VOL. 16, NO. 12, JUNE 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

IMPROVING POSTURAL COMFORT ON STUDENTS' CHAIRS

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ABSTRACT

University students spend most of their time in a sitting position. Prolonged sitting on ill-fitted furniture and the resulting lousy posture make students have different musculoskeletal disorders (MSDs) and are strictly related to students' learning outcomes. This study aims to improve postural comfort of chairs placed inside the Science & Technology Library at the University of Salerno. A previous study about these library chairs showed that the lumbar area was the most suffering part while perceived (dis)comfort was dependent on time. Based on this, an ergonomic redesign and, consequently, manufacturing of the chair has been done. A perceived-comfort comparison between the library chair and the redesigned one has been performed. A statistical sample of 28 healthy students performed a 20-minutes experiment two times, alternatively on the library chair and the redesigned one. The 20-minutes experiment was divided into two 10-minutes tasks ("Reading & Writing" and "Laptop use") to simulate a study day. The participants' postures were acquired non-invasively using cameras and processed by Kinovea; questionnaires were used to rate the perceived subjective (dis)comfort. A procedure for improving an existing product through a comfort-driven redesign is proposed. Results showed the redesigned library chair lead on increasing postural comfort (particularly in the lumbar area) thanks to the new design and modifications.

Keywords: design method, postural comfort, (dis)comfort, redesign, student seat, comfort-driven redesign, Taguchi method design.

INTRODUCTION

The analysis and the objective evaluation of (dis)comfort in human-artefact interaction is a hot topic in scientific debate. In the last ten years, both in workplace analyses [1-3] and product analyses [1, 3-5], (dis)comfort evaluation methods have been developed and tested. Seat and chair design is probably the main topic on which the researchers' efforts are spent [6, 7]. In particular, the chair is considered a critical element for postural comfort [8-10], especially for those who conduct a sedentary life, such as students [11, 12]. Indeed, uncomfortable and awkward postures can decrease students' interest and outcomes in learning [13, 14].

A previous study [15] conducted a postural analysis among the chairs inside the Science and Technology Library (S&T Library) [16] at University of Salerno (UNISA), designed by architect Nicola Pagliara [17]; results showed the un-suitability of the chair for students: even though the chair was utterly close to the desk, due to armrest height, the backrest was distant from the desk edge. Thus, to assume a comfortable sitting posture, the students were frequently forced to change the posture bending back and forth the back. Small movements around the static posture witnessed the increase of postural discomfort [18]. Furthermore, the lack of lumbar support resulted in comfort decay over time and the lowest comfort values for thoracic and lumbar areas: this confirmed the essential role of lumbar support on perceived discomfort [19, 20]. Thus, improvements in these parts were needed, particularly, a continuous contact in the lower back could lead to a considerable reduction of lumbar pain [21].

One way to develop these issues is to adopt the Taguchi method design philosophy for experiments [22, 23]. The basic approach consists of four stages [24]: planning the experiment, designing the experiment, conducting the experiment, and analyzing the experimental results. By applying this approach, the time required for experimental investigation could reduce significantly [22, 25] as studying the influence of individual factors to determine which one has more weight, and which less [22, 26, 27]. Thus, this paper focuses on redesigning the library chair developed in collaboration with the MGR Group S.r.l., an Italian company specialized in the upholstery sector. A comparison between two chairs (the original and redesigned ones) was made through experiments using subjective and objective data [28, 29].

The research question is: Which design procedure is needed to improve the perceived comfort while seating on library chairs, and how can we rate the improvement?

MATERIALS AND METHOD

Design from the Experiment

A postural comfort analysis was done in a previous experiment [15] to identify the critical factors that influenced the postural comfort sitting on the library-chair.

A brief evaluation showed the chair was not suitable for students; it means there were already prerogatives to force students moving on the chairs to find a comfortable posture. Indeed, positioning the chair entirely close to the desk, the armrests' height does not allow an appropriate (or comfortable) distance between the backrest and the desk's edge. Also, there is a gap between the backrest and the seat-pan of about 14 cm. Thus, students frequently changed the posture going from the one close to the desk to the one far from it with the back bent backwards to lean on the backrest. Consequently,

those aspects are all prerogatives of bad design, and experiments have been performed to identify each body part's comfort level after a study-day.

