Foot-Launched Flying Injuries

17

Hang Gliding, Paragliding, Powered Paragliding, and Powered Hang Gliding

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17.1 Introduction

The term *foot-launched flying* covers different sports, including hang gliding, paragliding, powered paragliding and powered hang gliding. The pilot flies using a paraglider or a hang glider with or without a mechanical propulsion device, launched and landed on foot with no landing undercarriage, wheels, skids or floats attached. The medical literature on injuries in these sports is scarce and fragmented, and these activities are often generically grouped together despite their differences in types of flight, equipment and conditions of practice. Instead, these sports should probably be considered as sharply distinct due to their different injury dynamics and patterns [1].

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17.2 Hang Gliding

Hang gliding is the original form of foot-launched flight. The sport has developed since its inception in the 1970s, and today hang gliders are constructed from aluminum alloy, carbon-fiber and high-tech sail fabrics. Modern equipment allows the pilot to cover hundreds of kilometers and to stay aloft for hours at a time. Lifting currents of air allow hang gliders to stay airborne, and pilots usually launch from hills facing into wind running to accelerate to flying speed. In flatlands, hang gliders can be towed aloft behind a microlight aircraft or by a land-based motorized winch (Fig. 17.1). During their flight, pilots are suspended from the glider by a special prone harness, and they control the glider by moving their weight in relation to the control bar. Flying a hang glider is a little more difficult to learn than flying a paraglider and somewhat more demanding, but hang gliders can reach much higher speeds, achieve better gliding performance, and can fly in stronger winds [2]. Although it is possible to perform acrobatics, the vast majority of pilots prefer soaring. Hang gliding competitions are held at national and international levels, and hang gliding is one of the competition categories in the World Air Games organized by the Fédération Aéronautique Internationale (FAI) which maintains the chronology of the FAI World Hang Gliding Championships [3].

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Fig. 17.1 Hang gliding: landing in Florida Ridge, Miami, Florida, USA

17.2.1 Causes of Injuries and Fatalities

Multiple reasons can lead to unsuccessful hang gliding flights resulting in injuries and even fatalities. These include insufficient training and incorrect use of technical equipment as well as misjudgment of weather conditions [12, 13, 15]. In particular, gusty or strong wind conditions have been reported as a determining or contributing cause of incidents in several studies [1, 4, 12, 13, 15, 16]. Given that the aim of the sport is to stay aloft in rising air, launching in the presence of thermal activity is common. Thermals moving at ground level can manifest as gusts, changing the intensity or the direction of the wind both laterally and vertically. Since hang gliders generally land at about 15 mph, a change in wind speed of around 10 mph may be enough to destabilize their flight. Additionally, nearly all hang gliders employ weight shift as their primary control method, where body movement causes changes in pitch (nose up/down) and roll, and strong gusts of wind can easily interfere with this means of control.

Pilot skill plays an important role in safety, and expert pilots have much wider margins of safety in any given weather condition. However, skilled pilots frequently monopolize that margin by taking greater risks such as gliding in bad weather conditions or by using uncertified equipment that can lead to incidents [6]. This is probably why hang gliders with little experience most frequently sustain nonfatal injuries, while pilots with more than 200 flights have a higher rate of fatal incidents [17].

Although equipment failures were uncommonly reported as a cause of incidents and generally did not result in serious events [4, 7–11], inadequate checking of equipment or planning of flights may cause fatal events [18]. The use of alcohol and drugs was also reported as a cause of incidents resulting in injuries or fatalities in some studies [6, 15, 19].

17.2.2 Dynamic of Injuries

Out of 127 hang gliding incidents reported by the United States Hang Gliding and Paragliding Association (USHPA) in the period between 2003 and 2013, 32.2 % (n = 41) occurred during takeoff, 36.2 % (n = 46) during landing, and 15.7 % (n = 20) in flight. Sixteen (12.6 %) towing launch incidents were also reported [11].

17.2.2.1 Takeoff

The most severe injuries are reported immediately after takeoff [4]. The majority of hang gliding takeoff incidents were attributed to insufficient airspeed. This situation can be determined by a launch run which is too brief or too slow causing pushing out or failure to control pitch attitude and angle-of-attack during the launch run [7]. Crosswinds, turbulence or gusty winds can also cause incidents during takeoff. In towed launches, incidents can be due to early releases, releases with insufficient altitude/airspeed or incorrect attachments [7].

17.2.2.2 Flight

Reported in-flight incidents include falls due to turbulence and collisions with buildings, other aircraft or electrical wires [12–14].

