

“Aircrew Endurance and Lethality” The Martin-Baker Approach to Comfort

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Abstract

With governments wanting better performance from their aircrew and aircraft, demands upon crews are increasing. In particular, increased mission durations have led to a degradation of crew comfort.

The subjective nature of previous evaluations and the previous short duration missions have often led crews to the belief that a seat is perfectly comfortable, and it is only when changed mission profiles requiring extended seated durations that discomfort becomes an issue. Martin-Baker have approached this issue using live subjects for extended duration comfort studies, utilising both the Tekscan pressure mapping system and the 11 point General Comfort Rating (GCR) questionnaire to understand how early pressure contour images can foresee the forthcoming discomfort, hours before they affect the sitting aircrew.

It is acknowledged that comfort affects the state of mental and physical well being of the aircrew, and their lethality. Therefore understanding their endurance requirements and providing solutions to solve these issues are imperative for the future of high performance fast jet aircrew.

Introduction

This program has been running for 8 months and during this time an investigation into how pilot comfort is affected by increased mission times has been addressed.

When designing ejection seat profiles, two main problems occur, the first is how sufficient comfort can be offered to a pilot so that backache, reduced blood flow and muscle damage leading to fatigue and reduced lethality can be prevented. Secondly, is how such a comfortable sitting posture can meet the requirements for a safe and optimal ejection from the aircraft.

It is considered that historically comfort has been neglected, and in the past with short sorties this may have been acceptable, but the emergence of this problem is all the more apparent since the introduction of mid-air refuelling and increased mission durations. This has led to pilots sitting for in excess of 8 hours with minimal movement.

Previous seat evaluations by Fernandez and Poonawala (1998) have been able to show that the comfort of a sitting platform can be assessed without the need for equal duration comfort trials. Their work explains how long it should take to evaluate a seat subjectively using 8-hour comfort trials and using the 11-point general comfort rating scale (GCR) (Fig. 1) devised by Shackel *et al.* (1969). They conclude that at the end of the third hour, the results obtained were not significantly different from those obtained at the end of 8 hours.

Rating	Description
1	I feel completely relaxed
2	I feel perfectly comfortable
3	I feel quite comfortable
4	I feel barely comfortable
5	I feel uncomfortable
6	I feel restless and fidgety
7	I feel cramped
8	I feel stiff
9	I feel numb (or pins and
10	needles)
11	I feel sore and tender
	I feel unbearable pain

Fig. 1 11-point general comfort rating scale devised by Shackel *et al.* (1969)

The introduction of pressure mapping techniques like the Tekscan System have increased the science behind comfort, moving it away from a purely subjective definition, to a quantifiable, graphical image, when used with reference to a controlled baseline.

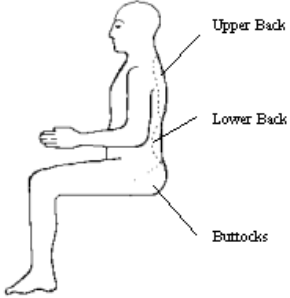
This comfort evaluation methodology when used in conjunction with a subjective questionnaire has been the chosen method for the recent stability improvement program (SIP) being undertaken on the NACES F-18 ejection seats.

Method

Two human anthropometric extremes volunteered to undertake comfort trials on various new cushioning materials and sitting profiles to determine the ability of each material to remain comfortable over 3 hours of seated duration. Wearing summer AEA and a PCU-56/P torso harness each subject was required to sit in an unarmed mock-up NACES equipped cockpit for three hours being monitored at 5-minute intervals by the Tekscan system, whilst completing a comfort questionnaire every hour (Fig. 2) produced from combining the 11-point general comfort rating scale (GCR) and the work of Lusted *et al.* (1994) who devised the body area chart discomfort checklist for monitoring the discomfort of any particular body part.

DOES YOUR BODY HURT NOW?

