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Publication date
2021

Document Version
Accepted author manuscript

Published in
Comfort Congress 2021

Objective comparison of two cushions: pressure distribution and postural perceived discomfort

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ABSTRACT

Designing seats is crucial not only for health issues but also for the (dis)comfort perception. The seat pan design could be mainly influenced by two factors: pressure distribution and seat contour. For seat pan discomfort, the lower average pressure is accompanied by less discomfort. Moreover, a seat contour with a large contact area is correlated with more comfort. So, a shaped seat pan was accurately realized following the buttock-thigh shape of an international population (including P5 females and P95 males). For the comfort assessment, a comparison was made between this shaped seat pan (shaped cushion) and a standard aircraft seat pan (flat cushion). Twenty-two international participants (11 males and 11 females, with BMI between 16 and 30) took part in the blind experiment assuming six different postures. Subjective data were gained from questionnaires, whose results showed that the shaped cushion is better in terms of perceived postural comfort. Also, 64% of participants chose the shaped cushion as a preferred cushion because it was more comfortable and suitable for the buttock shape. Objective data were gathered with a pressure mat, and results showed a higher contact area and lower mean pressure distribution for shaped cushion. Significant correlations were calculated between objective and subjective data with Spearman Correlation coefficients.

KEYWORDS

Seat-pan, Human-centre-design, Pressure map

Introduction

Remaining seated for extended periods, such in long-haul flights, increases the risk of pressure ulcers development over the buttocks, as the soft tissue in this area is squashed between two surfaces, the seat and the bones of the pelvis (Stephens and Bartley 2017; Schubert, Perbeck, and Schubert 1994). Thus, it is crucial for designing the seat not only for the (dis)comfort perception but also for the health issues. The seat pan design could be mainly influenced by two factors: pressure distribution (Kilincsoy et al. 2016) and seat contour (Smulders et al. 2016). Pressure distributions are assumed to correlate with seat (dis)comfort because they are obtained with a real sitting person (Franz, Vink, and Bubb 2010; R. Fang, Gao, and Xie 2016; Fasulo, Naddeo, and Cappetti 2019). Indeed, the pressure mapping system is the most widely used to assess the perceived(dis)comfort thanks to its relatively low cost and easy use (Zemp, Taylor, and Lorenzetti 2015; Wang et al. 2020). Also, the pressure distribution presents more statistical correlations with discomfort (De Looze et al. 2003; Hiemstra-van Mastrigt et al. 2016). Moreover, interface pressure depends on postures, seat characteristics (also the shape), assumed postures, anthropometric measurements (Hiemstra-van Mastrigt et al. 2016). For seat pan discomfort, the lower average pressure is accompanied by less discomfort (Noro, Fujimaki, and Kishi 2004). Moreover, there are indications that a seat contour resulting in a large contact area is correlated to more comfort (F. Fang et al. 2016; Zemp, Taylor, and Lorenzetti 2016; Zenk et al. 2012). One way would be to use a shaped contour shell derived from the human body and handle fewer foams to fit a considered large population, including the P5 females and P95 males. Consequently, authors realized a so-called “shaped cushion” aiming to follow the buttock-thigh shape of an international population (including P5 females and P95 males). A comparison is then required to validate the hypothesis that states: the shaped cushion could have more benefits than the standard commonly used “flat cushion”.

Materials & Methods

Experiment protocol has been approved by the Ethical Committee at Delft University of Technology (TU Delft), in the Netherlands. Participants have been explained about the protocol and asked to fill the Informed Consent before experiments.

Seat-pan cushions

Aircraft seats with two different seat-pan cushions have been used: 1) “Flat cushion”, having a fixed foam thickness, as commonly used in standard aircraft seats; 2) Shaped cushion”, made by the same type of foam but with a different shape and contour that could be suitable for an international population. Seat pan’s contour and shape were based on a dataset of pressure maps, aiming to follow the buttock-thigh contour.

Pressure mat

The Pressure mat Xsensor LX210:48.48.02 has been used to evaluate the pressure distribution. The total sensing area is 24 inches x 24 inches (about 60.9 cm x 60.9 cm) with a very low thickness (0.03 inches, that is about 0.09 cm) allowed to detect a wide range of population without influencing perceived (dis)comfort.