17.2.2.3 Landing

The most frequent injuries are reported as a result of landing problems, particularly uncontrolled landings after stalling and landings on hostile ground [5, 6]. Incidents in the landing phase can be caused by uncontrolled contact with the ground while maneuvering to land. This can happen with modern high performance gliders in particular because they tend to accelerate quickly and can rapidly develop high sink rates during un-coordinated turns [11]. Obstacles in the landing zone can contribute to incidents. Precise piloting is paramount on approach. Even minor contact of one wing with an obstruction such as a tree can result in loss of airspeed and rapid yaw, pitch and roll with insufficient altitude for recovery.

17.2.3 Injuries and Fatalities

The extent and severity of reported injuries range from skin lacerations to permanent neurological findings following injuries to the brain or spinal cord. Multiple injuries are common in hang gliding incidents and are reported in most studies [6]. The pilot is suspended from the glider by the harness in a prone position meaning that the head, the upper extremities and the trunk are in a fixed position and prone to injuries. Head injuries are reported as occurring in up to 23 % of cases in the cross-sectional studies and up to 27 % in case series [6]. According to the same reports, the frequency of trunk, spine or spinal cord injuries is between 1 and 34 %, and that of upper extremity injuries is up to 80 % while injuries to the lower extremities is up to 43 % of cases [6]. Some cases of burn injuries related to hang gliding into electrical wires have also been described [6, 14]. The reported fatalities were due to many causes: polytrauma, heart laceration, aorta rupture, pulmonary collapse, skull fractures with brain damage, retroperitoneal hemorrhage and thoracic and cervical spinal cord injury [6, 12, 17, 18]. In their study on fatal aviation incidents, Ast et al. [19] also reported two hang gliding crashes caused by pilot error or loss of aircraft control as a consequence of heart failure. Both cases were attributed to preexisting severe stenosing coronary sclerosis.

17.3 Paragliding

Paragliding is an aerial sport where the pilot flies a modified parachute called a paraglider wing (Fig. 17.2). Paraglider wings derived from skydiving canopies in the 1960s and still have the same fabric cell structure inflated by the wind. They are however not designed to tolerate the terminal velocity opening shock that sport parachutes are required to handle. While parachutes are required to be stronger and employ a staged opening to spread the opening shock (a deceleration from about 120 mph to less than 15 mph in just a few seconds), paraglider wings are designed to stay open and to reopen immediately in case of a wing fold or collapse. Indeed, the wing can fold in various ways, especially when flying in turbulence, usually causing a turn. Although the same phenomenon can affect skydiving canopies, the level of turbulence required is much greater, making it an extremely rare event.

In paragliding, the pilot is suspended from the wing by a network of suspension lines connected to a harness offering support in both the standing and sitting positions. Paragliding requires a slope in order to take off. The wing is inflated by an airstream either from an existing wind or one created by running. Launching is also possible by tow. The pilot uses hand controls called "brakes" connected to the trailing edge of both sides of the wing to adjust speed, steer, and flare during

Fig. 17.2 Red Bull athlete photo shoot with Honza Rejmanek training for the 2011 X-Alps competition in Salt Lake City, Utah. (Photo courtesy of Red Bull Content Pool/Michael Clark)

landing. The wing can also be steered by pilots shifting their weight. An additional foot control called the *speed bar* or *accelerator* attached to the paragliding harness and connected to the leading edge of the wing allows the pilot to increase speed by decreasing the wing's angle of attack. The vast majority of pilots use efficient types of specific wings for soaring. These exploit the rising air from thermals or lifted air over geographic obstructions such as ridges and mountains.

Different wing types are available, depending on their intended use. Special smaller wings (*mini-wings* and *speed-wings*) with more responsive handling and capable of higher speeds have recently been developed (Fig. 17.3) and are used in various disciplines including *speed riding* and *speed flying*. In *speed flying*, a wing about half the size of an average paraglider wing is used to fly in close proximity to a steep slope, generally in strong winds, while *speed riding* (or *ski gliding*) is a winter specialty practiced using skis.

17.3.1 Causes of Injury Events

According to the data collected by the German Paragliding Association, pilot carelessness, lack of experience, changes in wind conditions, and technical failure emerged as the main reasons for incidents from a detailed analysis performed by Schulze et al. [20] on 409 paragliding incidents (Fig. 17.4).

Alpine areas were at higher risk of incidents because of environmental dangers such as tight landing zones, strong valley winds and turbulent thermal conditions, while flights in lowland areas were significantly less dangerous [20].

Beginners and recreational pilots with less than 100 flights were most prone to incidents [20].

