A comfort evaluation tool for sitting postures: the case of Library chairs

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Abstract According to ergonomic researches regarding a good sitting posture, the chair, the desk and the objects on the desk, have to be aligned in a certain way to ensure to users a natural curve of the back in order to prevent musculoskeletal disorders. A brief observation among the main Scientific Technology Library inside the University campus showed that students used to complain about neck and lumbar pain, especially after a study day. Thus, a sitting posture comfort analysis had been performed on chairs inside the library. A long-time sitting posture during the daily study activity had been simulated with fifteen volunteer students performing 1-hour tests (divided into four tasks of 15 minutes each). Subjective perceptions had been gathered through questionnaires rating on a 5-point Likert scale both the expected comfort at the beginning of the experiment, and the Localized Postural Comfort at the end of each task. Moreover, just before the end of each task, postural angles had been detected by photographic acquisition and processed by Kinovea®; in addition, CAMan® software had been used to calculate the (dis)comfort indexes by detected postural angles. Finally, subjective and objective data had been statistically processed and compared. Results showed the lumbar area as the most suffering area (lower perceived comfort) while perceived (dis)comfort was independent on participants and tasks, but dependent on the time.

Keywords: comfort, office seat, university students, library, postural comfort

1 Introduction

Students spend the majority of their time studying, thus sitting on a chair. The importance of the environment cannot be underestimated due to the fact that negative feelings can affect the learning, especially for a long time sitting [1,2]. Indeed, uncomfortable and awkward body postures can decrease a student's interest in learning, even during the most stimulating and interesting lessons [3]. Considering the position of chair and desk, in literature there have been several studies regarding the correct sitting posture and the awareness of a good sitting posture [4–7]. Furthermore, it exists even an equation to quantify the comfort in function of measurements and distances between chairs, student and desk [8].

Any seat design is influenced by the context. Some studies, moreover, gave guidelines to design a comfortable seat, taking into account the natural curve of backbone, the body sensitivity [9–12], the performed activities and anthropometric measurements of the target group [13–17]. Different target groups have different body sizes and this implies differences in seat width, backrest length, seat pan length, armrest height, that should be designed to fit at least the 99% of the population [10]. However, the body's optimal position in terms of comfort requires every joint and eye position to be close to the neutral position, where the perception of comfort is high [18–21].

'Postural comfort' is commonly defined as the absence of discomfort, or a state where the need to change position is not present [22,23]. The comfort zone, defined as the area of the most comfortable motions/postures for a given task, does not predicate an absolute measure of well-being. Users within their comfort zone are unlikely to change into other postures.

The evaluation of postural comfort can be achieved through subjective or objective data. Subjective data are related with questionnaires, such as Localized Postural (Dis)comfort (LPD), Body Part (Dis)comfort (BPD) and so on [24–26], while the objective one can be obtained with tools such as pressure mate, sensors and so forth [27,28]. One of these tools is the software CAMan® [21,29–31] realized by University of Salerno: the software considers the human joints and the comfort curves over angles associated with them. Thus, for a given angle of a human joint, the software gives the associated comfort index (on an 11-point scale where 10 is the maximum comfort).

Despite this background, some applications on the daily life do not follow the ergonomists' tips, as in the case of this study.

The Science and Technology Library (S&T Library), designed by the architect Nicola Pagliara [32], is collocated inside the campus of the University of Salerno (UNISA) and is actually used as a place to study [33].

With a brief analysis among students inside the S&T Library, it came out there had been several complaints about neck and lumbar pain after a study day. Regarding this, one hypothesis was the students used to assume wrong sitting posture on those chairs.

Since the students tended to change posture frequently, a sitting postural comfort analysis had been done [35–37].

2 Materials & Method

2.1 Experiment setup

The experiment had been setup on the last floor of the S&T Library when there was less affluence of students, by permission of the library staff.

On each floor, there are 36 desks with corresponding chairs, grouped six by six, where three are aligned and the other three are opposed to them. For the experiment, three consecutive desks had been occupied to have a clear space.

Three Nikon D3300 cameras had been used and fixed on tripods among the desks: one had been placed on the left and one on the right to obtain the lateral views; and the last one behind the chair, at an adequate distance, to obtain the rear view. In addition, one phone-camera had been fixed on selfie-stick support to take photos from the top view.

