazine.com/forum/wiki/Fatality_Statistics [Accessed on January 2016].
4. British Hang Gliding & Paragliding Association. Available from https://contact.bhpa.co.uk/incident.php [Accessed on December 2015].
5. Canbek U, İmerci A, Akgün U, Yeşil M, Aydin A, Balci Y. Characteristics of injuries caused by paragliding accidents: a cross-sectional study. World J Emerg Med. 2015; 6(3):221–224.

6. Clough P, Houge Mackenzie S, Mallabon L, Brymer E. Adventurous physical activity environments: a mainstream intervention for mental health. Sports Med. 2016; 46(7):963–968.
7. Feletti F, Goin J. Accidents and injuries related to powered paragliding: a cross-sectional study. BMJ Open 2014; 4:e005508.
8. Feletti F, Goin J, Rekand T. Foot launched flying injuries. In: Feletti F, editor. Extreme Sports Medicine. Springer; 2016:209–220.
9. Feletti F, Westman A, Mei Dan O. BASE jumping and wingsuit flying injuries. In: Feletti F, editor. Extreme Sports Medicine. Berlin (Germany): Springer; 2016:235–240.
10. Foray J, Abrassart S, Femmy T, Aldilli M. Hang gliding accidents in high mountains. A propos of 200 cases. Chirurgie. 1991; 117:613–617.
11. Fountain JL, Meyers MC. Skateboarding injuries. Sports Med. 1996; 22(6):360–366.
12. French Free Flying Federation (Fédération Française de Vol Libre). Rapport 2011 sur les chiffres de l'accidentologie du parapente à la FFVL. Available from: http://federation.ffvl.fr/sites/ffvl.fr/files/accidentologie%20parapente%202011.pdf [Accessed on June 2016].
13. Goin J. Paramotor safety. foot flyer, educational excellence for aviators. Available from: http://www.footflyer.com [Accessed on March 2016].
14. Hasler RM, Hüttner HE, Keel MJB, Durrer B, Zimmermann H, et al. Spinal and pelvis injuries in airborne sports: a retrospective analysis from a major Swiss Trauma Centre. Injury. 2012; 43:440–445.
15. Howe S. Sick: a cultural history of snowboarding. New York (NY): St. Martin's Press, 1998:ix.
16. Katoh S, Shingu H, Ikata T, Iwatsubo E. Sports related spinal cord injury in Japan (from the nationwide spinal cord injury registry between 1990 and 1992). Spinal Cord. 1996; 34(7):416–421.
17. Krüger-Franke M, Siebert CH, Pförringer W. Paragliding injuries. Br J Sports Med. 1991; 25:98–101.
18. Lustenberger T, Talving P, Barmparas G, Schnüriger B, Lam L, et al. Skateboard-related injuries: not to be taken lightly. A National Trauma Databank Analysis. J Trauma. 2010; 69:924–927.
19. Margreiter R, Lugger LJ. Hang gliding accidents. BMJ. 1978; 1(6110): 400–402.
20. Mettler R, Biener K. Athletic injuries in windsurfing. Schweiz Z Sportmed. 1991; 39(4):161–166.
21. Nathanson AT, Reinert SE. Windsurfing injuries: results of a paper- and Internet-based survey. Wild Env Med 199; 10(4):218–225.
22. Olivier S. Moral dilemmas of participation in dangerous leisure activities. Leisure Studies. 2006; 25(1):95–109.
23. Ostrowski J. Corporate America makes pitchmen of pariahs. Street & Smith's Sports Business Journal. 2002; 19:26.
24. Pain MTG, Pain MA. Essay: Risk taking in sport. Lancet. 2005; 366(1): S33–34.
25. Puchan H. Living 'extreme': Adventure sports, media and commercialisation. Journal of Communication Management. 2005; 9(2): 171–178.
26. Rekand T, Schaanning EE, Varga V, Schattel U, Gronning M. Spinal cord injuries among paragliders in Norway. Spinal Cord. 2008; 46(6): 412–416.
27. Rekand T. The epidemiology of injury in hang gliding and paragliding. Med Sport Sci. 2012; 58:44–56.
28. Schmitt H, Gerner HJ. Paralysis from sport and diving accidents. Clin J Sport Med. 2001; 11(1):17–22.
29. Schofield J. BHPA, Elementary Pilot Training Guide. Version 2.2. Available from: http://www.bhpa.co.uk/pdf/BHPAEPTrainingGuide.pdf [Accessed on February 2016].
30. Schulze W, Richter J, Schulze B, Esenwein SA, Büttner-Janz K. Injury prophylaxis in paragliding. Br J Sports Med. 2002; 36:365–369.
31. Westman A, Bjornstig U. Fatalities in Swedish skydiving. Accid Anal Prev. 2005; 37(6):1040–1048.
32. Westman A, Bjornstig U. Injuries in Swedish skydiving. Br J Sports Med. 2007; 41(6):356–364.
33. Zeller T, Billing A, Lob G. Injuries in paragliding. Int Orthop. 1992; 16:255–259.