ORIGINAL ARTICLE

Injury prophylaxis in paragliding

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Br J Sports Med 2002;**36**:365–369

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Accepted 11 February 2002

Objectives: To show trends in paragliding injuries and derive recommendations for safety precautions for paraglider pilots on the basis of accident statistics, interviews, questionnaires, medical reports, and current stage of development of paragliding equipment.
Methods: All paragliding accidents in Germany have to be reported. Information on 409 accidents was collected and analysed for the period 1997–1999.
Results: There was a substantial decrease in reported accidents (166 in 1997; 127 in 1998; 116 in 1999). The number of accidents resulting in spinal injuries was 62 in 1997, 42 in 1998, and 38 in 1999. The most common cause of accident was deflation of the glider (32.5%), followed by oversteering (13.9%), collision with obstacles (12.0%), take off errors (10.3%), landing errors (13.7%), misjudgment of weather conditions (4.9%), unsatisfactory preflight checks (4.9%), mid-air collisions with other flyers (2.2%), accidents during winching (2.2%), and defective equipment (0.5%). Accidents predominantly occurred in mountain areas. Fewer than 100 flights had been logged for 40% of injured pilots. In a total of 39 accidents in which emergency parachutes were used, 10 pilots were seriously injured (26%) and an additional three were killed (8%).
Conclusions: Injuries in paragliding caused by unpredictable situations can be minimised by (*a*) using safer gliders in the beginner or intermediate category, (*b*) improving protection systems, such as padded back protection, and (*c*) improving pilot skills through performance and safety training.

Paragliding is a popular extreme sport. In 1965, gliders and steerable parachutes were developed in America and, in 1977, "parascending" was described as a less dangerous alternative to hang gliding and parachuting.[1 2] Since 1985, the sport has increased in popularity, first in alpine regions and, in the last few years because of improved tow winching, also in flat areas.[3] With increasing flight frequency and the first serious critical injuries, paragliding quickly fell into the category of high risk sports.[4 5] However, the risk of injury and the number of deaths in paragliding are not as high as in other aerial sports. Some[5] think that it should not be classed as a high risk sport. The number of paragliding accidents in Germany has fallen substantially over the last few years, while the number of licensed pilots has remained steady since 1993 (figs 1 and 2). Since the early days of paragliding, major improvements have been made to passive and active safety precautions. In many countries it is obligatory to carry a reserve parachute for flights more than 50 m above the ground. The use of ankle protecting, shock absorbing footwear has become standard, and wearing a helmet is a legal requirement almost everywhere. The limit of alcohol in the blood in Germany for paraglider pilots is lower than for drivers on the road. A blood alcohol level of 0.05% in a pilot will result in conviction for being incapable of flying. Furthermore the quality and extent of training that a pilot must receive to gain a licence has increased substantially.

The aim of this paper is to show the trends of paragliding injuries, and derive recommendations for active and passive safety precautions for paraglider pilots on the basis of accident statistics, interviews, questionnaires, medical reports, and current stage of development of paragliding equipment.

METHODS

In Germany, all accidents and problems involving German paragliders at home and abroad must be reported to the German Paragliding Association (DHV). A standardised questionnaire is used to obtain information on the pilot's training, the cause of the accident, and the area in which the accident occurred. In this study, the pilots involved or, when this was not possible, witnesses of the accident, were asked personally about the type and seriousness of the injuries, the back protection system used, the accident situation, and the position of the pilot on impact. Details from the hospitals where the injuries were treated were also included in the evaluation.

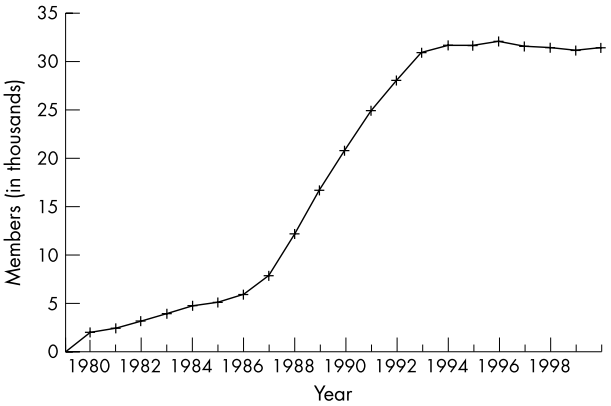

Figure 1 Membership of the German Paragliding Association, the largest representative of the interests of licensed paragliding pilots in Germany.

