

An Informal Survey of Flying Comfort of Glider Pilots: Some Observations Concerning Pilot Discomfort Generated by Glider Cockpits

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Abstract

An informal survey provides indications of the main problem areas and highlights where research needs to be focused with respect to glider cockpit design. Almost all pilots become uncomfortable with passage of flight time. The causes of such problems cannot usually be detected by pilots prior to commencing flight.

Introduction

Following publication of Emck's spine-shell, lumbar support¹, requests for help in reducing discomfort in the buttock and lumbar regions came in from worldwide sources. It became evident that little research had been done into the comfort of glider pilots in their cockpits. The purpose of this work is to assess the prevalence of discomfort and to identify the major issues that appear to be generating discomfort so that its causes subsequently can be examined more thoroughly.

Methods

A small, initial survey was carried out in the Lasham gliding club in 2003. To avoid the problem of bias towards participants who experienced discomfort making the effort to respond and others not bothering, a seminar was set up on the subject of a 750 km glider flight. The audience, made up largely of cross-country pilots, was surprised to find the talk consisting of a presentation on the effect of comfort on flying performance. During the seminar, all participants were asked to complete a chart, graphing their discomfort against elapsed time during a typical flight. Discomfort was rated on an 11-level scale where 0 corresponded to a perception of perfectly comfortable and 10 corresponded to extreme discomfort that necessitated a need to land immediately.

In 2004, it was decided to obtain some further but simple data that would give good indications of the main areas of concern, if any, that were leading to discomfort in glider cockpits. To achieve this, it was decided to undertake a relatively free-form survey of Lasham pilots, but with no compulsion to respond. This informal approach meant that it could be fairly criticized that the results obtained might be biased in favor of uncomfortable pilots making a special effort to respond. The questionnaire requested pilots to provide basic, personal data and details of flying experience in terms of flying hours and longest flights. Participants, then, were invited to comment on their perceived level of comfort in the glider cockpits that they had flown and to rate this on a 6-level scale, 0 corresponding to perfectly comfortable and 5 corresponding to extreme discomfort. The recognized weakness of this simple approach is that one person's level 2, for example, may be another's level 3. Also, if participants were asked to repeat their ratings, there is no guarantee that they would accurately replicate their original scores. Nevertheless, the method is sufficiently accurate to provide good indications of broad comfort levels. Participants

were also invited to comment on their different cockpit experiences. There was no compulsion to comment on every cockpit. As a result, the survey responses represented comments on discomfort that the participants deemed to be worth reporting. Although this approach did not provide a "cast-iron" statistical basis by any means, it did mean that, if several participants made the same complaint, it was a good indication that this was a topic worthy of more thorough investigation – indeed, the very purpose of this project was to identify those issues.

Results

Thirty-three pilots took part in the initial survey in November 2003. One-hundred-ninety-six pilots participated in the 2004 free-form survey. Details of their height, age and flying hours are shown in Table 1. One-hundred-eighty-four pilots were male, representing 35% of male flying members of all ages at Lasham. Twelve were female, representing 24% of female flying members of all ages.

Analysis of the data from both surveys revealed the following:

- almost all pilots became uncomfortable with the passage of time,
- there was no correlation between height and discomfort,
- cramped cockpits were by far the most important single source of complaint,
- by combining categories, lower limb discomfort was revealed to be by far the most important area of discomfort,
- beginner pilots were the least comfortable,
- comfortable pilots flew significantly more hours than others.

Almost all pilots became uncomfortable with the passage of time

This result is shown in Fig. 1, which comes from the 2003 survey. In addition, the 2004 survey showed that 70% of pilots experienced discomfort at some stage during their flying career. Furthermore, the overall, perceived level of discomfort appeared to increase approximately linearly with time. Figure 2 illustrates this, being the average of the individual 2003 survey results making up Fig. 1. This result is compatible with the 2004 survey.