17.3.2 Dynamics of Injury Events

The most common dynamic causing approximately one third of incidents is glider collapse or deflation (Fig. 17.5) often occurring following turbulence or gusts of wind. When the pilot is unable to recover from this dynamic, the result is a collision with the ground or with an obstacle [20, 21].

Incidents can occur in every phase of flight, but the most frequent incident types occur on landing. In a retrospective study by Zeller et al. on 376 non-fatal paragliding incidents, 48.7 % occurred during landing, 35.1 % during takeoff, and 16.2 % during flight [21].

17.3.2.1 Takeoff

During takeoff, pilots usually sustain low-energy trauma to the ankle and the upper extremities caused by falls during the fast run downhill

Fig. 17.3 Steve Mayer flying an early speed-wing at Point of the Mountain, Salt Lake City, Utah, USA

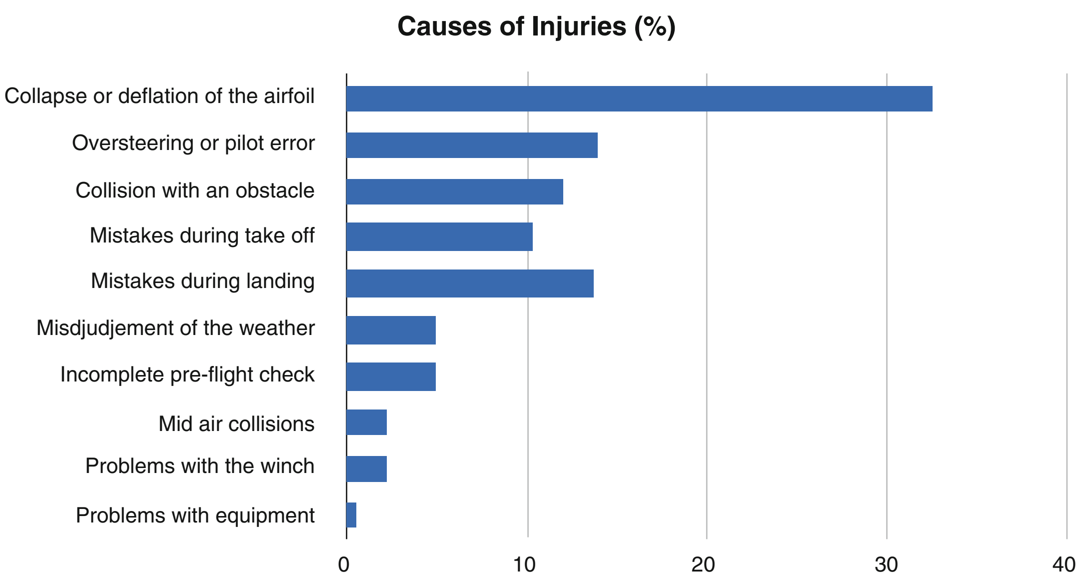

Fig. 17.4 Causes of paragliding incidents [20]

required to inflate the wing. Major spinal injuries reported during takeoff were due to an overestimation of wing lift causing the pilot to sit back too early resulting in slamming the buttocks on the ground [21].

Other less common causes of incidents were due to problems with the winch in towed launches. In these cases, injuries were generally caused by backlash from breakage of the towing cord. An incomplete pre-flight check can also

Fig. 17.5 Asymmetrical collapse. In the series by Schulze et al., an asymmetrical collapse (85.1 %) was a more common cause of incidents than a frontal collapse (15.9 %) [20]

cause incidents. Four fatal events reported by Schulze et al. were caused by failure of pilots to fasten the leg loops causing them to fall out on takeoff. Another incident dynamic was taking off with tangled or knotted lines [20].

17.3.2.2 Flight

During flights, a stall or collapse of the canopy (usually as a consequence of turbulence) can cause crashes from a great height leading to multiple injuries including fractures to the spine, pelvis and lower extremities. One highly dangerous situation involves the tips of the paraglider becoming entangled in its own lines following a full or partial stall resulting in spinning. This situation normally occurs almost exclusively among sport class, high-performance or competitive paragliders (categories 2 and 3 as per the quality categories used by the German Paragliding Association, the ACFPULS – Association des Constructeurs Français de Planeurs Ultra-Légers Souples/French Designing Engineers Association of Microlight Planes and the SHV – Schweiserischer Hängegleiterverband/Swiss Paragliding Association) [20]. Mid-air collisions with other paragliders or hang gliders are possible but rare events (2.2 %; $n=9$) [20].