To simulate a study day, two main tasks of the studying had been performed: writing and reading. Thus, books, pens, papers had been provided. To consider the time effect, each experiment lasted 1 hour, where the two tasks had been performed for 15 minutes each one, switching them at the end of the 15 minutes. Between the tasks, a pause of 1 minute had been given in order to fill the questionnaire. Photos had been taken from all cameras simultaneously at the end of each task to capture body posture and obtain then postures over time.

2.2 Experimental sample

Fifteen students of University of Salerno, 8 males and 7 females with the age between 23 and 31, took part to the experiment. Table 1 shows demographic data of participants. All students enjoyed good health. These anthropometric data had been gathered measuring directly the participants' body with a meter, and recorded in an Excel file.

Table 1. Demographics of participants

	Male (n=8)			*Female (n=7)*		
	Mean	*SD*	*Range*	*Mean*	*SD*	*Range*
Height (cm)	*178.5*	*6.2*	*168 – 185*	*162.7*	*5.7*	*154 – 169*
Weight (kg)	*72.5*	*10.2*	*57 – 90*	*57.1*	*4.8*	*50 – 63*

2.3 The chair

To obtain a complete overview, dimensions of the chair had been compared with human body measurements.

The dimensions of the chair are showed in Figure 1. The high of armrest is about 61 cm from the ground, while the lower part of the desk is 60 cm high from the ground: it means the chair cannot be positioned under the desk. Moreover, there is a gap between the backrest and the seat-pan about 14 cm (66,1cm – 52,4 cm); it means students have to move backward their back in order to lay on the backrest.

Fig. 1. Pictures of the chair in three views. Measurements of the chair are reported.

From DINED [38], choosing the international population, values regarding the sitting height, the hip breadth, popliteal height, buttock-knee depth and elbow-grip length had been gathered, as shown in Figure 2:

Measures sitting (mm)	International, female		International, male		International, mixed	
	Mean	SD	Mean	SD	Mean	SD
17) Sitting height	800	40	935	40	868	78
14) Popliteal height	365	29	460	27	413	55
33) Buttock-knee depth	505	33	615	33	560	64
25) Hip breadth	305	27	395	27	350	52
31) Elbow-grip length	305	21	375	21	340	41

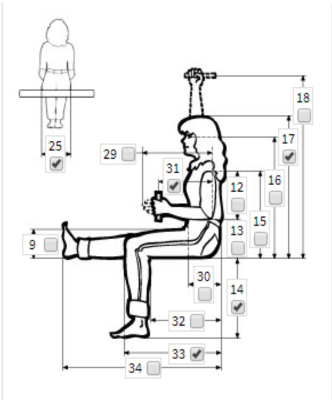

Fig. 2. Anthropometric measurements from DINED. The numbers refer on the picture placed on the right. Measurements refers on 50-percentile of the population, for both genders.

Comparing the measurements, it had been figured out:

- Popliteal height is not suitable for 50% of female population;
- Buttock-knee depth is not suitable for 50% of female population;
- The hip breadth for both population is smaller than the seat pan length.

2.4 Questionnaires

Questionnaires of Localized Postural Comfort have been used to collect subjective data regarding the postural comfort of participants.
Prior the experiment, participants were asked to rate on a 5-point Likert scale (from 1=No comfort to 5=High comfort) the expectation of perceived comfort once sitting on the chair, that is, how the chair seemed comfortable at the first sight [39].
At the end of each task participants were asked to rate on a 5-point Likert-scale [24]:

- The perceived comfort on the following body parts: neck, left shoulder, right shoulder, left arm, right arm, left forearm, right forearm, left wrist, right wrist, thoracic zone, lumbar zone;
- The global comfort.

2.5 Experiment protocol

Prior the experiment, participants has been asked to sign an informed consent and instructed about the experiment.
Then participants sat on the chair, positioning it closer to the desk and assuming a correct sitting posture, that is, forearms on desk, raised back, 90 ° legs, and feet leaning against the ground.
Tasks have been performed in sequence, alternating between writing and reading, both among the tasks and the sequential participants (Table 2). Each one lasted 15 minutes, which a stopwatch that told the time, and with a pause about 1 min between the tasks to fill the questionnaire; photos have been taken just before the end of the task.
Survey data have been analyzed calculating weighted averages and the comfort trend over time starting from the expectation.