There was no correlation between height and discomfort

This result is illustrated in the scatter shown in Fig. 3. Although tall pilots were no more uncomfortable than others, when they exhibited discomfort they were likely to suffer from feet and head problems. This is shown in Fig. 4.

Cramped cockpits were the most important cause of discomfort

This result is shown in Fig. 5. Cramped cockpits were mentioned about twice as many times as seating, the next most important source of discomfort. Table 2 shows the average pilot height for each of the categories in Fig. 5.

Lower limb discomfort was the most important area of discomfort

This result is illustrated in Fig. 6. In terms of individual categories, lumbar and buttock region discomfort were the most frequent sources of complaint.

Beginner pilots were the least comfortable

This result is shown in Fig. 7. Their average level of comfort corresponds to about level 3, approximately halfway on the scale used.

Comfortable pilots flew significantly more hours

This result is shown in Fig. 8. Completely comfortable pilots (level 0) flew approximately twice as many hours as those experiencing even mild discomfort (level 1).

Discussion

We observed that some senior pilots believed that discomfort in gliders was an insignificant problem. They regarded comfort as an irrelevance. These high-hours individuals were usually confident “movers and shakers” and reinforced a fundamental fallacy: if cockpits were comfortable for them they must be comfortable for everybody else. The reasons for their stance are made evident in the discussion below.

Pilot comfort and the passage of time

With the passage of time, two insidious phenomena take place in the cockpit:

- capillary blood flow that becomes occluded in tissue under compression results in metabolite build-up and the emergence of subsequent pain,
- muscle fatigue sets in due to prolonged static muscle tension.

Normal capillary blood pressure is around 32 mm Hg.² However, an external pressure on the skin well in excess of this value is necessary to block circulation of the capillary-blood. The build-up of metabolites and other mechanisms produces gradual pain – the increasing sensation of discomfort. Persistence of this condition can even produce tissue damage. Depending on the external pressure and pilot tolerance, given sufficient time, subjects gradually but almost inevitably become aware of the resulting pain. By way of an extreme illustration, in 2007, a professional Lasham instructor reported that

a pressure ulcer had been induced in his sacrum area by the accumulated results of repetitive flights.

Muscle also responds badly to prolonged, static mechanical loading. The body attempts to compensate in such circumstances by exerting muscles to maintain a correct, safe anatomical position. Lundervold³ showed that with the onset of fatigue, muscle activation then spreads to other groups that were initially quiet. More generalized muscle fatigue then sets in. Liu, et al.⁴ demonstrated by fMRI that the brain increases its output by recruiting more brain cells into reinforcing fatiguing muscle - “the brain similar to the motoneuron pools in the spinal cord attempted to compensate for the loss of force-generating ability of the fatiguing muscles by recruiting more cells into action”. Parnianpour, et al.⁵ also showed that, eventually, over the passage of time, “Fatigued muscles are less able to compensate any perturbation in the load or position of the trunk ...”

An example of a typical generator of muscle fatigue is the following. If heels are not properly supported to prevent feet constantly slipping to the cockpit floor, pressure on the rudder pedals is increased so that friction maintains the optimum foot-position. This requires static, muscle loading as both feet are pressed at once and in excess of the force needed to normally operate the pedals.

A corollary to all the above is that prior to flight, pilots cannot detect that they will become uncomfortable later on due to these mechanisms. This is extremely important.

Pressure-mapping work undertaken on discomfort and cockpit seating by Jackson, et al.⁶ as a result of this survey proved that clothing and items in pockets can generate extreme discomfort with the passage of time – although pilots cannot detect this prior to commencing flight. Pilots’ clothing, in particular trousers, frequently creates uncomfortable, high-pressure points where seams overlap or where studs and zips protrude. It is for this reason that Formula 1 racing-car drivers wear seamless overalls. Where possible, pilots need to adopt a similar policy. The role of garments, therefore, is critical (Figs. 9 and 10). The inclusion of objects in pockets also creates uncomfortable, high-pressure points. Even a single, small coin left in a back pocket can make a tremendous difference. Some people are so “angular” that even the elastic in their underwear can create pressures that will guarantee discomfort with the passage of time (see Fig. 11).