Questionnaires

Questionnaires were used to gather subjective data after experiencing one cushion to detect participants’ sensations, overall perceived comfort and discomfort. Participants were asked to rate two questions: 1) Overall perceived discomfort (1=No discomfort, 2=Low Discomfort, 5=Discomfort, 7=High Discomfort, 9=Extreme Discomfort); 2) Overall perceived comfort (1=No Comfort, 2=Low Comfort, 5= Comfort, 7=High Comfort, 9=Extreme Comfort). Finally, at the end of the experiment, participants were asked to choose the preferred cushion (first or second cushion since it was a blind-test not to influence participant expectations (Naddeo et al. 2015)) and to explain the choice’s reasons of.

Postures

The cushion and posture orders have been planned for each participant adopting the Latin Square Method to randomize the order keeping the experiments repeatability (Fisher 1992; Fiorillo et al. 2019; Piro et al. 2019). The time assumed on each cushion was 44 minutes, supposing that inter-differences were more evident only after 40 minutes. The 5 planned postures were based on literature studies and are commonly assumed by passengers (Liu, Yu, and Chu 2019):1) upright; 2) bending forward with elbows on legs; 3) upright with leg crossed; 4) bending on the side with arm on armrest; 5) bending on the side with arm on armrest and crossing the legs. The last posture was always the desired posture, where participants could assume their comfortable posture freely during a flight.

Participants

Twenty-two participants (11 males and 11 females) were recruited through social channels of TU Delft, especially spreading emails, obtaining a large sample of the international population with high variability on age, height, weight, and body shape, as shown in Table 1.

Table 1. Demographic data of participants (n=22). BMI = Body Mass Index; WHR = Waist-Hip Ratio.

	Average	Median	Standard deviation	Max	Min
Age	28,73	27,50	5,55	48,00	24,00
Weight (kg)	64,64	62,50	13,00	95,00	48,00
Height (cm)	169,32	167,00	9,42	193,00	155,00
BMI (Kg/m2)	22,40	22,06	3,05	29,40	16,60
WHR	0,84	0,84	0,06	0,96	0,72

Experiments protocol

Once the participant came to the experiment lab, he/she has been briefed on the blinded experiment protocol. Then, the participant sat on the planned first cushion assuming for 7 minutes each given posture. Within 7 minutes, the pressure-mat recorded pressure distributions three times, for 30 seconds, at beginning, in the middle and at the end of this time slot. After 42 minutes on the first cushion, the participant was asked to fill the questionnaire. Then a break of 5 minutes was given before repeating the experiment on the second cushion. After experiencing both cushions, the participant has been asked to choose the preferred cushion and explain why.

Results & Discussions

Subjective data were gathered from questionnaires, while objective data were gathered from the pressure mat evaluating pressure distributions and contact areas. Statistical differences were calculated with the Wilcoxon Signed-Rank test, and significant Spearman's correlations with IBM® SPSS® Statistic 26 software.

Subjective data

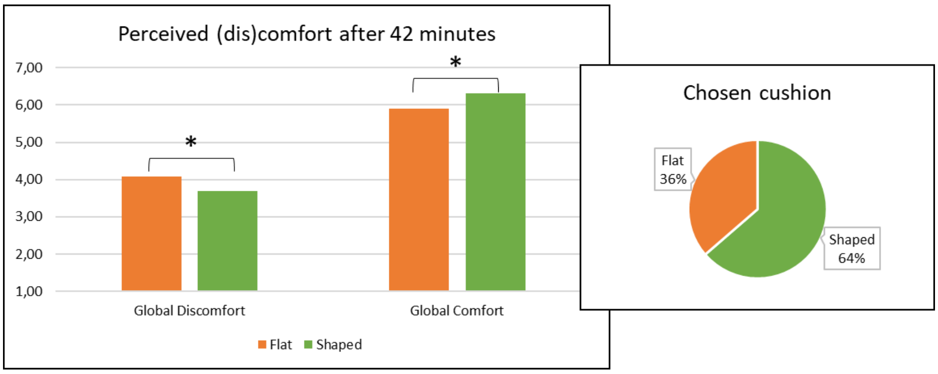

Figure 1: Results from questionnaires regarding the perceived postural discomfort and comfort rated on a 10-point scale. Significant differences are shown with *

Figure 1 shows results of Global Perceived Discomfort, Global Perceived Comfort and the percentages of the chosen cushion. Most participants chose the shaped cushion because they felt it softer, more comfortable and more adequate for their body shape. Instead, the flat cushion gave more support, but they felt more pressure on the lower body areas.