This paper concentrates on the 42 accidents that occurred in 1998 that resulted in spinal injuries. From these, 29 pilots were questioned about the circumstances surrounding the accident. In a further eight cases, information was received from eye witnesses because the pilots were suffering from post-traumatic amnesia. In five cases, no information at all could be gathered.

The paragliders were classified in accordance with the various quality categories used by the DHV, ACFPULS (Association des Constructeurs Français de Planeurs Ultra-Légers Souples/ French Designing Engineers Association of Microlight

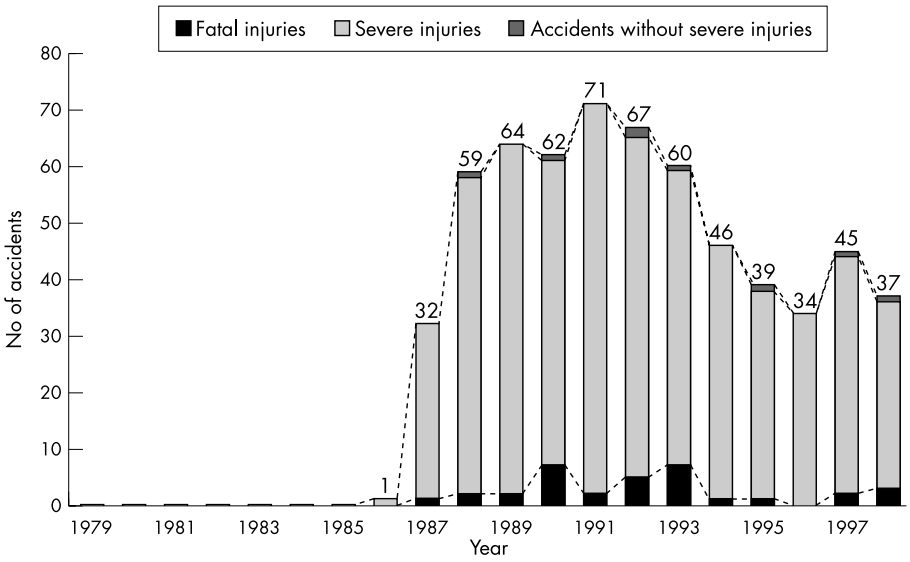

Figure 2 Accidents involving German paragliders in Germany.

Table 1 Proportion of accidents overall and serious and fatal injuries to pilots with a flying licence

Year	No with licence	No of accidents	No of seriously injured people	No of deaths
1997	16296	166 (1.01%)	82 (0.50%)	10 (0.06%)
1998	18331	127 (0.69%)	74 (0.40%)	8 (0.04%)
1999	20091	116 (0.58%)	65 (0.32%)	7 (0.03%)

Planes), and the SHV (Schweiserischer Hängegleiterverband/ Swiss Paragliding Association).[3]

Category 1: beginner level paragliders, which are easy to handle and can compensate for considerable pilot error. They are used for training and recreational paragliding.

Category 2: sport class paragliders, which require a certain amount of skill in handling and do not allow for pilot error. These gliders react dynamically in the event of problems or steering mistakes, and only pilots with substantial flight experience and proper training should use them.

Category 3: high performance or competition paragliders requiring a skilled pilot. These paragliders have the highest performance at the expense of safety. The pilot needs to be skilled and experienced enough to react quickly and correctly to all problems that can occur during a flight.

Paragliders with characteristics of different categories were classified as category 1–2 or 2–3.