By way of illustration of the potential, unfortunate consequences of discomfort building up over time, during an Open Class Nationals at Lasham, towards the end of a long flight a pilot spun down through a glider gaggle, fortunately missing all other aircraft. On being questioned later, the pilot said there was no excuse as it was entirely due to his own error. When pressed further an answer did emerge – leg muscle fatigue⁷.

No link between pilot height and discomfort

This was an unexpected result. Instead of discomfort becoming disproportionately apparent in tall people, it appeared

that pilots of all heights were equally likely to exhibit discomfort.

Cramped cockpits, the biggest single source of complaint

Cramped cockpits do not always pose problems for height reasons (tall people have differing ratios of torso to limb length) but also, for example, for musculoskeletal range of movement reasons. The site of musculoskeletal discomfort does differ according to pilot height (Fig. 4).

Both military and commercial aviation have long recognized the need to improve pilot comfort. After aircraft have been designed and built, there is typically sufficient cockpit space to permit modifications for pilot comfort and ergonomic reasons. In the case of gliders, their small fuselage cross-section makes cockpit retro-modification impractical. Boermans, et al.⁸ showed that the length of a glider may be increased without drag penalty. However, an increase in 10% in the height of a fuselage to create space for improved crashworthiness leads to a 13% increase in drag coefficient. For performance reasons, this maintains the incentive to reduce cockpit cross-sectional area at the expense of pilot space.

Gliding, therefore, is faced with an apparently intractable problem. Pheasant⁹ showed that in virtually all European countries plus the United States, Canada and Australia, the increasing trend in stature of the young adult population is 10 mm per decade. This will continue into the first or second decade of this century. Cole¹⁰ confirmed this and also highlighted a 30 mm increase per decade for young adults in most East European countries. Taller, young adults are more likely to experience a cramped cockpit than older, shorter pilots and this trend is set to increase as the younger generation gradually supplants the shorter gliding population. With increased experience, young, taller adults will be attracted to purchase the more affordable club-class gliders designed in an earlier age of shorter pilot and designer¹¹. Many will inevitably become uncomfortable in them.

Legislators, unaware of the critical dimensions of glider cockpit space, and without knowledge of the critical implications of adult height increase, also seek to impose additional cockpit instrumentation, adding to the physical restrictions imposed on the pilot.

By combining categories, lower limb is the most important area of discomfort

Every body is different. For example, one pilot may have a considerably greater range of ankle movement than another of similar stature and sex. Women have 5-15% more flexibility than men⁹ but their leg-length is 72% that of men¹². Furthermore, Tanner, et al.¹³ and Ali, et al.¹⁴ point out that the incremental growth in stature of the adult population occurs through an increase in lower-limb length rather than the torso. This may explain the predominance of lower-limb discomfort shown in the survey. It strongly suggests that lower-limb disorder will become more prevalent in the future unless cockpits are enlarged.

As well as limb-length, the range of joint and muscle movement that is available also plays an important role. Poor design can mean safe limits being exceeded. For example, rudder pedals can cause discomfort and possible injury when a greater range of ankle and foot movement is required than is anatomically possible. A pilot's resulting compensatory action, then, affects the whole leg. The optimum for muscle tension is situated within its midrange of movement. In the case of the ankle, for example, Marsh, et al.¹⁵ describe how the "*optimum length of muscle and maximum voluntary torque is developed at 10 degrees of plantarflexion, and decreases sharply as the ankle is dorsiflexed beyond 5 degrees*" in healthy, young men. Thus, only a 15 degree ankle-joint arc movement is sustainable. As a consequence, in gliders, at the point of greatest arc extension, when the muscle-generated force is lowest, the rudder pedal requires the greatest force. This is because, at this juncture, the rudder makes the greatest deflection into the air-stream. The US Department of Defense states that "*Rudder pedals should [also] be capable of supporting both the ball of the foot and the heel*"¹⁶. In an upright, seated position in military aircraft, this is achievable. This is not the case in modern gliders' supine seating position. This produces the following consequence. The foot-length of the 95th percentile of British males aged between 19 and 65 years is 285mm and that of the 5th percentile of women is 215mm. There is, therefore, a difference between them of 70mm. Yet pedal foot-length remains non-adjustable in gliders (see Fig. 12).