According to results, thoracic and lumbar areas were confirmed as critical: improvements in these parts are needed, like as reducing the gap between the seat pan and backrest.

Redesign of the Library Chair

Based on the previous paper results [15], the primary intent was to add thoracic-lumbar support to increase postural comfort and reduce back pain.

After a brainstorming session, the following steps have been deployed:

a) A cardboard model of the back-seat was designed to realize the physical prototype. Sheet steel was manufactured by plasma cut and curved to fit the structure of the chair. After adjustments, the best fit between back-seat and chair was obtained;
b) The back-seat was coated with a 3cm high-density foam, shaped for best fitting with the backrest;
c) The seat pan was also coated with a 1cm low-density foam to prevent the buttocks slipping. Also, the density choice was made in order not to increase the seat height;
d) The back-seat and the seat pan were coated with black eco-leather and then riveted to the chair.

The final prototype is shown in Figure-1.

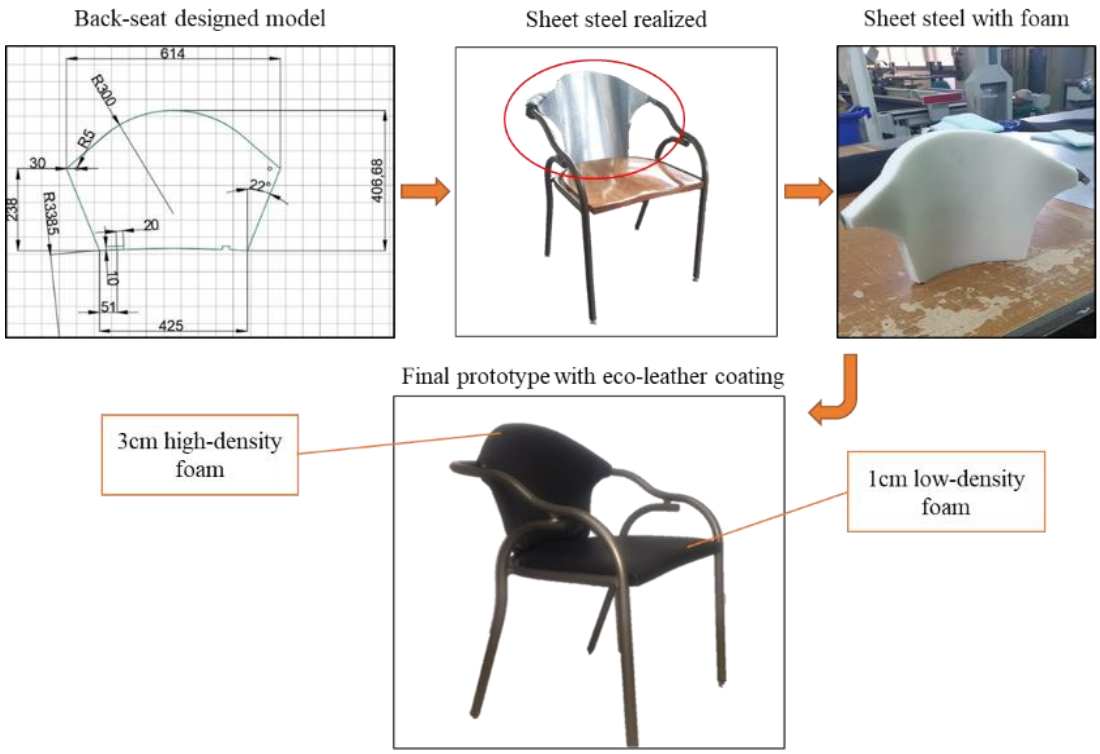

Figure-1. Redesigned chair with details.

Experiment Setup

The comparison between the Library Chair and the Redesigned Chair has been made through experiments set up at S&T Library of the Salerno University. The building is composed of four floors (one underground) with a total of 144 desks and corresponding chairs. Each desk can seat six people, and it is also provided with additional lamps and sockets. As freedom of movement and large spaces were needed to conduct the experiments, the latest desk on the third floor was chosen, in agreement with the library staff. Since the aim was to simulate a study-day, an online survey was spread before experiments to determine the main study tasks in S&T Library: 98 students declared to perform mainly "Reading & Writing" and "Laptop use" activities. Thus, books, pens, papers, and a laptop had been provided during tests.