Table 2. Protocol regarding time

	Task 1	**Task 2**	**Task 3**	**Task 4**
Participant A	Reading	Writing	Reading	Writing
Participant B	Writing	Reading	Writing	Reading
	15 min	*15 min*	*15 min*	*15 min*

1 min *1 min* *1 min*

2.5 Postural angles and the simulation

A total of 240 photos (15 participants x 4 tasks x 4 views) have been analyzed with Kinovea® to gather postural angles, trying to be as accurate as possible, aware of any human errors, both in visual perception and in the program operation.
Analysis has been made of the following upper limbs movements: head rotation, head bending, head flexion, shoulder rotation, shoulder bending, shoulder flexion, trunk rotation, trunk bending and trunk flexion. Body rotation has been analyzed in the transverse plane, body flexion in the frontal plane and body bending in the sagittal plane. Considering the aforementioned correct sitting posture as a reference posture, the gathered angles have been defined as the deviations from the reference posture.
A virtual environment of S&T Library have been realized in Delmia® (Figure 3), representing one floor with fifteen students. French mannequins, that represent the European standard, have been used to simulate participants' movements through the gathered postural angles. Anthropometric data, movements and tasks have been respected.
Through the simulation, it was possible to see the temporal changes for each student, going from a correct posture to the last one gathered.

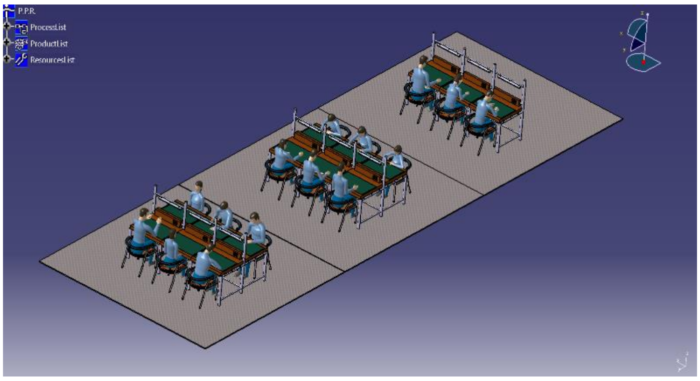

Fig. 3. Virtual representation of S&T Library on Delmia.

2.5 CAMan: objective comfort indexes

To obtain objective comfort indexes from the collected angles, the CAMan® software [21] has been used.
The CAMan® software is based on experimental studies conducted by A. Naddeo et al. to give a comfort index according to postural angles assumed, especially the angles of the human joint. As far as upper limbs, it considers:

- neck: frontal flexion, rotation and lateral flexion
- shoulder: frontal flexion, abduction/adduction
- elbow: flexion/extension, pronation/supination
- wrist: flexion/extension, radio/ulnar deviation

For each joint, curves of postural comfort over angles are used. Comfort indexes are rating on an 11-point scale where 0=”no comfort” and 10=”maximum comfort”.
These comfort indexes consider the limbs moving freely in the space, without any kind of support.
Since students used to lay their wrist, forearms and elbow on the desk for the whole of time, only neck and shoulder comfort indexes have been evaluated.

3 Results

As regards the trend of global comfort over time, results are shown in Figure 4. The values represent the average of expected comfort and global comfort for each task. There was a decay over time, starting from a higher comfort expectation to the lower perceived comfort in “Task 4”.

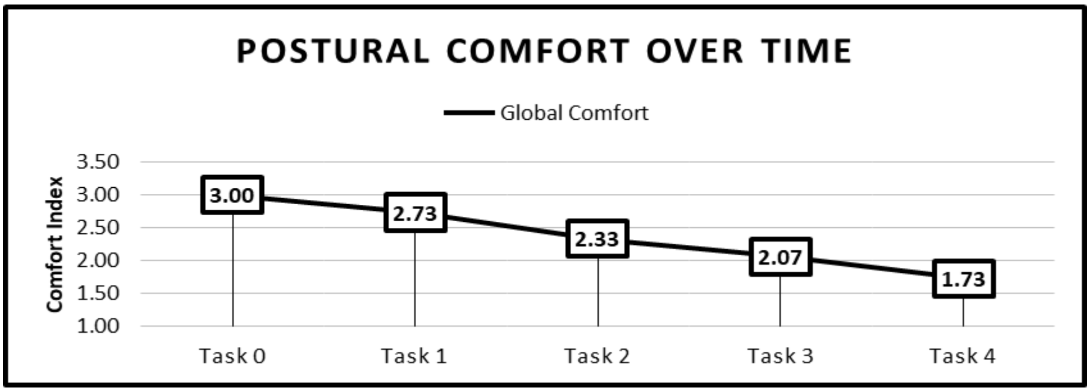

Fig. 4. Evolution of the average global comfort over time (Task 0 represents the expected comfort, while the other tasks the evaluation given by participants). Values are the average mean on a scale from 1=”no comfort” to 5=”maximum comfort”.

