Ergonomics of paragliding reserve deployment

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ABSTRACT

Paragliding is an emerging discipline of aviation, which is considered relatively high risk. Reserve parachutes are rarely used, but typical deployments are at low altitude, with pilots under the extreme stress of a life-threatening situation. To date, paraglider equipment design has focused primarily on weight and aerodynamics, so reserve parachute deployment systems have evolved haphazardly. Our study aimed to characterise deployment behaviours in amateur pilots. Fifty-five paraglider pilots were filmed deploying their reserve parachutes from a zipline. Test conditions were designed for ecologically valid body, hand and gaze positions; cognitive loading and switching; and physical disorientation akin to a real deployment. The footage was reviewed by two groups of subject matter experts. It was noted that pilots searched for the reserve handle using the hip as an anatomical landmark and tried to extract the deployment bag upwards, irrespective of optimum direction. Recommendations, which are being incorporated into the latest draft of the European Norm for harness design included: positioning reserve handles at the pilot's hip; better system integration between different manufacturers; and containers being designed so deployment bags are extractable at any angle of pull. Deployment in a single, sweeping action should be encouraged in preference to the multiple actions sometimes taught.

KEYWORDS

Equipment failure, personal protective equipment, accidents, aviation

Introduction

Paragliding is a widely practiced form of unpowered flight (Paragliding Manufacturers' Association 2014). While paragliding has become safer over time, it remains a relatively high-risk pursuit and accident investigations have often commented on the failure of paraglider pilots to deploy their reserve parachutes in time (BHPA 2017). In an analysis of incident reports from 2017, the Fédération Française de Vol Libre (FFVL) concluded that in 90 % of accidents, the reserve parachute was not deployed (FFVL 2017), consequently those accidents led to nine deaths (FFVL 2019). Training of reserve parachute deployment in paragliding is inconsistent and the deployment systems vary significantly in design. Concerted, systematic efforts to improve and standardise equipment and training are imperative for the evolution of the sport and the safety of its practitioners. For that to occur, further research is required to understand how equipment is used currently. This study observed current paraglider pilots deploying their reserve parachutes in a controlled environment, to characterise the desirable pilot behaviours that might be encouraged through improved design.

Methods

The study was carried out at an annual event called the Big Fat Repack, which gives pilots the chance to throw their reserve parachutes and then repack them under expert supervision. Fifty-five practicing paraglider pilots volunteered to take part in the study (mean [SD] age 49.2 [12.5] years). Twenty-seven (49.1 %) had been flying for three or fewer years. Thirty (54.5 %) had some experience of reserve parachute deployment, defined as having thrown their reserve at a previous indoor event, during a training course or in a real emergency.

Participants began at a practice station, where they sat in their own harnesses, practiced the tasks detailed below and located their reserve handle. When gripping the reserve handle, they were measured for acromion-olecranon and olecranon-wrist crease lengths and angles of flexion at the shoulder and elbow (Peebles and Norris 1995). On the zipline, they were held suspended by a tether at an awkward angle approximately 15m above the floor, to heighten anxiety and to create sensations of drop, pitch and yaw akin to their wing collapsing in flight when released. Their hands were in dummy paraglider control lines. Participants were asked to look up at two LED lights and, when one switched on, to apply input to the control line on the corresponding side. At the same time, they were given a form of the Verbal Fluency Task (Shao, Janse et al. 2014) which engaged executive function and working memory. They were then released down the line, without warning, 15-60 seconds after beginning the zipline tasks. Thus, at the point of release, participants had their hands in the control lines in their usual flying position, their gaze was directed upwards (towards their ‘collapsed wing’) and they were experiencing high levels of cognitive load in multiple domains.

Zipline descents were filmed by two cameras attached to the zipline trolley (GoPro Inc., San Matteo, USA), edited, analysed and shown to two groups of subject matter experts. For comparison of deployment speeds, the primary metric was elapsed time from control line release, rather than from the start of zipline descent. This meant that the reaction time component (the time taken for a participant to realise that the descent had started, and start the deployment sequence) would not affect the results.

The study was approved by the University of Portsmouth Science Faculty Research Ethics Committee [SFEC 2018-133] and complied with the declaration of Helsinki.

Results

Of the 47 participants with under-seat reserves, 33 (70.2 %) were able to reach their reserve handle with both hands, while suspended in the harness during the practice station. Eight (17.0 %) could do so with difficulty, and six (12.8 %) could reach it with one hand only.

Fifty-three of the 55 participants were able to successfully deploy their reserve parachute before reaching the end of the zipline. For successful deployments, the mean time from zipline descent to releasing the deployment bag at the end of the throw was 2.64 (0.78) seconds (range 1.44 - 5.12 seconds). The mean time from control line release to releasing the deployment bag was 1.85 (0.69) seconds (range 0.84 - 3.72 seconds).

When released, participants typically made bracing or oppositional movements. Forty (85.1 %) of those with under-seat reserves first attempted to locate the reserve handle on their hip [Figure 1A] and seven (14.9 %) on their lateral thigh (irrespective of the handle’s actual position). Consequently, only 15 (31.9 %) of these participants touched the handle on the first attempt. No matter whether the deployment bag in under-seat systems was designed to be pulled out laterally or vertically, 33 (70.2 %) of participants’ initial movements was an upwards or upwards-backwards pull, effected by shoulder abduction (19, 57.6 %), extension (6, 18.2 %) elevation (4, 12.1%) in combination with elbow flexion [Figure 1B]. Design errors were noted in the length of strops, the presence of clutter near the reserve handle, and in front-mounted reserve containers unsecured at the base [Figure 1C].