17.3.2.3 Landing

Mistakes during landing include landing with a tailwind, incorrect approach (too high or too low), fast curves close to the ground, and sudden, erroneous correction of direction [20]. In 13.9 % ($n=57$) of the cases reported by Schulze et al. [20], incidents happened as a result of oversteering or pilot error which is most often a consequence of incorrect break-line handling during high-speed descent maneuvers including B-line stall, parachute flight, *big ears* or steep spirals [20]. Major injuries during landing are generally the result of an excessively rapid descent due to turbulence or pilot error [21]. This phase requires pilots to stall their paraglider wing just above the ground and may result in a hard landing if performed too early. During landing, legs bend and absorb part of the impact. Landing with straight legs may cause varying degrees of injury. Mistakes during landing most often occur in hostile environmental conditions such as restricted or difficult landing areas, particularly those with strong winds or strong thermal activity. Collisions with obstacles on land, especially during landing, such as trees (78 %) but also buildings and vehicles represented 12 % of incidents ($n=49$) [20]. Even more dangerous, although rare (6 %), are crashes into cable cars or into electrical lines which may cause burn injuries [6, 20].

17.3.2.4 Emergency Parachute Deployment

Schulze et al. [20] also reported 39 cases in which emergency parachutes were used. Among these, there were ten cases of serious injuries and three fatalities. One pilot died due to the impossibility of opening the parachute due to having secured the deployment mechanism too tightly, and two pilots died after deploying their emergency parachutes too close to the ground. Emergency parachute deployment was followed by injuries in some instances. In three cases, the emergency parachute was too small. In two cases, the emergency parachute did not open completely or wrapped itself around the glider. In two cases, the emergency parachute was deployed at too low an altitude in order to open quickly enough to function adequately. Finally, in one case, the pilot hit the ground in an unfortunate position due to the extreme oscillation of the emergency parachute. Two pilots were injured by landing on rocky ground.

17.3.3 Injuries

The injuries sustained in paragliding tend to affect different parts of the body in comparison with those sustained in hang gliding. Due to their sitting position, paragliding pilots are more susceptible to lower limb and lower back injuries. Lower limb injuries represent up to 47 % of the total [6, 21, 23] and injuries to the spine and spinal cord are reported in up to 45 % of injured athletes [24]. Multiple injuries are common in paragliding, and a concurrence of lower limb and lower back fractures is a characteristic result [6, 26].

In their analysis of paragliding incidents in remote areas, Fashing et al. [30] found that fractures represented 84 % ($n = 32$) of lower extremity injuries. According to Zeller et al., 80.5 % ($n = 178$) of lower limb injuries were to the lower leg including 120 fractures or ligament injuries to the ankle. Meniscal and ligament injuries of the knee represented 15.3 % ($n = 34$) [23]. The pathogenetic mechanism of ankle injuries involves a combination of compression and rotational forces due to a forced pronosupination movement of the joint [33].

Analysis by Schmitt and Gerner [22] of all sport injuries causing paraplegia or tetraplegia found that paragliding causes more spinal injuries than many other sports. Hasler et.al. as well as many other studies on paragliding injuries [20–22, 24, 28] found a high occurrence of spinal injuries, particularly vertebral body compression fractures (type A, according to the comprehensive classification of thoracic and lumbar injuries by Magerl et al. [27]). Spinal fractures (Fig. 17.6a, b) may occur at any level, but are more often located in the lower thoracic or upper lumbar regions since the pilot is in a seated position, and the energy which causes such injuries is mainly distributed to the thoracolumbar junction [21, 24, 28]. In particular, L1 and Th12 are involved in 25.2 % and 18.5 % of the vertebral fractures respectively (in a series of 119 athletes) according to Zeller et al. [21].

Among the airborne injuries studied by Hasler et al., spinopelvic dissociations were found in the subgroup of paragliders only with a 21 -times greater odds ratio than in the general trauma population [25]. Flexion (type 1 and 2) and extension (type 3) (Fig. 17.7) spino-