Analyzing the questionnaire results, Figure 5 shows the values of average mean of postural comfort for each body part. Comfort indexes in "Task 4" scored lower values than the ones in "Task 1": this confirms the comfort decay over time. Furthermore, the lumbar zone scored the lowest values of comfort, followed by the neck, torso and shoulders, while the arms, forearms and wrist scored the highest values.

Wilcoxon test have been performed to compare each task and results were significant at $p<0.05$, especially between "Task 1" and "Task 4". It means there are significant differences between the first task and the last task.

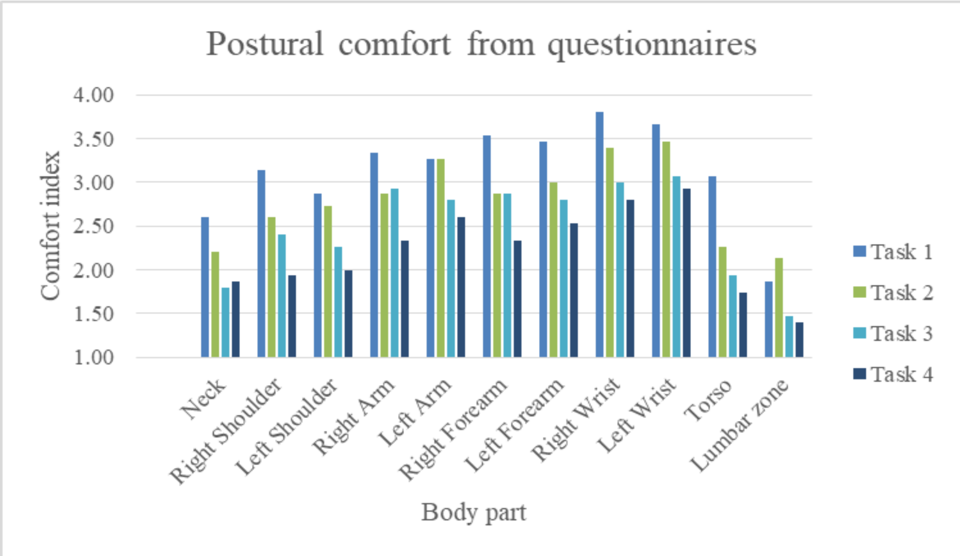

Fig. 5. Mean values from questionnaires for each body part (1=no comfort; 5=maximum comfort)

3.1 Correlations

Correlations between subjective comfort indexes from questionnaires and objective comfort indexes from CAMan have been calculated with IBM® SPSS® Statistics version 24, taking into account even the dependence on type of activity, it means to evaluate whether the comfort depends or not on the initial activity.

Thus, correlations have been calculated between the following comfort indexes:

- body parts from Questionnaires & body parts by CAMan®
- body parts from Questionnaires & Global Comfort from Questionnaires
- body parts by CAMan® & Global Comfort from Questionnaire

It has been found that height, weight and gender did not affect the Global Comfort. There have not been correlations between the first task and the last task: this is coherent with the decrease of the Global Comfort over time. Each single task affected only the next one.

Outcomes from results:

- strong correlations between body part questionnaire & body part CAMan (mean p~0.8)
- strong correlations between body part questionnaire & Global Comfort Questionnaire (mean p~0.7)
- strong correlations between body part CAMan & Global Comfort Questionnaire (mean p~0.6)

Doing the same analysis by grouping the participants that began with the same task, only few correlations had been found out, therefore the postural comfort depends only on the time evolution.

4 Discussion

Due to students' disorders and complaints, a postural comfort analysis had been done, following the existent methods in literature [35,40,41].