All this shows that the complaint of mildly overstraining lower-limb muscles in gliders seems to have an evident explanation. To overcome this, one pilot went to the length of building up the cockpit floor using expanded polyurethane foam. This enabled him to support his heel to position the ball of his foot at the most advantageous position on the rudder bar when the pedals were slid back to his preferred flying position (see Fig. 13).

Complaints about the lower limb even included the position of instrument panels. One pilot (height 1.91m, age 28, with 17 hours total flying experience) complained that the panel in a training glider had worn a hole through his trousers and bruised his shin. Despite the front-cockpit rudder pedals being adjusted fully forward, he was unable to reach them due to the panel obstructing his leg (see Figs. 12, 14 and 15).

Beginner pilots' lack of comfort

Experienced pilots may well have forgotten any discomfort experienced during their training of decades ago. For trainees, discomfort becomes a subsidiary issue when faced with the initial excitement of learning to fly. As experience grows and flight times increase, the time-factor-dependent issue of discomfort (described earlier) can start to emerge. Drop-out of early, pre-solo pilots is well known. Derek Piggott estimated that during his tenure as CFI at Lasham, 50% of new trainees failed to renew for a second year. Birch¹⁷ confirmed that at Cambridge, the historical drop-out was 45%. It

is not impossible that an uncomfortable training and early-solo experience contribute partly to this significant fall-out ratio.

Comfortable pilots fly more hours

This phenomenon has informally become known as the “Purnell Effect”, being originally hypothesized as a result of the 2003 survey. The late Alan Purnell, who participated in the latter, professed to be extremely comfortable at all times. He flew 300 hours in 2003, having built up a total of 10,000 gliding hours. A consequence of the Purnell Effect is that the comfortable enjoy more flying than others at a lower hourly cost.

A corollary to this is that high-hours pilots are likely to be amongst the most comfortable. In turn, they can be particularly skeptical that cockpit discomfort can even exist as an issue. As such individuals are often influential, the topic of cockpit discomfort has a tendency to be relegated to the unimportant. As an illustration of this, a senior and influential instructor stated, “*I can comfortably mould myself into any glider.*”

Conclusion

“Discomfort” describes an insidious condition that strikes pilots of all experience and abilities. Because it manifests itself with the passage of time, it is difficult to detect before flight. It reveals itself to be a serious inhibitor to the build up of flying hours in gliders.

Discomfort generated in the lower limb is the most significant area of concern and appears to have been underestimated by glider manufacturers.

As well as the above, we recommend further detailed research in the other areas where the surveys provide clear indications of the topics that require serious attention, which include lumbar, buttocks⁶ and cramped cockpits.

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Table 1
Summary of 2004 Survey, All Pilots.

2004 Survey	Age (yrs)	Height (m)	Height (ft)	Total hours flown	Total hours flown 2004	Longest flight achieved (hrs)	Longest flight in 2004 (hrs)	Cockpit comfort level (0-5)	Cockpits reported
All respondents:				207,779	10,297				820
Average :	54.1	1.78	5.83	1,060	53	6.4	4.5	1.9	4.2
Males	54.3	1.79	5.87	1,095					
Females	51.0	1.65	5.41	524					

Table 2

Items in the cockpit that cause pilot discomfort

Cockpit item reported	*Reports	Average. Pilot height (m)
Cockpit too small	112	1.82
Seat	53	1.79
Controls	41	1.77
No support	20	1.77
Canopy/headroom	18	1.85
Parachute	13	1.78
Panel/cutting, rubbing	12	1.82
Cold/noise	9	1.76
Headrest	4	1.82
Bladder	5	1.77
	287	1.80