	How bad is it? (Mark scale to indicate intensity)		GCR Scale Rating	What kind of sensation? (indicate one or more)	
	No Pain or Discomfort	Agony			
			1 to 11		
Head or Neck				<input type="checkbox"/> Ache <input type="checkbox"/> Burning <input type="checkbox"/> Tingling	<input type="checkbox"/> Sharp pain <input type="checkbox"/> Numb <input type="checkbox"/> Other
Shoulder				<input type="checkbox"/> Ache <input type="checkbox"/> Burning <input type="checkbox"/> Tingling	<input type="checkbox"/> Sharp pain <input type="checkbox"/> Numb <input type="checkbox"/> Other
Upper Back				<input type="checkbox"/> Ache <input type="checkbox"/> Burning <input type="checkbox"/> Tingling	<input type="checkbox"/> Sharp pain <input type="checkbox"/> Numb <input type="checkbox"/> Other
Arms & Hands				<input type="checkbox"/> Ache <input type="checkbox"/> Burning <input type="checkbox"/> Tingling	<input type="checkbox"/> Sharp pain <input type="checkbox"/> Numb <input type="checkbox"/> Other
Lower Back				<input type="checkbox"/> Ache <input type="checkbox"/> Burning <input type="checkbox"/> Tingling	<input type="checkbox"/> Sharp pain <input type="checkbox"/> Numb <input type="checkbox"/> Other
Buttocks				<input type="checkbox"/> Ache <input type="checkbox"/> Burning <input type="checkbox"/> Tingling	<input type="checkbox"/> Sharp pain <input type="checkbox"/> Numb <input type="checkbox"/> Other
Thighs				<input type="checkbox"/> Ache <input type="checkbox"/> Burning <input type="checkbox"/> Tingling	<input type="checkbox"/> Sharp pain <input type="checkbox"/> Numb <input type="checkbox"/> Other
Knees				<input type="checkbox"/> Ache <input type="checkbox"/> Burning <input type="checkbox"/> Tingling	<input type="checkbox"/> Sharp pain <input type="checkbox"/> Numb <input type="checkbox"/> Other
Lower Legs/ Calves				<input type="checkbox"/> Ache <input type="checkbox"/> Burning <input type="checkbox"/> Tingling	<input type="checkbox"/> Sharp pain <input type="checkbox"/> Numb <input type="checkbox"/> Other
Ankles and Feet				<input type="checkbox"/> Ache <input type="checkbox"/> Burning <input type="checkbox"/> Tingling	<input type="checkbox"/> Sharp pain <input type="checkbox"/> Numb <input type="checkbox"/> Other



Total Sector Length

Hours Elapsed

Date

Subject

Signature

Fig. 2 Comfort questionnaire

Further to this, a joint venture with the Rapid Manufacturing Group at Loughborough University has been to determine an improved sitting profile and rapidly manufacture it for testing has lead to 15 RAF pilots having their buttock indentation determined, scanned and computerised. This was achieved by using a Burnett beanbag seat. The pilot was seated in the correct position; the air was then evacuated, leaving an indentation of the pilot's buttocks. This was then laser scanned into a computer and analysed.

Results

The descriptive statistics for the two subjects are shown in Table 1. The score awarded to each cushion per hour is displayed in Figures 1, 2, 3 and 4 for the lower back and buttock region, for both the small and large subjects respectively.

Table 1. Subject descriptions

Subject	Sex	Age (Yrs)	Weight (Kg)	Height (mm)	Shoulder Height Sitting (mm)
Small	F	18	100.25	1645	704
Large	M	32	51.7	1900	561

