A body-shaped lumbar-sacral support for improving car-seat comfort

Alessandro NADDEO[1*], Liliana DI BRIGIDA[1], Carlotta FONTANA[1], Jessica MONTESE[1], Manuel QUARTUCCIA[1], Mario NASTI[1], Matteo MARIA PISANI[1], Vito TURCO[1], Marco DE STEFANO[1], Iolanda FIORILLO[1], Rosaria CALIFANO[1]

[1] University of Salerno – Fisciano (SA), 84084 Italy.

* Corresponding author. Phone: +39 3207406170, Mobile: +39 089964061. E-mail address: anaddeo@unisa.it

Abstract Nowadays the ergonomic study of the driving position is a critical aspect of the design in the automotive field. Indeed, due to the rising needs on the market, car industries are focusing even on internal comfort. The use of the seat could cause some complaints in various regions of our body, especially in the lumbar-sacral one for prolonged postures. Thus, in order to reduce this kind of complaints, a comfort evaluation on a special lumbar support for driver seat has been done. Two prototypes of lumbar/sacral support have been realized: the first one was integrated into the seat and the second one was shaped as a removable pillow (removable support). Fifty participants were asked to rate the perceived comfort in lab tests performed on a seating-buck. Three tests, 5 min each, were performed in three different conditions: standard car seat, car seat with removable support, car seat with integrated support. Both subjective data (by questionnaires) and objective data (pressure at interface between backrest and driver) have been acquired and processed. Correlations between subjective and objective data have been calculated by statistical analysis and showed interesting results about comfort improvement through the adopted solutions.

Keywords: Car seat comfort, Seat design, Lumbar-sacral support, Body shaped pillow

1 Introduction

An automotive trade journal "Wards Auto" [1] estimated that the number of cars in the world surpassed 1 billion in 2010. Thus, the car is an integral part of our everyday routine. Despite of that, there are still some unsolved issues related on driving comfort, especially on car seat that represents an important factor [2,3].

Studies have been carried out to improve comfort by changing the seat pan tilt angle and the friction coefficient of the seat surface [4]; or by studying the pressure at the seat-man interface, where it had been found out there is a strong correlation between the pressure distribution and the lumbar-pelvic area pain [5].

Furthermore, a study indicated the ideal pressure distribution on the seat is the one with the minimum load in the pelvic area [6].

To study the seat's comfort, objective and a subjective method can be used. The subjective results are linked with questionnaires, such as Localized Postural Discomfort, Body Part Discomfort, CP-50 scale and so on, which differ on the scale [7]. The objective data can be gained from pressure-mat, sensors, tools and so on.

As regard as the pressure mat, information related to the seat–man interface contact, such as medium pressure contact, peak pressure, and contact area, could be sufficient for a short/medium time session analysis [8].

Moreover, De Looze [9] demonstrated that the pressure distribution is the objective measure with the most associations with the subjective evaluations.

A lacking of a lumbar support plays an important role on the global discomfort of the seat [3,10], thus a continuous contact in the lower back leads to a considerable reduction of lumbar pain [11] and to an improvement of seat comfort [12].

According to this, two lumbar supports had been realized following the comfort curve of the seat [13]: one integrated with the seat and one as a removable support.

The impact of those supports have on the driver comfort perception had been analysed and compared with the standard seat (without the support).

Since there are not substantial differences between with and without legroom in the analysis results [14], the man-seat contact had been analysed in laboratory.

This work aims to see whether the lumbar supports influence the postural comfort.

2 Materials & Methods

2.1 Realization of integrated lumbar support

Basing on the natural spine curvature while seated [13], a lumbosacral support, whose dimensions are chosen in order to involve a limited contact area with the body (i.e. a height at least equal to 200mm from the seat pan), has been modelled in the virtual environment of Rhinoceros®. The seat of the Fiat Grande Punto MY2013 was chosen as reference seat.

The curve representing the spine-shape was modelled and used for creating a solid that match perfectly the backrest.

Once obtained the virtual model, the physical model of the support was manufactured (hand made) using elastic-plastic with hysteresis foams; two types of foams, with different densities, has been chosen to achieve the desired shape: SIP 30PK and memory foam. The innermost layer was made with SIP 30 PK that has a higher density than the memory foam; memory foam was used as a surface layer for its heat-sensitive property. Indeed, the memory foam gradually deforms with the body heat, keeping this deformation in memory for a few seconds so adsorbing the gaps between the own subject's back shapes and the support itself and distributing the pressure evenly.