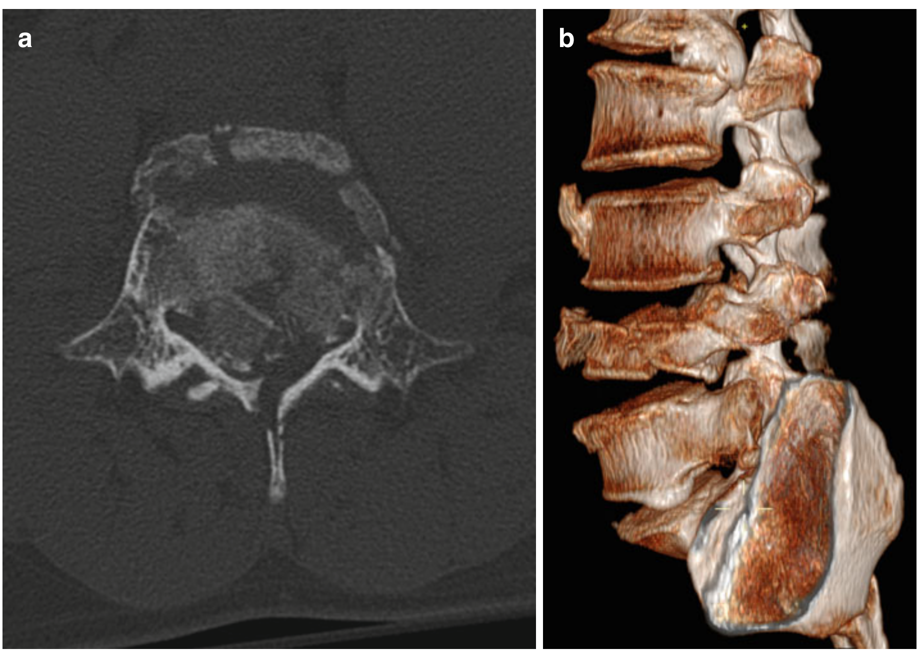

Fig. 17.6 L4 burst fracture in a 47-year-old paraglider resulting from a landing on the buttocks without any kind of back protection following deflation of the wing during approach. (**a**) CT axial scan of L4. (**b**) Volume-rendering 3D reconstruction

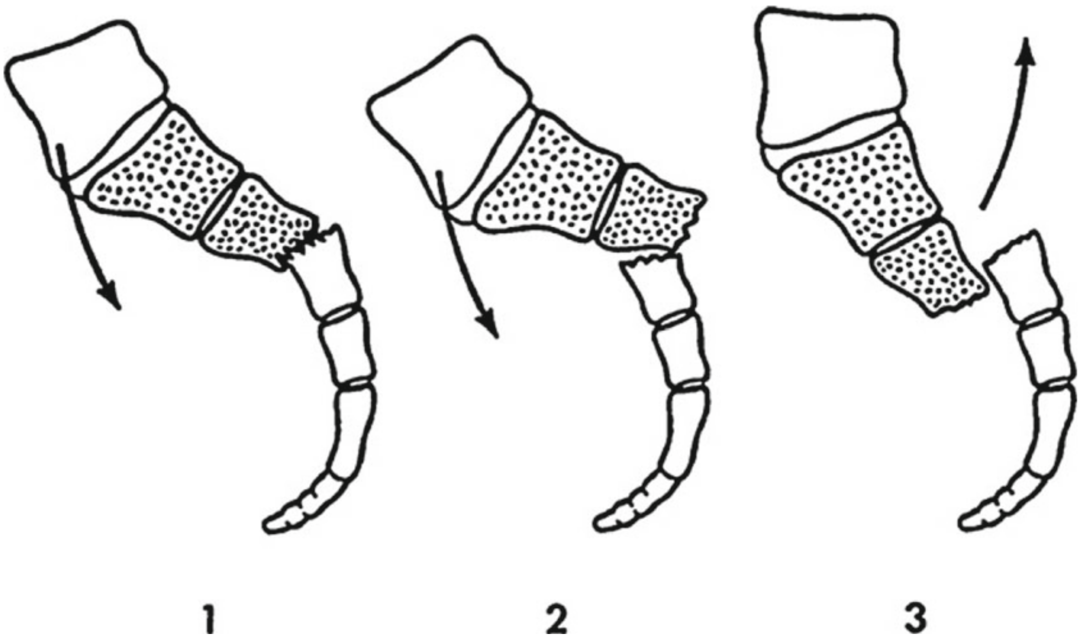

Fig. 17.7 Roy-Camille classification of spinopelvic dissociations (also called suicidal jumper's fracture, or U-shaped sacral fractures) [20, 29]: type 1, flexion fracture; type 2, flexion with displacement of the distal sacral fragment anterior to the proximal tract; type 3, extension fracture with posterior displacement of the distal sacral fragment (Image reproduced with permission from Hasler et al. [25])

pelvic dissociation fractures were equally represented, but the rate of the latter was higher in paragliding than in the general trauma population. Type 1 and 2 spinopelvic dissociations (Fig. 17.7) may be a consequence of the position assumed spontaneously as unintentional means of protection during paragliding landing, whereas type 3 injuries may occur when, during landing, the inertia of the axially and horizontally moved mass of the torso forces the lumbar spine into lordosis, adding horizontal force vectors to the impact.