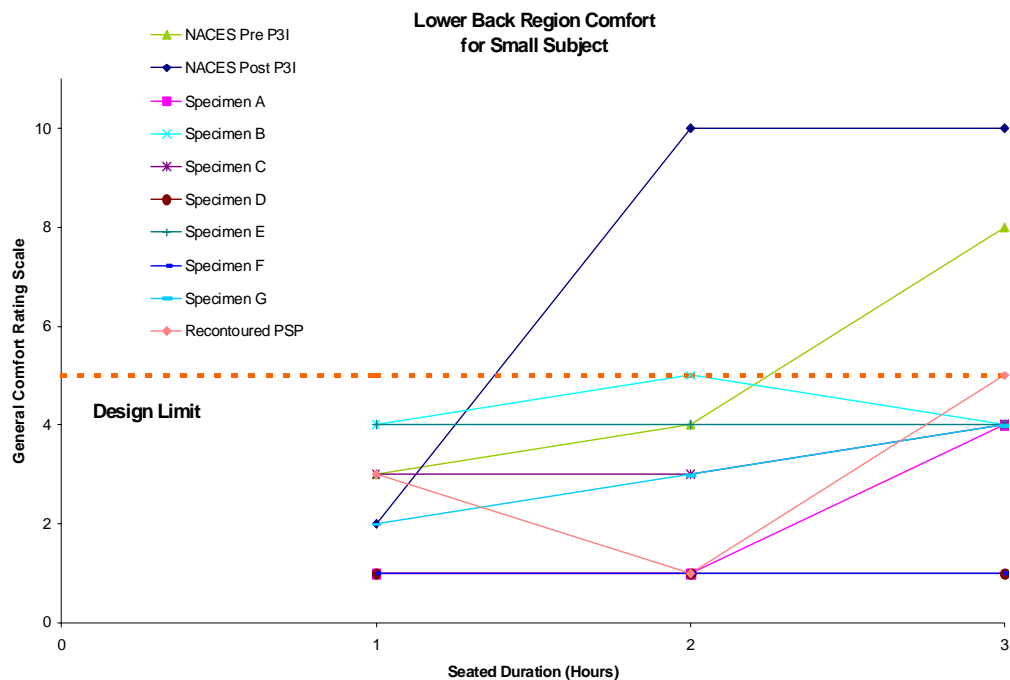
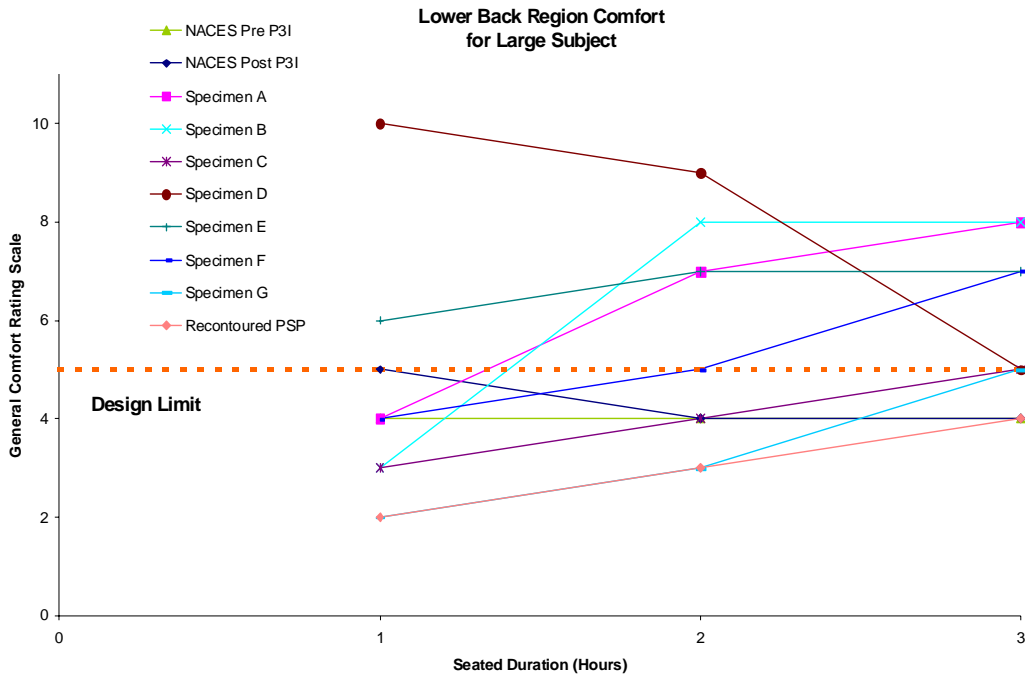


Figure 1. Displays how the small subject evaluated the comfort of the lower back for various seated profiles and cushions over a 3-hour period.