Foam layers were assembled by the Aquagum B/194-EC glue, applied with a catalyst by a special external mixing gun.

This foam support was split in two and integrated inside the seat-pan and the backrest of the FIAT seat (see Fig. 1), that was previously emptied for achieving an appropriate space for the pillow.

Fig. 1. Seat with integrated cushion

2.2 Realization of a removable lumbar support

In line with the aim of realizing a universal lumbar support that can be applied to any type of seat, it was decided, subsequently, to realize a removable support (Fig. 2). The dimension of the integrated model had been modified. In particular, in correspondence of the upper area, the thickness has been reduced from the initial value of 40mm to a value of 9 mm, to avoid that the passenger perceives a feeling of discomfort in that area.

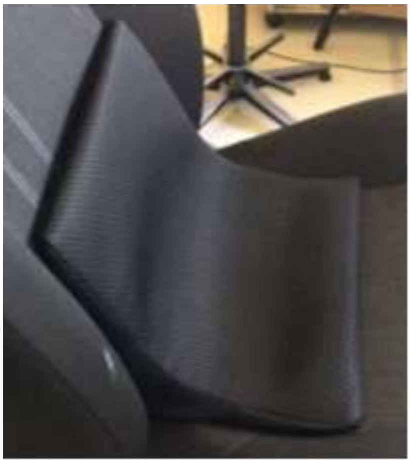

Fig. 2. Real prototype of the mobile cushion

This second support has been realized with the same sponges of the previous one and covered with DOUPLEX / 230 material (having characteristics very close to the seats' one).

2.3 Experiment set-up

The validation of the lumbar-sacral support function was obtained through a series of tests carried out in the laboratory on University of Salerno (UNISA).

Using a seating-buck system, two seats of the Fiat Grande Punto, one standard and one with the integrated support, has been placed opposite position. The seats layout and engagement system on the seating-buck metal frame allowed the longitudinal translation of the seats. The inclination between the back-pan and seat pan had been fixed at 101° for both seats [15]. The driving posture had been simulated by a built-in foot support.

Medilogic® Seat Pressure Measurement System had been used and positioned along the backrest (see Fig. 3) in order to acquire the pressure between the human back and the backrest itself.

Fig. 3. The Medilogic® Seat Pressure Measurement System placed on the seat

2.4 Participants

Fifty volunteer students, 17 females and 33 males, took part to the experiment. The 76% of them used to drive the car every day. Table 1 shows statistics about participants.

Table 1. Statistics of participants

	Range	Mean	SD
Age (years)	29÷19	23.4	2.02
Height (cm)	191÷150	173.04	9.42
Weight (kg)	90÷48.5	71.72	10.89
Body Mass Index	31.57÷17.71	23.92	2.95

2.5 Questionnaires

Questionnaires had been used to collect subjective data. Participants were asked:

- To give information about age, height and weight;
- To rate on a 10-point scale the expected comfort on the testing seat (from 1=”minimum comfort” to 10=”maximum comfort”);
- To rate on a 9-point Likert scale the body part perceived comfort after the test (from -4=”maximum discomfort” to 4=”maximum comfort”). The investigated body parts were: neck, upper back, lower back, buttock, upper tight, lower tight;
- To rate on a 10-point scale the global perceived comfort (from 1=”minimum comfort” to 10=”maximum comfort”);
- To express a comfort sensation choosing between “annoying”, “intrusive”, “cozy”, “unstable”, “no sensation”, “other”.

2.6 Protocol

Prior the experiment, participants signed an informed consent and had been instructed on how to perform the experiment.

The experiment had a total duration of 15 minutes spread over three different tests: test without support (standard seat), test with support, and test with integrated support. Each of these three tests lasted 5 minutes. For each test, the pressure has been measured through the Medilogic® System, connected to the backrest.

At the beginning of each test, once participant sat on the seat, the expected comfort has been asked and the pressure-mat system has been activated.

Then, after each test, participants have been asked to complete the questionnaire about the perceived comfort related to each specific part of the body.

After the experiment, the acquired pressure maps have been processed by Enthought Canopy software [16], a Python open access source, to obtain mean values of coordinates of the center of gravity, total load, coordinates of the involved area, total area of the mat, average pressure, number of sensors involved. Then, those data have been statistically processed by Excel routines.