Head injuries, although less common in paragliders than in hang gliders, have nevertheless been reported in a number of studies [21, 24, 30]. The reported head injuries included concussions, brain contusions and major brain damage as well as minor injuries such as soft tissue trauma, nose fractures and loss of teeth [23, 24]. Although upper extremity injuries are mostly rebound injuries after colliding with the ground, dislocation of the shoulder is also common as a consequence of the particular movement performed when pulling up the sail [23].

17.3.4 Injury Outcome and Protection

Injury outcomes vary from complete recovery to permanent injury of the nervous system to fatality as the worst-case scenario. There are few studies showing long-term outcomes of paragliding injuries, but cases resulting in disability are reported in all series. Paraplegia along with other neurological deficits has been reported in several studies [20, 22, 24, 28]. Persistent neurological impairment is a common consequence of spinopelvic dissociation. Nerve roots below L5 may be strained, compressed by fracture fragments, or completely disrupted, sometimes leading to permanent loss of bowel and/or bladder control [25]. Fatal cases have been reported as a consequence of severe head and cervical spinal cord injuries.

While the number of paragliding participants has increased, the total rate of injuries has decreased over time [31]. This decline may be explained by better training, improvement of equipment, and the protective measures adopted by pilots. In Germany and Austria, for example, following introduction of a new spine protector system, the number of vertebral fractures decreased significantly between 2000 and 2003 [31]. A number of safety measures are now widely adopted by paragliders; the use of shock-absorbing footwear which protects the ankle has become standard while helmets are a legal requirement almost everywhere [20]. Education has focused on pitfalls in flight planning, and most lower extremity injuries could be avoided by responsible flight conduct. Qualified instruction, regular training, and equipment development based on data from well-conducted scientific studies on injuries will help to further improve safety in paragliding. Better understanding of aerodynamics and landing techniques in particular may reduce the risk of paragliding incidents [28].

17.4 Powered Paragliding

Powered paragliding or paramotoring is a sport in which pilots fly using a paraglider wing wearing a motor on their back to take off (Fig. 17.7). The use of a motor frees pilots to fly with no need for thermals or wind and allows take off from flat areas (Fig. 17.8). To avoid a bumpy ride, paramotor pilots typically fly in the mornings and evenings when thermal turbulence is low. As early powered paragliders increased in efficiency, they eventually reached the point where the thrust required was minimal. While early versions may have required 30 horsepower to fly, current models can manage with as little as 10 horsepower.

17.4.1 Causes of Injury Events

A paramotor is flown very differently from a paraglider or a hang glider resulting in injury dynamics and patterns almost entirely distinct from each other. In a cross-sectional study on 384 incident reports gathered by the US Powered Paragliding Association from 1995 to 2012, the primary cause of incidents was attributed to pilot error alone in 53.5 % ($n = 205$) of cases, mechanical failure in 17.5 % ($n = 67$) of incidents, while weather conditions alone were responsible for incidents in just 5.7 % ($n = 22$) of cases [32]. The role of weather conditions, therefore, is lower than in paragliding [21]. Indeed, the thrust of the engine allows the paramotor pilot to take off and fly without the need for strong winds or thermals, hence in safer and more stable weather conditions.

At the same time, however, the versatility of the paramotor wing coupled with its ability to fly anywhere allows pilots to explore higher-risk areas such as those over water. Immersion in water is particularly feared among paramotor pilots because the weight of the engine can rapidly drag pilots under the surface giving them no time to free themselves from the equipment. Actually, 71.4 % of the powered paragliding incidents involving water immersion were fatal [32]. Paramotor flying also allows steep maneuvering low to the ground which produces its own set of incidents. Although free flyers (non-motorized hang-gliders and paragliders) often perform acrobatics, they tend to do so at higher altitudes. Since the engine allows pilots to recover height rapidly, some paramotor pilots perform steep flying close to the ground putting themselves at a higher risk. Steep spirals are particularly dangerous maneuvers in powered paragliding. The position of the pilot and the centrifugal acceleration increased by the thrust of the engine may reduce blood supply to the brain with the potential to cause a momentary state of mental confusion or even blackouts at a time when the maximum level of attention is required [33]. The engine itself can also be a direct cause of incidents. Contact with the propeller caused 11.22 % ($n = 43$) of incidents and was responsible for the majority of injuries to the upper limbs [32].