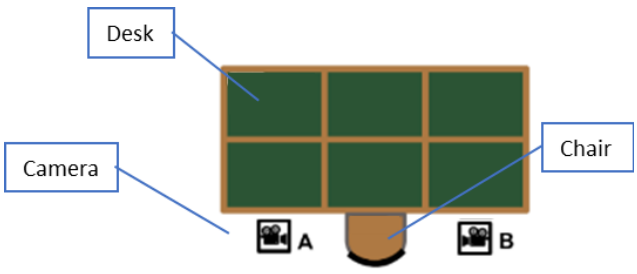

Figure-2. Experiment setup.

For postural angles detecting, the video acquisition system was equipped with two phone-cameras (FHD 1920x1080) fixed on tripods to obtain the lateral views (Camera A, B in Figure-2). Videos from the two perspectives were registered simultaneously. The experiment setup is shown in Figure-2. The angles were detected for counting the macro-movements of human joints [30] related to perceived discomfort.

Participants

Twenty-eight students, 11 females and 17 males, aged between 23 and 30, were recruited among the Salerno University population.

All students enjoyed good health and 50% of them slightly frequented the S&T Library. Table-1 shows the statistics of participants.

Table-1. Demographic data of participants.

	Male (n=17)			Female (n=11)		
	Mean	**SD**	**Range**	**Mean**	**SD**	**Range**
Height (cm)	167,1	4,6	168 - 186	150,0	7,0	152 - 177
Weight (kg)	72,2	12,3	55 - 100	54,0	7,4	50 - 73

Questionnaires

For the acquisition of the subjective data, a two-sections questionnaire was used. The first questionnaire section is about anthropometric data, frequency of use of S&T Library study-areas (never, once a week, 2-3 times a week, more than 3 times a week) and expected perceived comfort on the chair to test [5] (that is, how the chair to test seemed comfortable at first sight).

The second questionnaire section is designed to rate the Localized Postural (Dis)comfort perception [31] related to the different body parts: neck, right and left shoulders, thoracic area, lumbar area, buttock, right and left thighs, right and left ankles. The last question regarded global comfort evaluation.

The expected perceived comfort, the postural (dis)comfort perception and the global comfort were evaluated on a 7-point Likert Scale [32], from -3="Extremely Uncomfortable" to 3="Extremely Comfortable" (Figure-3).