Statistical analysis

The questionnaires were analysed using descriptive statistics with respect to the following outcome parameters:

- number of accidents;
- causes of accidents;
- terrain in which accidents occurred;
- level of training of pilot;
- emergency parachutes;
- accidents resulting in spinal injuries.

Descriptive subgroup analysis of these variables was carried out for the year of the accident and level of training. The χ^2 test was used to analyse differences in the distribution of the subgroups, with a significance level $\alpha = 0.05$.

RESULTS

Number of accidents

Between 1997 and 1999, 409 accidents involving paragliders were reported. Over the study period, there was a substantial decrease in the number of reported accidents: 166 in 1997, 127 in 1998, and 116 in 1999. This trend is confirmed when the proportion of accidents overall, and serious and fatal injuries to pilots with a flying licence are considered (table 1).

In 1997, 1998, and 1999 spinal injuries made up 37% (62/166), 33% (42/127), and 33% (38/116) respectively of the reported accidents.

Causes of accidents

Collapse or deflation of the airfoil (n = 133 (32.5%))

The collapse of the glider is the most common cause of accident (table 2). An asymmetric collapse (85.1%) was more common than a frontal collapse (15.9%).

In 59.9% of accidents, failure to correct the situation after deflation led to the pilot hitting either an obstacle or the ground. Pilots often sustained serious injuries from high speed impact caused by the G forces attained as a result of the glider spinning out of control after deflation. About one third (30.1%) of accidents were caused by incorrect use of the break lines resulting in stalling. Cases in which the pilot was able to stabilise the glider by correct use of the break lines to prevent the glider spinning represented only 10% of all accidents and almost always resulted in minor injuries only.

After a stall or full stall, the tips of the paraglider can become entangled in its own lines resulting in spinning. In 1999, five such accidents were reported compared with seven in 1998 and nine in 1997. This highly dangerous situation occurred almost only with gliders from category 2 and higher.

Table 2 Accidents resulting from collapse of the paraglider, and market share of the gliders according to category

Year	Injuries from collapse in categories 1 and 1–2	Market share of categories 1 and 1–2 (%)*	Injuries from collapse in category 2	Market share of category 2 (%)*	Injuries from collapse in categories 2–3 and 3	Market share of categories 2–3 and 3 (%)*
1997	5	24	36	54	17	22
1998	5	57	24	26	13	17
1999	7	67	18	25	8	8

*Estimated from the sales figures of DHV airworthiness certificates.

Oversteering or pilot error (n = 57 (13.9%))

Airflow interruption was invariably pilot error caused by incorrect break line handling—that is, in rapid descent manoeuvres, such as steep spirals, B-line stall, and "big ears", or parachutal flight.

A paraglider is normally landed by stalling it just above the ground. Poorly trained pilots may perform this manoeuvre incorrectly, especially at too great a height, resulting in a hard landing.

A recent problem with the newer generation of gliders was that they could become locked into a spiral after intentional performance of this manoeuvre by a pilot not trained properly to counteract it on the model being used.

Collision with an obstacle (n = 49 (12%))

This occurred during take off, while soaring close to cliffs, and, most often, during landing. In 78% of cases, a tree was the obstacle. Serious injuries were rare. More dangerous, but much more rare, were collisions with cable cars or power lines (6% of accidents). The final 16% involved buildings, vehicles, or other obstacles.

Mistakes during take off (n = 42 (10.3%))

The most common mistakes were made while getting into the harness before taking off, which resulted in further contact with the ground.

Mistakes during landing (n = 56 (13.7%))

Incorrect landing approaches (too high or too low), erroneous correction of the direction, fast curves close to the ground, and landing with a tailwind were all causes of accidents. Miscalculations were often the result of difficult landing conditions such as particularly strong winds, thermal activity, small landing areas, and obstacles on the edge of the landing area. During the actual landing itself, the mistakes were not getting out of the harness quickly enough, braking too hard, and miscalculating obstacles leading to a crash landing.

Misjudgment of the weather (n = 20 (4.9%))

The most common problems were underestimating the velocity of the wind and meteorological miscalculations.