*Several reports may relate to one cockpit

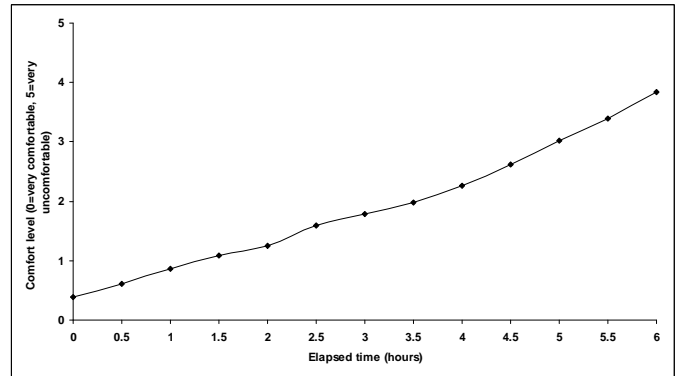


Figure 2 Average comfort level of all participants in Fig. 1. The perceived level of discomfort appeared to increase approximately linearly with time. Figure 2 is rescaled for comparison with the 2004 survey.

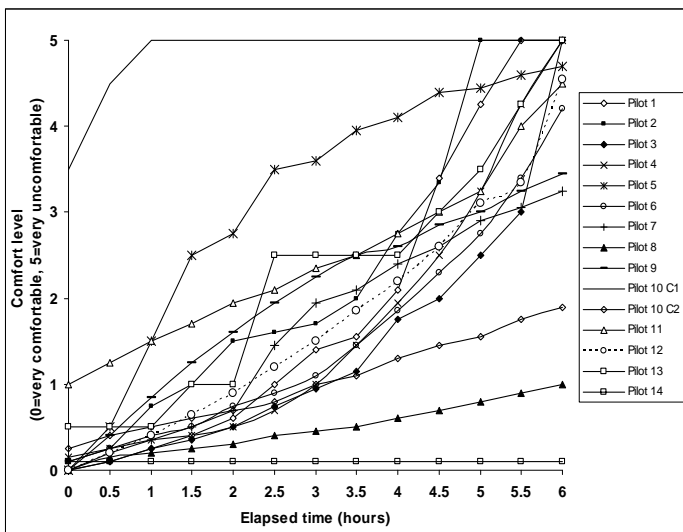


Figure 1 Almost all pilots become uncomfortable with the passage of time; 14 pilots report, 15 cockpits, Pilot 10 reports cockpits C1 and C2.

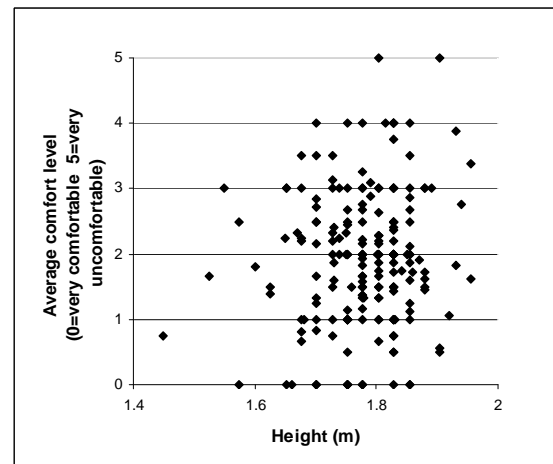


Figure 3 There was no correlation between height and discomfort.