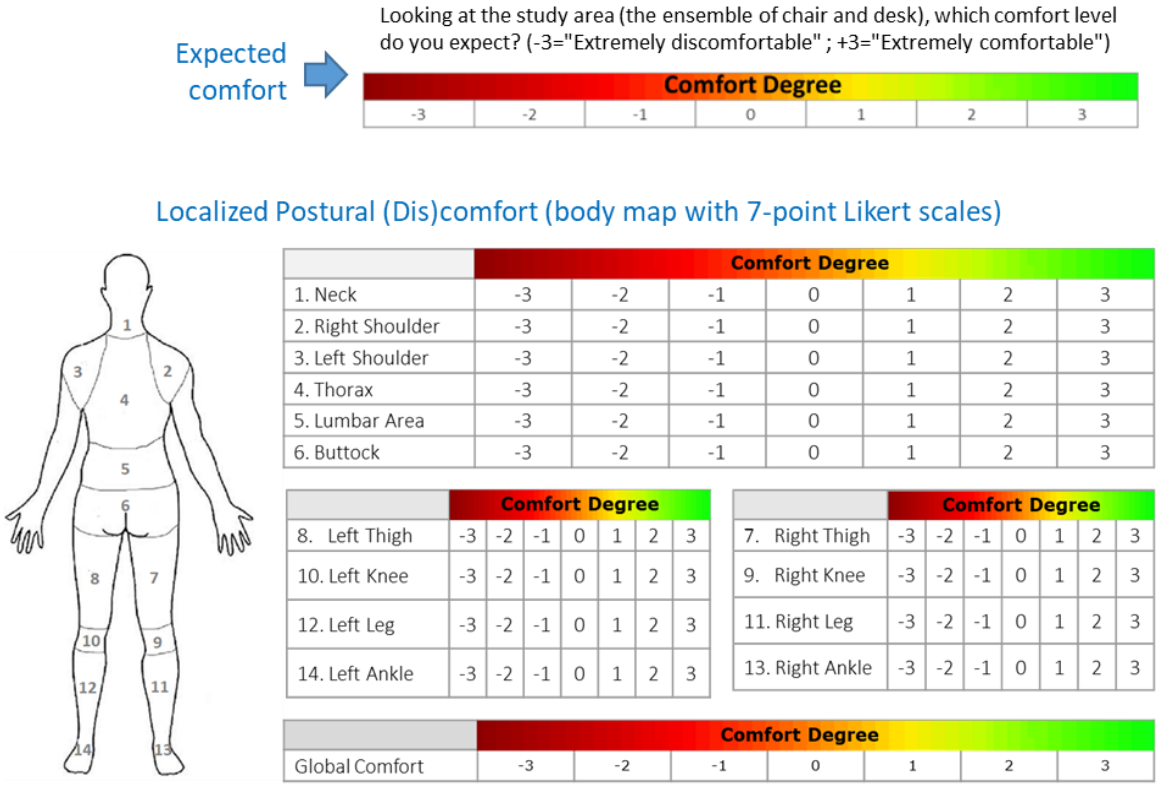

Figure-3. Parts of questionnaire: questions regarding the expected comfort and the Localized Postural (Dis)comfort.

Experiment Protocol

Students were asked not to wear wet clothes or short trousers to avoid clothing influence on comfort perception [32] and were invited to sign the "Informed Consent".

Experiments were split into two different days: on the first day, participants tested the "Library Chair", while on the other day the "Redesigned Chair".

The order was meant not to influence the expected comfort due to the pre-conceptual idea formed in the participant's mind after the first test (whatever it was) and to make the comparison only through performed tasks.

For each day, the following procedure has been deployed:

a) Participants were asked to fill the first section of the questionnaire and invited to have a look at the study area (the ensemble of chair and desk) to rate the expected comfort;
b) Participants sat on the chair and started to perform the two 10-minutes activities with a pause in between. At the end of each task, the second questionnaire section has been filled by subjects;
c) Throughout the experiments, body postures were recorded through videos, from lateral sides;
d) Once performed all experiments, videos were processed by the software Kinovea® to acquire the angles of body joints.

Angles Acquisition

Postural angles have been acquired through Kinovea® software. The focus was the body areas in contact with the seats: thoracic, lumbar and buttocks. Analyzing deeply the angles that could influence more the postural (dis)comfort, three main angles (Figure-4) were highlighted for movements analysis:

A - Thoracic zone flexion
B - Lumbar area flexion
C - Hip flexion

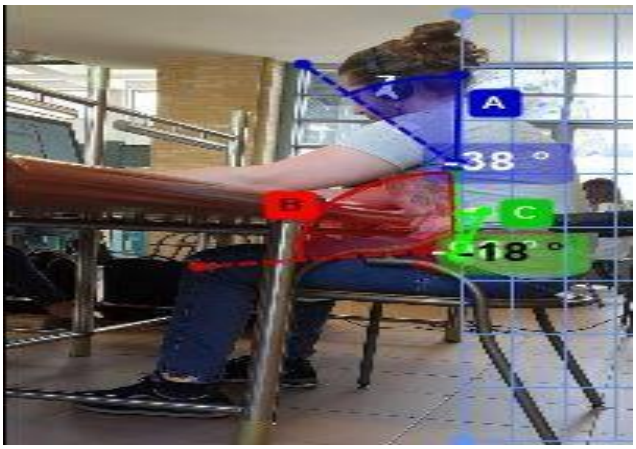

Figure-4. Analyzed postural angles where the letters stand for: A - Thoracic zone flexion; B - Lumbar area flexion; C - Hip flexion.

RESULTS

Figure-5 shows results from the Localized Postural (Dis)comfort questionnaire: the redesigned chair always scored higher comfort values than the previous library chair. In particular, there is a postural comfort improvement in the thoracic (50%) and lumbar (60%) areas. Thus, the main goal of this work has been reached.