17.4.2 Dynamics of Injury Events

17.4.2.1 Takeoff

According to the previously mentioned series [32], takeoff was the most dangerous phase of flight in powered paragliding; 32.8 % ($n = 126$) of incidents occurred during this phase, a percentage which increases to 42.9 % if extended to include incidents during run-up ($n = 17$) and

Fig. 17.8 Tim Kaiser flying his paramotor in central Florida; cruising (**a**) and landing (**b**)

inflation ($n = 22$) which are considered integral parts of paramotor takeoff. On the other hand, both in paragliding and in hang gliding, landing is the most dangerous phase of flight. During powered paragliding takeoff, the motor exerts its thrust on the crew (suspended from the wing by means of long cables) and on the wing itself despite not being, however, directly connected to it. This makes takeoff a critical phase in powered paragliding since it requires balance between engine thrust, crew weight and lift of the wing. Another contributing factor is the modality of the takeoff itself. While paragliding requires a descent to take off resulting in a rapid increase in distance from the ground, a paramotor can take off from level ground thanks to the power of the engine allowing the powered paraglider pilot to move slowly away from the ground. As a consequence, the falling distance remains low for much longer during takeoff, limiting the possibility of adopting emergency maneuvers including use of an emergency parachute.

17.4.2.2 Flight

In the cross-sectional study recently published by the authors [32], 27.9 % ($n = 107$) of incidents occurred during cruising; in particular, falls during flight represented 9.7 % of incidents, and collision with other aircrafts/ultralights was reported as a cause of incidents in 3.6 % of cases.

17.4.2.3 Landing

In the aforementioned series [32], only 14 % ($n = 55$) of incidents occurred during and after landing, and hard landings represented 10.4 % of powered paragliding incidents.

17.4.3 Injuries

Powered paragliding injuries were found to have the following anatomical distribution: 44.5 % to the upper limbs ($n = 114$), 32 % to the lower limbs ($n = 82$), 9.7 % to the back ($n = 25$), 3.1 % ($n = 8$) to the pelvis, 7 % ($n = 18$) to the head, and 2.7 % ($n = 7$) to the chest [32]. The different distribution of injuries between the upper and lower limbs and the lesser involvement of the spine in powered paragliding than in paragliding is due in part to the different dynamics of the incidents discussed above, and in part to accidental contact with engine parts resulting in injuries specific to this sport [32]. Contact with the propeller caused the majority of injuries to the upper limbs, particularly deep wounds, fractures and fractures with amputation involving hands, wrists (Figs. 17.9 and 17.10), forearms, arms, and shoulders, while contact with hot engine parts was reported as the cause of burns to the face, neck, back, shoulder, arm, elbow, forearm, calf, thigh and ankle. Two cases of generalized burns were the result of a fire caused by combustion of the engine fuel.

In powered paragliding as opposed to paragliding, the thrust of the engine and the weight of the equipment must also be considered as elements with the potential to aggravate the dynamics of injury in case of an incident. High-speed impact injuries including a case of diffuse axonal injury have been documented in this sport, and drowning is a common consequence of water immersion due to the engine weight [32, 35]. Although powered paragliding is widely believed to be safer than paragliding (and fatalities considered to be rarer than in paragliding), 6 % ($n = 23$) of incidents in powered paragliding were found to be fatal [32], a figure that is comparable with 6.1 % of fatalities reported in paragliding by Schulze et al. [20].

Of the 23 fatal incidents reported in powered paragliding [32], death was caused by severe head trauma in four cases. Two were fatal due to cerebral spine fractures with spinal cord damage, and another five fatalities were the result of drowning following an involuntary landing in water. In one of these last cases, the autopsy revealed the cause of drowning to be head injury with hemorrhage and loss of consciousness. In all the remaining cases, death was the result of high-energy polytrauma.

17.4.4 Safety Equipment

Mounting a *safety ring* on the engine cage may help prevent injuries due to contact with the spinning prop. It consists of a ring of the same radius as the prop mounted just forward of the radial arms [32], and it is designed to make it difficult for the upper limbs to reach the prop. Made from aluminum, the *safety ring* is an inexpensive addition and adds very little to the equipment in terms of weight. An auto-inflating flotation device is an essential piece of safety equipment for pilots wishing to fly a paramotor over or near water. It is mounted on the paramotor frame and activated by a CO2 cartridge which fires on submersion with no pilot input required.