3. Results & Discussions

3.1 Questionnaires

Outcomes from questionnaire results:

- The integrated lumbar support scored the higher comfort values than the standard seat: 7.18 vs 6.86 at the beginning of the tests, and 7.06 vs 6.48 at the end of the tests (Table 2).
- The removable support was the only one to score about same values of *Initial Comfort* and the final *Global Comfort* (Table 2).

- The integrated lumbar support scored highest comfort values for each body part, except for buttock where the best one was the removable support, and the upper thigh where the best one was the standard seat (Table 3). It was assumed that the removable support was more beneficial on the buttock area, while the integrated one on the lumbar area.

Table 2. Results from questionnaires – Comparison between *Initial Comfort* and *Global Comfort* rated at the end of test, where μ is mean, σ standard deviation. The rating scale was from 1="*minimum comfort*" to 10="*maximum comfort*"

		Initial comfort	*Global comfort*
Standard seat	μ	6.86	6.48
	σ	1.16	1.31
With removable support	μ	6.94	6.96
	σ	1.24	1.52
With integrated support	μ	7.18	7.06
	σ	1.44	1.86

Table 3. Results from questionnaires – Mean values (μ) and standard deviations (σ) of body perceived (dis)comfort. The rating scale was from -4="maximum discomfort" to 4="maximum comfort"

		Neck	*Upper Back*	*Lower Back*	*Buttock*	*Upper thigh*	*Lower thigh*
Standard seat	μ	1.44	1.98	1.30	2.38	2.36	1.96
	σ	1.53	1.81	2.09	1.47	1.17	1.21
With removable support	μ	1.58	2.14	2.22	2.40	2.10	2.06
	σ	1.53	1.51	1.75	1.31	1.22	1.25
With integrated support	μ	1.66	2.32	2.32	2.30	2.22	2.14
	σ	1.36	1.35	1.74	1.61	1.37	1.34

As far as the questions about the sensations, participant felt cosier with the lumbar supports than the standard seat, in which participant felt mostly no sensation in this area (Fig. 4).

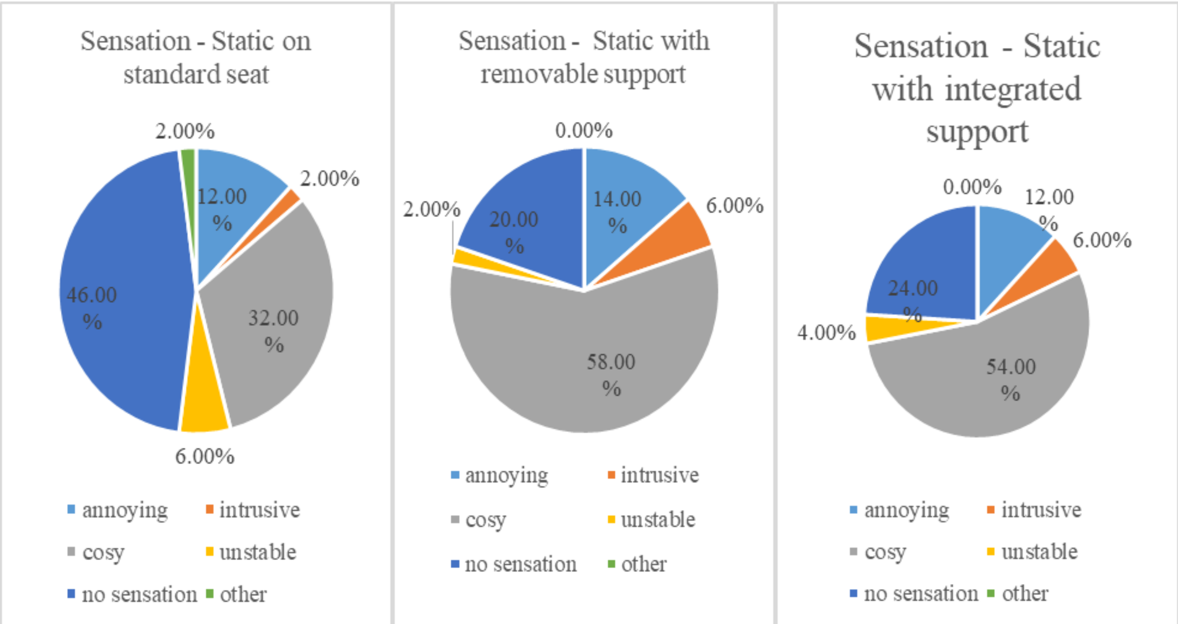

Fig. 4. Results from questionnaires – Participant sensations on lumbar-sacral area.