Incomplete preflight check (n = 20 (4.9%))

In 1997 and 1998, there were four fatal accidents resulting from the pilot not fastening the leg loops and falling out on take off. No such accidents occurred in 1999.

The second most common cause of accident was taking off with tangled or knotted lines: eight in 1997, nine in 1998, and four in 1999. A further, rare, cause of accident was loss of the emergency parachute during the flight because it was not secured during the preflight check. This was recorded twice in 1997, once in 1998, and twice in 1999.

Mid-air collisions (n = 9 (2.2%))

In the cases where two paragliders collided, one pilot was seriously injured and the rest were able to land with little or no injury using the emergency parachute. In the three cases where a paraglider collided with a hang glider, two of the three hang gliders were killed because their emergency parachutes did not open properly.

Problems with the winch (n = 9 (2.2%))

Injuries were caused by backlash from the towing cord breaking or after being cut.

Problems with equipment (n = 2 (0.5%))

The accidents were caused by age related performance changes of the gliders.

Terrain in which accidents occurred

Most accidents occurred in alpine areas. Of the 32 accidents caused by collapse of the paraglider reported in 1999, 27 occurred in the mountains. The number of pilots having accidents in autumn and winter flying over areas such as Turkey and Spain increased.

In low mountain ranges, most accidents were caused by collision with an obstacle and by take off and landing errors. Because of the slight differences in height, many pilots flew very close to, and in some cases even into, cliff edges. The number of landings in trees was above average.

Flights in lowland areas were significantly less dangerous. Seven of the 10 accidents were the result of problems with the winch start. Parachute flight during towing or mistakes made by the pilot after a cord ripped were predominant. During the actual flight itself, only three accidents were reported. In all three years of the study, the number of accidents in flat areas after a winch start remained less than 10% of the total, even though the number of such take offs has increased in Germany over that period. Currently, almost 40% of all paragliders have the supplementary licence required for winch towing.

Level of training

Beginners and recreational pilots with less than 100 flights (40%) were the most accident prone group. In this category the number of accidents that occurred during take off and landing as well as due to oversteering was above average. For reasonably experienced pilots with up to 200 flights (27%), there was no predominant cause of accident. A large number of the accidents resulting from collapse of the paraglider occurred in this category of experienced pilots with over 200 flights (21%) and very experienced pilots with over 500 flights (12%). Irrespective of the number of completed flights, the two years immediately after gaining the pilot's licence were the most dangerous.

Excluding students gliding without licence during training and under supervision (16%), statistical analysis of the difference between independent pilots with an intermediate licence (49%) and those with an advanced licence (35%) did not provide any additional information. The number of accidents during training was above average. Only a few accidents involving tandem paragliding occurred during the three year period, with a slight upward trend (three in 1997, four in 1998, and five in 1999).

Emergency parachutes

During the period of this study, 39 cases were reported in which emergency parachutes were used. In 26 cases the pilots

suffered bruises that did not require treatment or they were not injured. Of the 10 pilots who suffered serious injury on landing after deploying their emergency parachutes: three were carrying an emergency parachute that was too small, resulting in high impact on landing; two were injured by landing on rocky ground; in the case of two others 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 for it to open quickly enough to function adequately; in one case, because of extreme oscillation of the emergency parachute, the pilot hit the ground in an unfortunate position.

Two pilots died after deploying their emergency parachutes too close to the ground, and one died because he had secured the deployment mechanism too tightly and was unable to open the parachute.

Accidents resulting in spinal injury

Thirty seven accidents resulted in spinal injury. Two pilots suffered permanent complete paraplegia. Twelve pilots can expect permanent neurological deficits and considerable reduction in the flexibility of the spinal column and coordination. A further 12 accident victims will suffer slight impairment of movement in the spine as well as temporary pain. Eleven pilots either have already recovered or are expected to recover fully.

Back protection

Of the pilots with spinal injuries, 10 had no back protection and 10 used only a hard shell. In 15 cases, protectors made of hard material and foam were used. Two pilots used airbag harnesses.