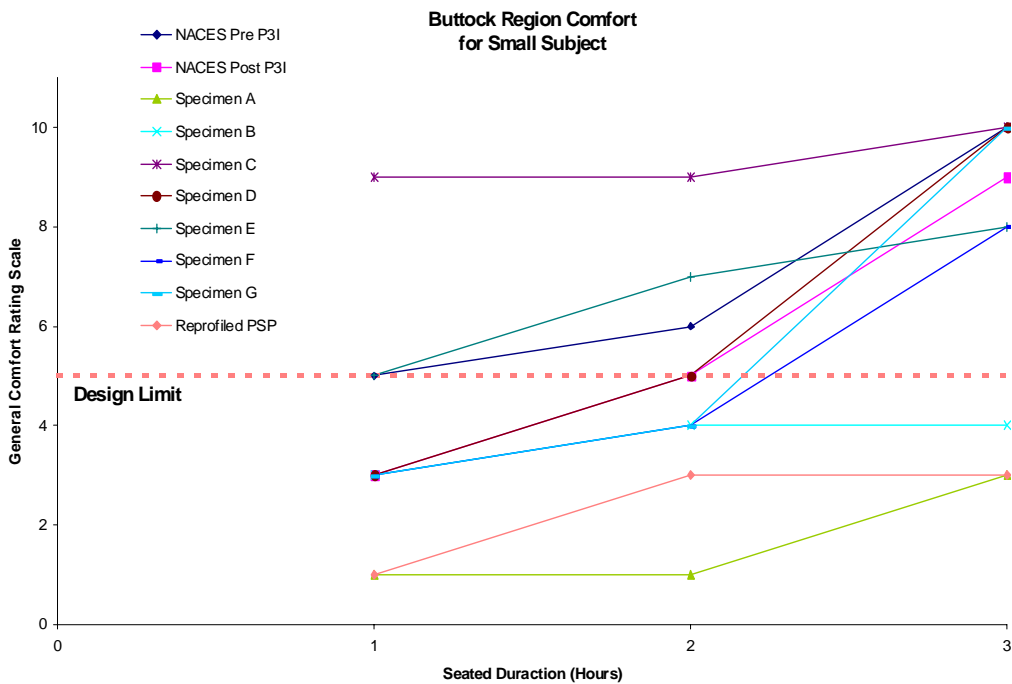
A design limit is displayed at a general comfort rating value of 5 “I feel uncomfortable”; this is to show the comfort limit of any seated duration cushion. If the subject becomes uncomfortable, the cushion or profile has not succeeded. It must also be considered that if only the base cushion has changed then the buttock results are of greatest importance.

The various cushions tested are [1] air-filled, specimens A and B, [2] slow response/memory foam, specimen C, [3] gel filled, specimen D, [4] structural honeycomb, specimen E, and [5] re-shaped foam, specimens F and G.



Figure

re 2. Displays how the large subject evaluated the comfort of the lower back for various seated profiles and cushions over a 3-hour period.



Figure

3. Displays how the small subject evaluated the comfort of the buttocks for various seated profiles and cushions over a 3-hour period.

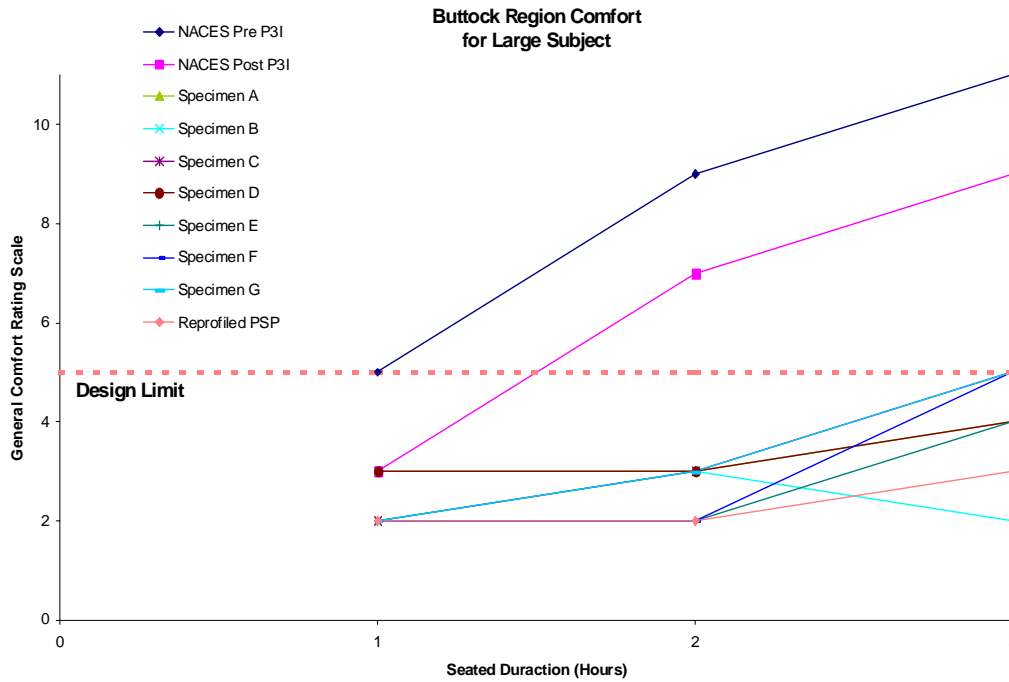


Figure 4. Displays how the large subject evaluated the comfort of the buttocks for various seated profiles and cushions over a 3-hour period.