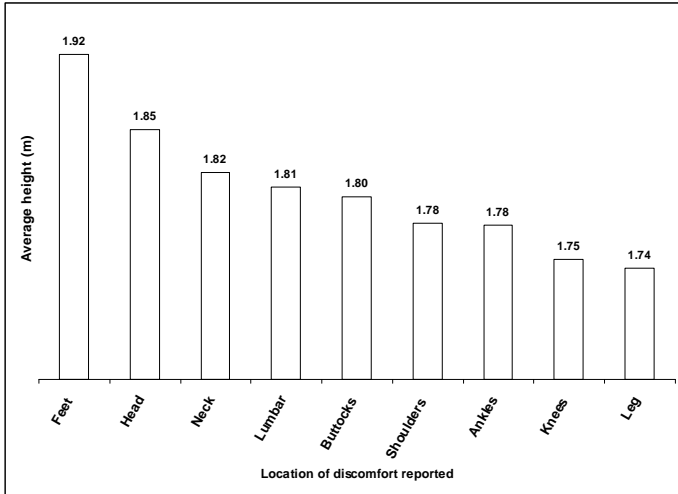


Figure 4 Although tall pilots were no more uncomfortable than others, when they exhibited discomfort they were likely to suffer from feet and head problems.

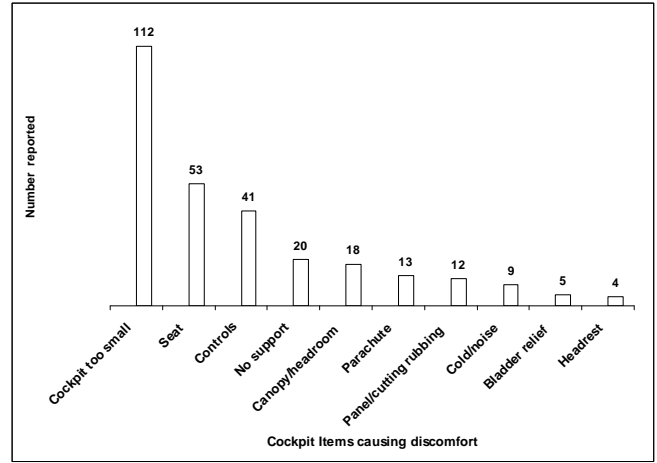


Figure 5 Cramped cockpits were by far the most important source of complaint relating to items that cause discomfort.

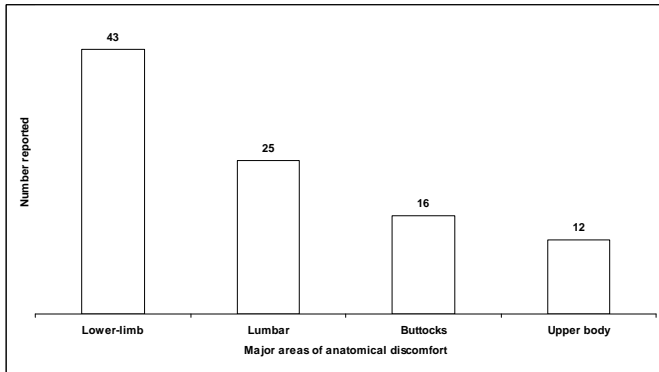


Figure 6 Combining categories of Fig. 4, lower limb discomfort was revealed to be by far the most important area of discomfort.

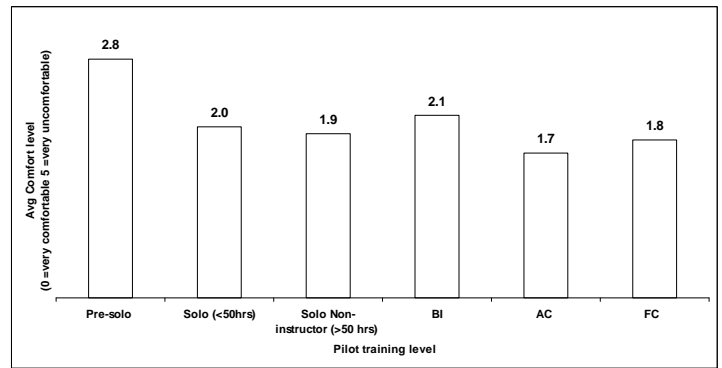


Figure 7 Beginner pilots were the least comfortable (BI: Basic instructor, AC: Assistant category instructor, FC: Full category instructor).