Accident situation

In 17 out of 37 cases (46%), deflation close to the ground caused the accident. In eight cases (22%), it was due to oversteering followed by a negative spin, parachutal flight, or stall, and in five cases (13%), an incorrect landing approach. Four pilots (11%) were injured on landing with the emergency parachute, and three accidents (8%) were caused by collision with an obstacle.

Position on impact

Twenty two pilots (59%) landed on their backs or buttocks, eight (22%) on their sides, and seven (19%) with outstretched legs. Of the 22 pilots who landed on their backs or buttocks, 16 had no back protection or only hard shell protection, resulting in serious and critical back injuries. One pilot fell in a full stall from a height of 10 m, without braking, on to his back and buttocks; he fractured a lumbar vertebra but had no neurological deficits. He was wearing a protector classified in the DHV test as highly effective. A further three pilots using protectors of the same category suffered no injury whatsoever after a very hard fall.

DISCUSSION

This analysis is based on the accidents reported to the DHV. However, it must be assumed that the actual number is considerably higher than the official statistics suggest.[3 6] Most insurance companies refuse to pay compensation for paragliding injuries, therefore many pilots probably do not give the real cause of the accident. A poll of 1500 pilots showed that one third had been involved in an accident.[4] A survey of spinal injuries after paragliding accidents treated in five accident hospitals in 1998 indicates that there were about double the number of accidents reported to the DHV.

The reduction in number of accidents from 1997 to 1999 is, however, noteworthy when one considers that the administration of justice with regard to insurance in Germany remained unchanged during the period of the study. This is presumably due to increasing acceptance of training courses, wider use of modern back protection systems, and the fact that more pilots tend to use the easier to handle beginner's and intermediate gliders.

Incorrectly handled collapses were found to be a major cause of accident. It was predominantly DHV class 2 and 3 gliders that were involved in such accidents. These high performance gliders are notable for their sensitive handling characteristics and, unlike the beginner's or intermediate models, a pilot must fly particularly actively in order to stabilise them. Therefore recreational pilots should not fly such high performance gliders. One could propose a system of training in stages up to the level of the pilot's licence for these gliders, similar to that for motor cycles. Improved performance and better image of gliders in categories 1 and 1–2 have increased their popularity allowing most pilots to enjoy stress-free flying. The new models in the intermediate class are noted for their handling and also their user friendly break pressure characteristics. A pilot who changes to another glider of the same category, but of newer construction, should have instruction on how the new glider flies. It is important that a glider is the correct size. Although an oversized glider allows a pilot to gain more altitude in weak thermal conditions, its increased vulnerability to turbulence is a safety risk.[3]

As previously shown,[5 6–8] human error is partly responsible for most accidents, especially oversteering of the glider. The trend towards safety and performance training is reflected by an increasing acceptance among recreational pilots of the need for practice.

Flight preparation should include assessment of the regional and general weather situation, finding out about peculiarities of the area, and inspection of the take off and landing area.

A further common cause of accidents is an insufficiently structured landing approach. The planned flight path is often considered too late, and the remaining altitude allows only a small variation or even demands a direct landing approach. In this case it is impossible for correct orientation to the force and direction of the wind on the landing site, the activity on the ground, obstacles, or other approaching pilots. Strong winds or thermals then lead very quickly to extreme situations.

After a series of accidents resulting from unfastened leg loops, no further accidents were reported in 1999. The DHV campaign to highlight the importance of the preflight check must have reached the pilots and made them aware of the seriousness of the problem.

Accidents from tangled or knotted lines decreased over the study period. This is presumably due to better ergonomics with regard to handling the lines, including fewer lines, colour differentiation between the different levels, and a reduced tendency of the lines to loop.