Table 2 shows significant correlations from Spearman Correlation analysis; in particular, the global comfort is negatively correlated with the global discomfort meaning that by reducing the discomfort, the perceived comfort could arise per each cushion.

Table 2: Significant Spearman Correlations for subjective data. LBD=Lower Body Discomfort

		Global Discomfort Flat	Global Comfort Flat	Global Discomfort Shaped	Global Comfort Shaped
Global Discomfort	Flat	-	-,750**	,762**	
	Shaped	,762**	-,614**	-	-,697**
Global Comfort	Flat	-,750**	-	-,614**	,668**
	Shaped		,668**	-,697**	-

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Objective data

The comparison among cushions was evaluated confronting pressure distributions and contact areas by differences: data from the shaped cushion have been subtracted with data from the flat one. Negative values of average pressure mean the pressure distribution on the shaped cushion is lower than the flat cushion; positive values of contact area mean the contact area on the shaped cushion is higher than the flat one. Figure 2 shows this comparison's results for each assumed posture, demonstrating that the shaped cushion presented less pressure and higher contact area than the flat cushion.

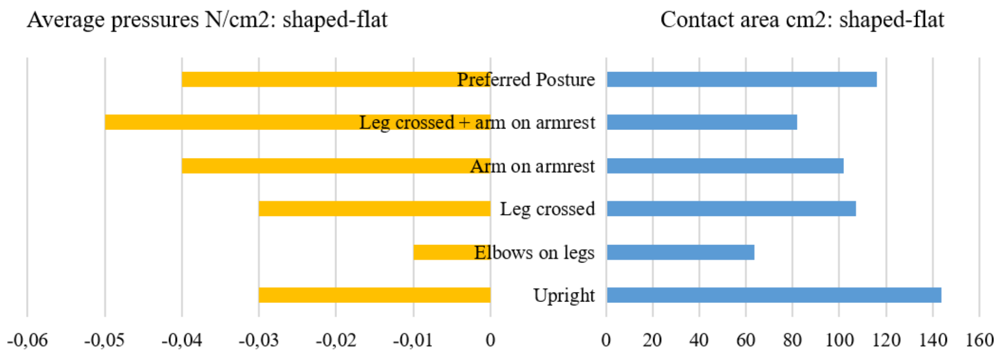

Figure 2: Result from the pressure mat: differences of average pressures and contact areas

Significant correlations have been calculated between objective data and subjective data with Spearman Correlation coefficients, as shown in Table 3. The presence of correlations between pressure distributions and perceived discomfort is aligned with literature studies. Moreover, pressure distributions and contact areas were strongly correlated with gender (p~0,6), indicating that these values were higher for men than women.

Table 3: Significant Spearman Correlations calculated between objective and subjective data for Flat and Shaped cushions (n=22).

		Average pressure					
		P1	P2	P3	P4	P5	P6
Global Discomfort	Flat	,770**	,503*	,432*		,656**	
	Shaped			,602**	,805**	,433*	,423*
Global Comfort	Flat	-,627**	-,597**		-,697**	-,556**	
	Shaped	-,433*		-,593**		-,457*	-,566**

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Conclusions

Sitting is an everyday activity that for a prolonged amount of time could lead to discomfort or, in the worst case, health problems. For these reasons, it is essential to design a comfortable seat preventively. Less pressure distribution at the contact interface between the seat pan and buttock-thigh area could lead to higher perceived comfort or discomfort reduction. The blind experiments performed at TU Delft demonstrated a shaped seat-pan cushion (designed as the buttock-thigh shape) was more comfortable than the flat standard cushion considering mainly objective data of pressure distributions. The shown subjective data of (dis)comfort perceptions were rated after experiencing each cushion and considered for correlations' purpose. The blind test was meant not to influence participant expectations knowing the difference between cushions a priori. In particular, results showed that the flat cushion scored higher perceived global discomfort while the shaped higher perceived global comfort. Also, 64% of participants preferred the shaped cushion because it was more comfortable and suitable for the buttock shape. As far as the pressure distribution, the contact area was always higher on the shaped cushion, even for all postures. The average pressure distributions for the shaped cushion were always lower than the flat one. Thus, the shaped cushion, having a wider contact interface, was more comfortable and results confirmed literature studies. Since this study could obtain pressure distributions for each cushion and each assumed posture, the next step will be developing pressure distributions maps to study the ideal pressure distribution and contact interface for aircraft seats.

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