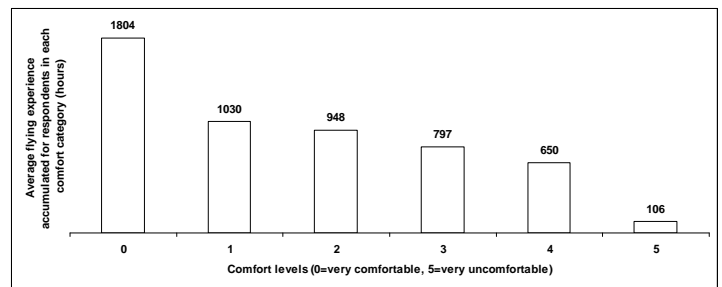


Figure 8 Comfortable pilots flew significantly more hours than others.



Figure 9 Seam ridge in jeans.

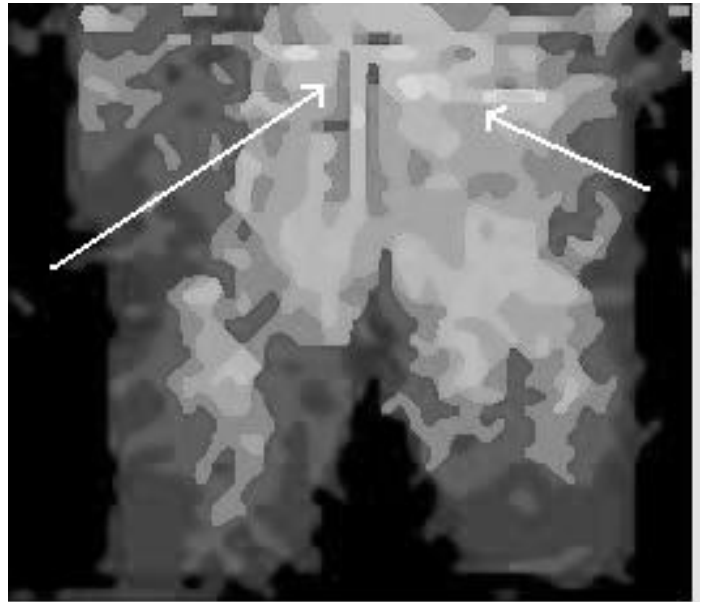


Figure 10 High-pressure lines produced by jean seams. Tekscan pressure map: highest pressure lightest.

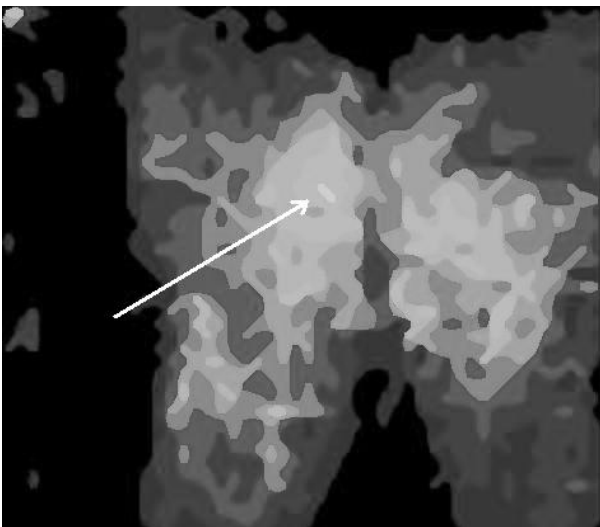


Figure 11 High pressure created by elastic in underwear. Tekscan pressure map: highest pressure lightest.



Figure 12 Cockpit floor raised for leg and heel support. .



Figure 13 Foot reach to pedal impeded by panel.



Figure 15 Instrument panel edge in leg contact.



Figure 14 Hole worn in trouser leg.