Most accidents occurred in alpine areas which have particular dangers such as strong valley winds, large lee, and rotor areas with turbulent thermal conditions. The large number of accidents that occurred during landing may be explained by the use of landing areas that were too small and the lack of room for flight correction when coming in to land. In low mountain ranges, slight height differences led to collisions, especially with trees. The usually generous landing possibilities and the lack of turbulence and lee sides makes flying over flat land much safer. Accidents are usually due to pilot error during towing.

The fact that accidents occurred to pilots who have flown more than 100 times shows that beginners' mistakes are not the only cause. Regular fliers must also practice unusual manoeuvres in order to be able to react correctly and consistently in dangerous situations. The growing acceptance of performance and safety training reflects increasing risk consciousness. Furthermore, cross country and thermal seminars are available, which continue to train pilots after they have gained their licence and, in some cases, lead to the correction of years of mistakes and bad habits. The number of accidents

involving pilots without a licence has fallen considerably. In contrast with early studies,[5 9] which predominantly reported accidents in trainee pilots, the number of such accidents had already fallen to 50% in 1990.[3] In a study of 1994–1998 or 1996–1998, such accidents represented just 7.5% of all accidents[8] and in this study 16%. These values confirm the appreciable qualitative improvement in training, the practical sections of which are now mostly carried out with the help of radio.

This study makes clear that emergency parachutes may save lives and prevent injuries when used in time: 26 out of 39 pilots remained uninjured or did not require treatment. Two pilots were killed after deploying their emergency parachutes too close to the ground, and one other died because of problems manipulating the deployment mechanism. Not only the glider itself, but also the legally required emergency chute, must be in a condition conforming to the required standard. It must be appropriate to the pilot's weight on take off as well as compatible with the harness. It is recommended that the emergency parachute is checked and repacked every six months.

This study confirms the typical distribution of serious injuries found when paragliding first started.[5 6 10 11] The most common injuries were spinal, predominantly thoracolumbar compression fractures. The rare neurological deficits are mainly explained by an axial bending pathomechanism.[8 11–13] Schulze *et al*[8] showed that spinal fractures due to torsion are the exception, the vast majority of unstable complex pelvic fractures being marked by a tangential component of the high velocity trauma.

This study underlines the importance of an appropriate system for the prevention of injuries and fractures of the chest and the lumbar vertebrae. The foam multichamber and airbag harnesses are considered the best protection against fractures of the spine and pelvis. These can at least gradually absorb the shock of impact. Of 22 pilots who landed on their buttocks or back, 16 seriously and critically injured their backs because of a lack of, or inappropriate, back protection. Both paraplegics who were questioned had used systems that offered only limited protection. Back protection has been required by law since 1 January 1998 in Austria and 1 January 2000 in Germany. The large percentage (21.6%) of sideways crash landings, as well as the complex pattern of injuries in the mostly unstable pelvic fractures shown by a recent study,[8] corroborate the current development of side protectors.

Conclusions

Paragliding is a fascinating sport, in which the risks are determined by the pilot's sense of responsibility. To avoid injury, pilots should consider the following points.

(1) Performance and safety training offer a good opportunity to learn and reinforce elements of active flying under supervision after completion of the initial training.

(2) New generation DHV category 1 and 1–2 gliders offer performance orientated and, with their balanced handling characteristics, stress-free and safe flying.

(3) A high quality back protection system offers the best protection from pelvic and spinal injuries.

Take home message

Injuries in paragliding caused by unpredictable situations can be minimised by (*a*) using safer gliders in the beginner or intermediate category, (*b*) using protection systems, particularly for the back, and (*c*) continuous updating of skills.

(4) A complete preflight check should always be carried out immediately before take off. Examination of the secured leg loops should be top priority.

(5) Incompatible combinations of equipment should be eliminated by having everything checked at a flight school or by a manufacturer. This applies to non-functional combinations of harness and protector as well as the emergency parachute.

(6) A helmet and high, shock absorbing shoes that protect the ankles are essential for every flight.

(7) In the case of bad weather conditions, a flight should be cancelled or promptly ended.

ACKNOWLEDGEMENTS

We would like to thank the DHV for substantial assistance in data acquisition.

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