Discussion

The previous four figures display a trend showing that as the seated duration increases most cushions are perceived to become less comfortable. This is to be expected, as people do not like sitting for long periods of time without movement. The results from the comfort questionnaire show that air-filled base cushions, i.e. specimen A and B have good comfort properties for the buttocks along with the results from the re-profiled sitting platform.

The difference between the small and large subject are significant in understanding comfort. For example the large subject found the specimen E and the specimen C cushion acceptable giving them a score of 4 and 5 respectively after 3 hours, this compared to the small subject for which the cushions scored 8 and 10 respectively. It is important to understand how the cushion holds the subject, and whether the subject gets hot by a temperature rise within the cushion.

The Tekscan system allows a more qualitative approach to comfort, as long as a scale and baseline are used.

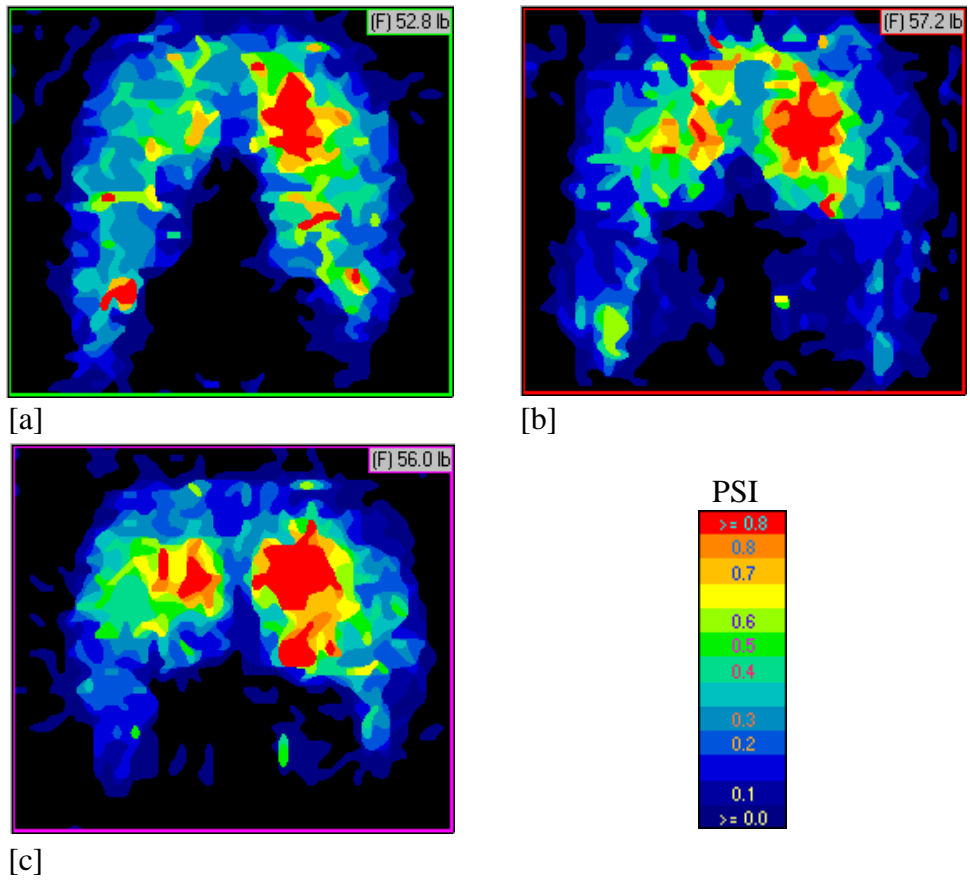


Figure 5. Tekscan images taken of the small subject positioned in a NACES cockpit on three different sitting base surfaces. [a] a flat surface, [b] the existing NACES profile and [c] the new re-contoured profile.

From solely viewing the images in Figure 5, there is no clear way to see which will be most comfortable. All three images appear to display ‘hot spots’ nucleating around the Ischial Tuberosities, the sitting bones. Surrounding the red area is a gradual pressure decline displayed by the slow reduction in colour presenting a smooth loading rather than a point load, where a point load would include shear stresses in the surrounding muscles and flesh reducing the blood flow to the legs and become uncomfortable with an hour or two. It is therefore hard to see that [c] is the most comfortable seated image for both the small and large subject with no modifications to the contour or cushion.