3.2 Pressure mat

In Table 4, there are the output values of pressure mat, used to gain the pressure distribution that can be linked with the lower-back comfort.

Table 4. Results from pressure-mat, where μ is mean, σ standard deviation

		Max Load [kN]	*Area [cm^2]*	*Mean Pressure [N/mm^2]*	*Max pressure [N/mm^2]*
Standard seat	μ	527	254	20.51	66.97
	σ	202	58	4.24	11.96
With removable support	μ	659	311	20.33	78.77
	σ	374	74	6.78	34.18
With integrated support	μ	472	272	17.08	69.58
	σ	238	78	5.22	23.59

These data show there was a bigger contact area between seat and participants in the two different solutions because they were able to lay their back entirely on the backrest.

3.3 Correlations

Analysis of Pearson correlation coefficients has been done through IBM® SPSS® Statistics. Results are shown in Table 4-5-6. Moreover, there was a negative strong correlation (p=-0.397**) between the lower back and the weight in the case of standard seat.

Table 5. Correlation between *Overall Comfort* and other parameters for each case

		Initial Comfort	***Neck***	***Upper Back***	***Lower Back***	***Buttock***	***Upper Thigh***	***Lower Thigh***
Overall comfort	*Standard seat*	0.808**	0.513**	0.510**	0.541**	0.506**	0.390*	0.282*
	With removable support	0.724**	0.405**	0.498**	0.797**	/	/	0.301*
	With integrated support	0.791**	0.387**	0.653**	0.713**	0.651**	0.555**	0.628**

Table 6. Correlation between *Mean Pressure* and other parameters for each case

		Gender	***Height***	***Weight***	***Area***	***Max Pressure***	***Total Load***
Mean pressure	*Standard seat*	0.478**	0.547**	0.369**	0.485**	0.516**	0.852**
	With removable support	/	/	/	0.656**	0.652**	0.931**
	With integrated support	/	/	/	0.368**	0.757**	0.847**

Table 7. Correlation between *Max Pressure* and other parameters for each case

		Initial Comfort	***Buttock***	***Overall Comfort***	***Area***	***Total Load***
Max pressure	*Standard seat*	/	/	/	0.545**	0.600**
	With removable support	/	/	/	0.389**	0.564**
	With integrated support	-0.372**	-0.382**	-0.519**	/	0.523**

4. Conclusions

To reduce lumbar pain, relating to a standard seat, a lumbar support had been realized. In order to verify its performance, two solutions had been tested: a seat with removable support and a seat with integrated support. Both the solutions seem actually advantageous compared to the standard seat. In particular, the integrated support increased the comfort on the lumbar zone while the removable one on the buttock area. These perceptions could be valid for a large number of people because the interviewed population that appreciated the two different new solutions belonged to a percentile bigger than the fiftieth one. Subjective data had been gathered through questionnaires, while the objective ones through the Medilogic® pressure-mat: the correlations between the comfort perception and the pressure distribution at interface gave the possibility to obtain important results. For utilizing simple instruments, this methodology can be easily replicated. Furthermore, the performed analysis is multiphysics and psychological together because the objective postural data, physical data of pressure, subjective data from the questionnaires had been acquired in different temporal moments then to use everything for a targeted planning.

Analyzing the results, it was figured out that in the standard seat the comfort decreased over time more quickly than the solutions with the lumbar support, as confirmed in literature [17]. Indeed, there was a bigger contact area between seat and participants in the two different solutions respect the standard one because they were able to lay their back entirely on the backrest. In addition, participants felt cozier on the seat with a lumbar support than the standard seat.

Moreover, some limitations of this experiment have to be acknowledged. Firstly, the seat angle had been fixed and the seat had been placed in a fixed position. Some research with different angles and regulations could be done. Secondly, there was a lack of freedom of movement during the test because the aim was to focus on the perceptions of the lumbar-sacral zone. Thus, more experiments leaving the participants free to move themselves needs to be performed, in order to be closer to reality. Finally, this work did not consider the temperature at the interface, thus more experiment could be carried on to understand the influence of the temperature in the long run contact.

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