A brief evaluation showed the chair was not suitable for students (Figure 1 & Figure 2); it means there were already prerogatives to force students moving on the chairs to find a comfortable posture.

As a matter of fact, considering the correct sitting posture, it means sitting up straight, leaning arms on the desk, keeping feet on the floor, the chair seems too large to fit an international population (Figure 2) with medium anthropometric measurements [34]. Indeed, even if the chair is completely close to the desk, due to the height of armrests, the backrest is too far away from the edge of the desk (Figure 1). Thus, the students, in order to assume a good posture, are frequently forced to change the posture going from the one near to the desk to the one distant from the desk and the back leaned on the backrest. During the tests, all participants accused pain in the lumbar region, because to sit properly they were unable to lean their back on the backrest and to unload the weight of the head and the back.

Furthermore, as far as the people with the height approximatively lower than 1.60 m, they have some problems with the chair because their knees lean on the seat-pan when their back is leaned on the backrest, thus they are not able to bend the knees and to put their feet on the ground.

The postural comfort trend over time, starting from the correct sitting posture, had been simulated through the two main tasks of the study (writing and reading). To keep the importance of time effect, tasks had been performed in succession without a long pause. Results showed a decay over time; it means the chair was not comfortable as expected at the beginning, scoring the lowest value of global comfort in the last task.

There had not great differences between expectation and the values of global comfort because some students had already some experience with the chair and this could have influenced the answers about the expectation.

Postural angles had been gathered by Kinovea® using pictures taken during the experiment.

The virtual simulation had been done in Delmia® to see the postures assumed by students over time: starting from the correct sitting posture, they used to assume a slouched one at the end of the experiment.

It is recommended to make modifications to the virtual environment and test the renovation to improve students' postural comfort, by assuming the correct sitting posture.

Objective indexes of postural comfort had been collected by CAMan®, where for each human joint angle a comfort index had been obtained.

There are some limitations of CAMan® software to be acknowledged. Firstly, the software considered the participant itself positioned in the space without any kind of support: comfort perception is different in the presence of support. Indeed, if someone bends the upper limbs in the space, without any support, the feeling of comfort is very low; instead, with a presence of a support to unload the weight, the comfort perception is higher. Since during the tests, participants laid their forearms on the desk, the comfort perception on this posture was higher than the same posture without the desk. This has been even confirmed by questionnaire results (Figure 5). Thus, objective comfort indexes of elbow and wrist had been excluded.

Secondly, when the experiment had been performed, the CAMan® version did not consider the lower limbs. Thus, it was not possible to compare the subjective results of the lumbar zone with the objective indexes of lower limbs from CAMan®. Thus, it is recommended to repeat the experiment implementing the evaluation of lower limbs.

Using CAMan® allowed comparing subjective comfort indexes with the objective ones, given more validity to the experiment and its results.

The chair could be improved by increasing the area of backrest using, for example, a pillow in the lumbar region. Otherwise, it could be better to amend the chairs by reducing the width in order to reduce the gap between the seat pan and the backrest.

5 Conclusion

After a brief investigation among students inside the S&T Library, it had been found out a general physical complaint. Thus, a postural analysis had been performed following a systematic method. A typical study-day had been represented through two tasks: writing and reading. During the experiments, photos had been taken from four different views to detect postural angles by Kinovea®. Those postural angles had been used both to realize a simulation inside the virtual environment of Delmia®; and to obtain objective postural indexes by CAMan®.

In summary, this paper argued that:

- The comfort perception decreased over time;
- The lumbar region scored the lowest value of comfort, thus, this region influences all postural performance, as confirmed by literature studies;
- Software CAMan® had been used as a tool to obtain objective data of postural comfort;
- There had been correlations between subjective and objective comfort indexes;

The main goal was to demonstrate through the postural comfort analysis that the chair was few comfortable, so it is necessary to do some modifications, like an extension of the back-support area or a reduction of the seat-pan width. These renovations can be simulated with Delmia® through a careful analysis, in order to detect quickly the areas to be improved, then to realize a prototype already optimized.

Furthermore, in this work, a method for the definition of comfort indexes has been shown. All the acquisition methods used are very cheap and easy to use. The precision of the acquisition method, as well as the fact that by not using complicated, expensive acquisition methods, gave us the possibility to reach a very good numerical/experimental level obtaining important results revealed by this paper. The method can be easily reproduced for other applications.

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