Twenty-eight (60.9 %) participants with under-seat reserves threw the deployment bag away from the harness in a single sweep, once they had extracted it from the container. The remaining 39.1 % attempted to bring the bag upwards and forwards before throwing it back (a ‘compound’ action, taught by some schools). The participants who threw with a single, sweeping action had significantly faster deployments than those who employed compound actions (1.70 vs. 2.26 seconds, $p = 0.002$, $n = 46$) and the compound actions appeared more hazardous [Figure 1D].

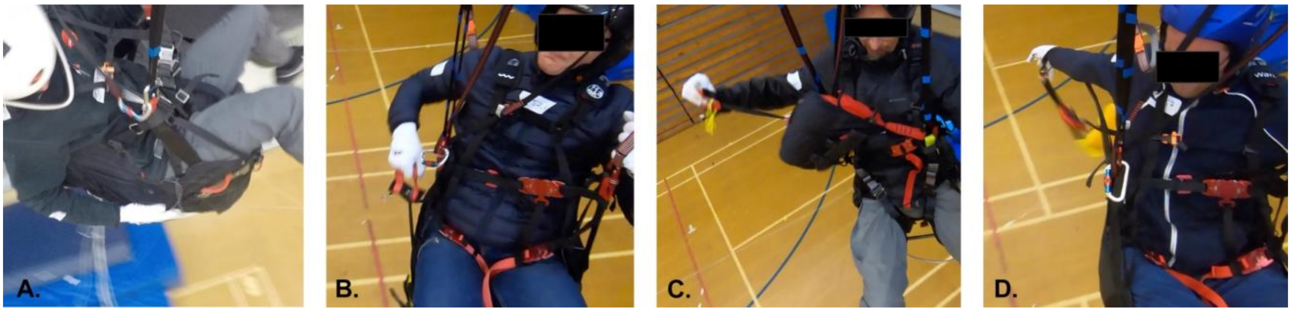

Figure 1: A) Participant searches for handle on hip. B) Participant pulls vertically upwards causing the deployment bag to stick. C) Unsecured reserve container lifts up when handle pulled. D) Reserve bridle wraps around participant's wrist, risking severe injury if the parachute had deployed.

Discussion

The necessity of the study was highlighted by the high proportions of participants who did not find their deployments instinctive, easy or effective. Indeed, two (4 %) participants failed to deploy altogether, with potentially fatal consequences in a real emergency. For an essential piece of safety equipment, these implied significant room for improvement, both in terms of pilot training and equipment design.

Participants appeared to locate their handle more by touch than by sight. Locating the handle on the first attempt saved an average of half a second. It was notable that 85 % of participants with under-seat systems first felt for the reserve handle on their hip and then along the line of the femur, which may have indicated a natural tactile or proprioceptive response corresponding to the appendicular skeleton. Moving the handle to the area of the harness overlying the greater trochanter when seated would very likely increase success. It would also move it clear of other components of the harness, such as the stirrup or speed bar, grasped in error by some participants.

Seventy percent of participants' initial movements was an upwards or upwards-backwards pull, even if the harness design demanded otherwise. This caused resistance to bag extraction, but participants were observed to adjust their grip to pull upwards even harder when they felt resistance, rather than change their angle of pull. This apparent tendency to pull upwards, rather than outwards, may have been due to participants' desire to extract their reserve parachute with strength and urgency. Pulling upwards predominantly engaged the biceps and large muscles of the chest and upper back, while keeping the arms close to the body. To extract it laterally required participants to abduct and rotate at the shoulder and then pull the bag out using the triceps and lateral deltoid from a relatively weak (and vulnerable) point in the shoulder's arc. This weaker movement may have felt less instinctive to participants under the stress of deployment, even though it was what the equipment demanded of them.

While those with front-mounted systems generally extracted the deployment bags with relative ease, it was notable that if the front-mounted container was unsecured at the base, it could lift up with the handle pull, increasing difficulty and reducing mechanical advantage. This would be a very straightforward issue for manufacturers to correct.

The participants who threw with a single, sweeping action had significantly faster deployments than those who employed compound actions. Video analysis also demonstrated that, because of the inertia of the deployment bag, it appeared to 'lag behind' the throwing hand during compound actions. This caused a loss of throwing power and appeared to increase the risk of entanglement. In one deployment, it led to the bridle wrapping around the participant's wrist [Figure 1D]. In another, it led to the participant's face being covered in the lines of the reserve parachute.

It was hypothesised that prior experience of reserve deployment would be correlated with improved performance in the study, but that hypothesis was rejected. However, in the opinion of the expert focus groups, even those participants with the most experience of deployment were still much undertrained in the task (reflecting the wider paragliding population). They were therefore unsurprised at the lack of correlation, and viewed it as another argument for improving training and strengthening the European standard for harness design.

The most important limitation of our study was that, unlike in a real emergency, there was no threat to life. There was no requirement for altitude awareness and also no inhibition to throwing the reserve: in live flight, there is always a judgement required between the need to deploy and the risks of deployment. When descending the zipline, participants primarily experienced linear, forward acceleration (Gx forces). However, in many emergencies there are significant and disorientating rotational forces. These would likely have exacerbated many of the difficulties faced by our participants in the study, particularly the 30% of participants who could only locate the handle easily with one hand. Other limitations included a self-selected sample, a practice at handle location before deployment (an opportunity that may not occur in life) and standardisation of gloves and control line grip.

All of the limitations above meant that participants in the study had an easier task than those in a real emergency. Therefore, we believe that the issues highlighted by the study are more pressing given the study's limitations, rather than less.

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