Although head injuries accounted for just 7 % of all injuries in our study, these can be potentially severe. Diffuse axonal injury may be a consequence of powered paragliding incidents even in cases where the pilot was wearing a helmet due to the fact that the effectiveness of the helmet may be limited by the direction and intensity of the deceleration [35]. Diffuse axonal injury is caused by angular accelerations and occurs as a consequence

Figs. 17.9 and 17.10 Serious lesions to the upper arms caused by contact with the engine prop; these injuries are specific to powered paragliding. Photo courtesy of US Powered Paragliding Association (USPPA) [34]

of lateral rather than frontal decelerations, while helmets decrease linear head accelerations with limited effects in side impact conditions. Similar results have emerged from helmet studies on skateboarding [36], and the possibility of a fall involving higher angular head accelerations should be considered in studies of protective headgear systems in powered paragliding as well as in other extreme sports. In the traditional motor sports field, new shell and liner materials with properties optimized to minimize head and brain loads in radial, tangential and oblique impacts are constantly being developed [37]. In all probability, the same technology should be applied to the production of helmets for powered paragliding in the future, but further research into the biomechanics of traumatic brain injuries in motorized, foot-launched flying sports is needed.

17.5 Powered Hang Gliding

Powered harnesses are powered units which can be attached to any hang glider with a rigid frame, usually a delta wing. They require significant skill due to the higher running speed involved in foot launching and landing and the resulting difficulty. They are not commonly used and are flown almost exclusively by experienced pilots. They are rarely used for training by inexperienced hang glider pilots (Fig. 17.11).

Hang glider trikes represent a distinct subtype of powered hang gliding. They are wheeled crafts that use a heavier, purpose-built hang glider wing. More commonly grouped together with ultralights or microlights, they are not dealt with here. Pilots learn on these just like other powered aircraft, and although there is some overlap, most are not former or current foot-launched hang glider pilots (Fig. 17.12).

17.5.1 Injuries and Fatalities

The BHPA incident reports collected between 2001 and 2012 included 24 events involving powered hang gliders [1], most of which (82.5 %) took place with wind speeds lower than 20 knots (37 km/h) and without thermals. Powered hang gliding is usually practiced in calmer conditions than those required for non-motorized, foot-launched fight sports since the motor renders thermals unnecessary to gain altitude while strong winds increase the effects of mechanical turbulence and are widely considered to be dangerous [1]. The most commonly reported causes

Fig. 17.11 Powered hang glider during takeoff

Fig. 17.12 Hang glider trike (Photo: Jeff Nielson)

of incidents were pilot error (45.8 %), engine malfunction (16.6 %), and hang glider failure (12.5 %), while weather conditions were rarely held liable for incidents (4.2 %).

One half of the incidents caused injuries, and one was fatal. Half of the injured patients sustained multiple injuries; more than one third (35.7 %) of injuries involved the head/facial region including two facial contusions, one concussion and one case of brain injury, while the rest of the injuries were equally distributed between the trunk and the upper and lower limbs. Generalized injuries included two cases of bruising and two cases of electric burns, one fatal and the other affecting 15 % of the body surface. Although the limited sample size does not permit us to draw any general conclusions with regard to injuries, it seems that the head is often affected by injuries in powered hang gliding, a result in keeping with that previously reported in hang gliding [1].

Conclusions

The term *foot-launched flying* groups together a number of sports which are actually characterized by different injury rates, injury dynamics, and injury patterns due to the different kinds of flight, equipment and conditions of practice in each. In powered paragliding, for example, most incidents occur during takeoff, while in paragliding and hang gliding, most of these occur during landing.

In hang gliding, the pilot is suspended from the glider by the harness in a prone position, while in paragliding the harness offers support in both standing and sitting positions. As a result, injuries to the head, the upper limbs, and cervical spine are more common in hang gliding, while injuries to the ankle and thoracolumbar spine are more common in paragliding. Serious hand lesions caused by contact with the engine prop are specific to powered paragliding. Weather conditions seem to be implicated less often in motorized sports incidents, while the engine and its thrust can be the primary cause or may aggravate the outcome. This may be a reasonable explanation for our recent findings of fatal outcomes of 4.1 % and 4.9 % in powered hang gliding and powered paragliding respectively. These were significantly higher than the value of 2.5 % we found in both hang gliding and paragliding [1].

For these reasons, we believe that foot-launched flying sports should be considered separately in future studies. A final consideration is that reported injuries in foot-launched flying sports are always sudden-onset injuries. There are no reports of overuse injuries in these sports [6], and this may be due to the greater focus on reporting more life-threatening or debilitating injuries. It is our belief, therefore, that more attention should be paid to studying overuse injuries in these sports.

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