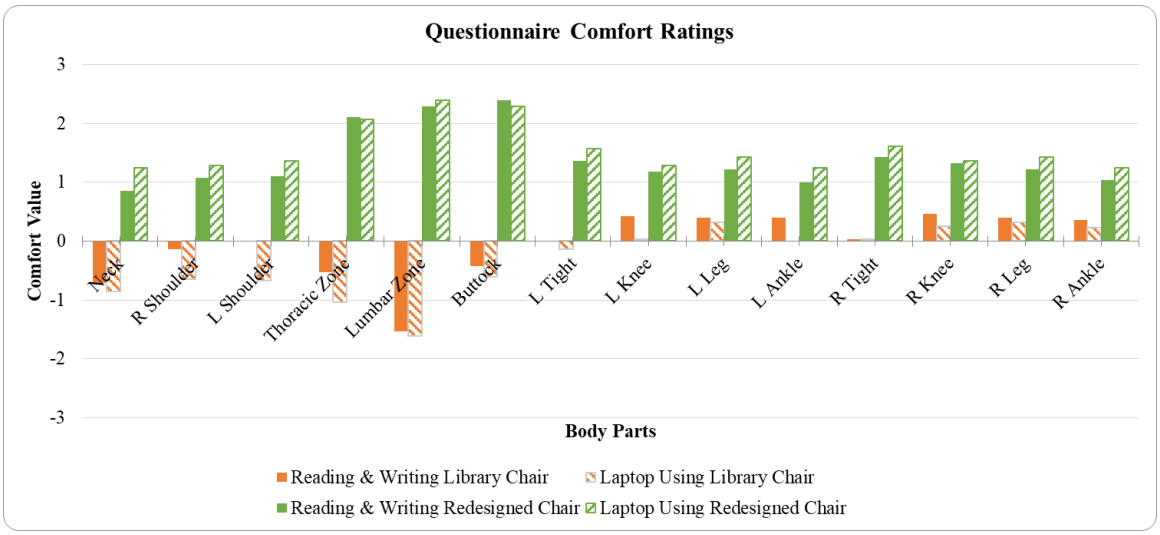

Figure-5. Results from the localized postural (Dis)comfort questionnaire.

Furthermore, participants expected low postural comfort for the "Library Chair" than the "Redesigned Chair" (Table-2). Besides, after performing the two tasks, the "Library Chairs" lead on the decreasing of Global Comfort (Table-2), while, the "Redesigned Chair" showed an increase of Postural Comfort (Table-2).

Table-2. Results from questionnaires - expected and global comfort values. Rated on a 7-point Likert scale (-3=Extremely Discomfortable; 3=Extremely Comfortable).

	Expected Comfort	Global Comfort for "Reading&Writing" task	Global Comfort for "Laptop use" task
Library Chair	0.500	-1.036	-1.464
Redesigned Chair	1.889	2.036	2.179

As far as postural angles, Table-3 shows the percentages of movement reduction of participants: the more movement reductions, the higher benefit of postural comfort.

Table-3. Percentages of movement reductions.

	Reading and Writing	Laptop Using
Thoracic Zone	57%	68%
Lumbar Zone	71%	71%
Hips	64%	68%

CONCLUSIONS

The proposed procedure for responding to the research question is the following:

- individuation of critical areas in terms of postural comfort through the subjective and objective rating of perceived comfort;
- identification of critical aspect of the product and brainstorming among experts about technical solutions
- redesign delivery and realization of prototypes;
- comparison analysis between the original library chair and the redesigned one throughout experiments to collect subjective data (questionnaires) and objective data (video recording to detect postural movements);
- statistical analysis and discussion of outcomes for improvement assessment.

Summarizing, questionnaires analysis reveals that the Redesigned Chair gave postural comfort benefits thanks to the thoracic-lumbar support. This result is proved by the highest comfort ratings scored by the redesigned chair. Besides, a reduction of movements number (and angles ranges) and an increase of comfort perception has been detected. A future improvement of this analysis can be implemented by evaluating the suitable back-seat shape for this chair.

ACKNOWLEDGMENTS

Authors want to thank the management and the operator MGR GROUP S.r.l., for the support in this study development. Special thanks to the student group that attended the last year of MD in Mechanical Engineering and MD in Industrial Engineering of 2018-2019 Academic Year at University of Salerno (Italy). Particularly: Giovanni Baglivo, Claudia Chirico, Antonietta Dello Russo, Jose Garro, Michele Leo, Conrado Pacheco, Gianluca Vitolo.

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