The only way to review this is by understanding that the cushion needs to support the body and buttock flesh, containing it rather than allowing it to spread sideways. By achieving this, a smaller more uniform surface area can be shown, i.e. Figure 5 [c]. This allows the body to utilise its own natural padding to support the subject’s weight, and separate the Ischial Tuberosities from the sitting surface. By supporting the body and making contact with it, by re-contouring a rigid surface, or using a foam material, the cushion and back pad will perform in a more comfortable way. A soft-top layer can be added, but completely soft is not believed to be the way to a duration comfortable position.

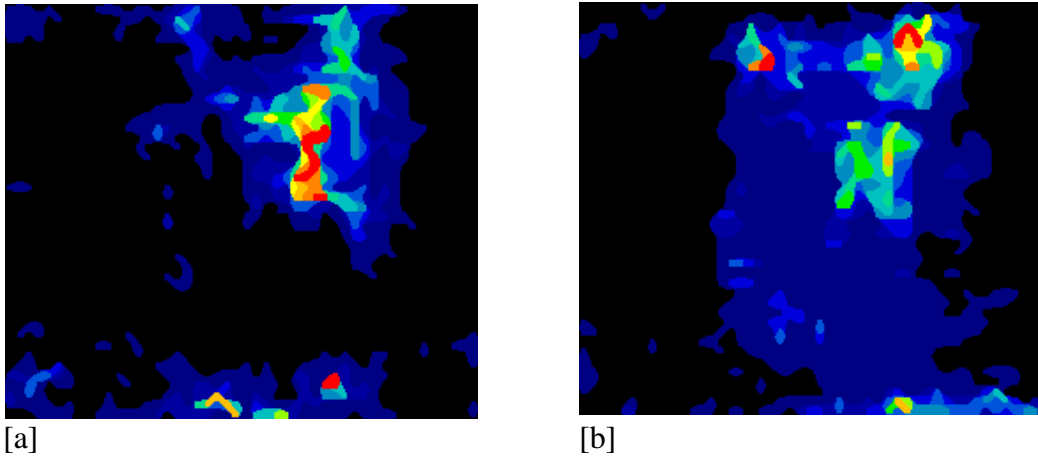


Figure 6. Displays the Tekscan image of two back pads for the small subject. [a] NACES Pre P³I and [b] specimen A

Figure 6 displays the difference between two cushion back pads. Referring back to Figure 1 shows that when there is no lumbar contact initially comfort is assumed but over time, the lack of lumbar support results in a GCR score of 8. This compared to the image of specimen A, where a greater contact area can be observed, supporting the back better, and resulting in a GCR score of only 4 after 3 hours. These conclusions can be drawn quickly when using the Tekscan pressure mapping system and have increased accuracy when compared to the perceived comfort of the subject after only a few minutes.

Many cushions display instantaneous comfort but over time the cushion collapses ‘bottoms out’ or experiences a temperature rise due to its inability to breathe. These test results show that most cushions only begin to become uncomfortable after 1 or 2 hours, therefore previous short duration studies (less than 1 hour seated) cannot be used to effectively assess the duration comfort of a cushion. For pilots instantaneous comfort is not the solution, rather it is an unchanging cushion solution that will remain comfortable and acceptable for the entire flight duration. Leaving the pilot unaware of they’re sitting surface and free to concentrate without fatigue on their mission.

Conclusion

Based on the results of this early study, we can conclude that short duration studies using only a perceived comfort evaluation will not predict the true behaviour of the cushion after 2 or 3 hours.

The devised comfort questionnaire has improved the quality of the subjects evaluation by limiting the variables and removing the need for comments by introducing crosses and the GCR number scale, which is much quicker and easier to use.

The introduction of the Tekscan pressure mapping system can show if the back has a full even contact with the back pad cushion. If the lower region around the lumbar displays a lack of contact, aching will occur in the lower back within 3 hours and this can be seen within moments of the subject sitting down.

Presently, understanding comfort for the buttocks is more complex. A smaller more uniform contact area, which supports and holds the buttocks, is proven to be better than one that allows

the flesh to spread outwards. But for both comfortable and uncomfortable cushions, similar 'hot spots' are being observed and this phenomenon needs further investigation.

Our aim is to shorten the sitting duration required to accurately assess a cushion using various pressure mapping and comfort assessment techniques and therefore bring it in line with the ability to quickly assess if lower back pain will emerge within 3 hours.