TOWARDS BETTER SEATING DESIGN – A DISCUSSION AND COMPARISON BETWEEN OFFICE CHAIRS AND CAR SEATS

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This paper describes different methods to obtain information about how to better design chairs and future seating; the methods described have been used in real development projects. Comparison between subjective and objective measurements on discomfort is discussed. Results are shown from biomechanical computer simulations of the sitting man, as well as field studies from long-term follow up on sitting behaviour in a chair. It is concluded that an interdisciplinary approach is needed in order to introduce more beneficial chairs designs.

Sitting, computational biomechanics, seating, discomfort

1 Introduction

Sitting is probably the most common working posture today in the industrialized world. It is also commonly recognized that constrained sitting postures can lead to discomfort and health disorders (for example back pain and neck-shoulder complaints). The cost for society is major, and it can also be shown that the reduction of work effectiveness costs a lot too, both for the individual and for the company (Johanson & Johrén 2002). Therefore, seat ergonomics and usability are important selling points for manufacturers.

In order to achieve better designed work places, different theoretical models have been proposed (for example Mandal 1985, Makhsous et al. 2003). Some aspects of these models have been tested in laboratory environments (Andersson 1980, Makhsous et al. 2003). However, when focusing on biomechanical models of sitting there seems to be a tendency to forget the huge amount of variation between users, and also deviation for the same user during the day. Variations occur in gender, age, working postures, working tasks, exposure time etc. Also, most studies focus on a single source of injury or discomfort such as the load on the lower back.

There are different working methods that can be used when mapping the behaviour of the user, such as video-recordings, EMG-analysis, logging devices of handlings, biomechanical computer models and subjective methods. For some working situations critical factors can be easily recognized, for other situations such factors are not that clear. In the latter case it is important to first map the overall situation in order to get familiar with the special issues. It is also important not only to focus on the most beneficial posture on a too local level (for example the lumbar spine region). An

optimized situation for one body region might worsen the situation on another region, or cause discomfort.

This paper demonstrates three aspects that should be included in the product development strategy of chair manufacturers. These are:

- subjective and objective measurements of discomfort;
- using computer simulation tools for the musculoskeletal system;
- field studies for long term follow up at real work places.

These three aspects are also today used in real product development projects.

2 Discomfort in Sitting

The chair comfort is said to be a crucial factor from a marketing view point. However, from a scientific point-of-view the comfort is difficult to capture experimentally and has more factors influencing it than simply absence of discomfort. Ergonomists tend to define comfort as the well being that may arise from an appealing design or the acoustic quality of the room, while perceived discomfort is easier to link to concrete physical or physiological phenomena such as localized pressure on the skin or the fatigue of a muscle. In other words, comfort and discomfort are different phenomena and not simply opposite ends of the same scale. This paper deals with discomfort. It is important to keep in mind that the perceived discomfort changes over time (can be characterised as initial, static, transient or dynamical), and is also influenced by aesthetical and social factors.

Several possible measurement methods exist to evaluate discomfort:

- theoretical methods (biomechanics, anthropometry)
- observations (video recordings)
- subjective judgments (e.g. Borg scales)
- objective/direct measurements (EMG, pressure recordings)
- computer simulation

In a methodology study taken from the automotive industry two versions of driver car seats were tested (Osvalder et al., 2006); one that was subjectively considered as ’hard’ and one considered to be more ’soft’. The aim was to study if subjective methods (description of discomfort, questionnaires, interviews, and subjective estimations) gave the same discomfort indications as objective methods did (video recordings, EMG, pressure recordings). The tests were carried out by six test subjects in the ages between 55-65 years driving on a highway for a total period of 2-3 hours at two occasions. Only the car seats were changed but all other car parameters and environmental factors were constant (route, weather conditions, time of the day etc.).

The results from the study showed that the subjects could distinguish discomfort between the car seats, and their subjective judgements were in accordance with the ‘hard’ and ‘soft’ description. The subjective statements also pointed out specific body regions were discomfort was more pronounced during drive. These findings were supported by the objective measurements from EMG and recordings of sitting pressure. The conclusions

from the tests were that discomfort measurements are possible in field environments using a combination of subjective and objective methods.

3 Biomechanical Computer Modelling

Computational mechanics and the general improvement in computational speed have recently enabled the advent of software such as the AnyBody Modeling System (Damsgaard et al., 2006) for detailed analysis of the biomechanics of the human body. Some of these models are suitable for analysis of the human in a seated posture (Rasmussen et al., 2007).

The advantage of biomechanical models in relation to empirical/experimental methods is that the former allow for investigation of influences that may be difficult to measure in parameters that may be difficult to control. For instance, it is possible to measure spinal disk pressure experimentally (Takahashi et al., 2006), but it is an invasive experiment for which the ethical justification is difficult. Therefore, a computational method is the only viable option for investigation of various sitting parameters' influence on the spinal load.

The seated human model is a generic model of the human physiognomy seated in a parametric chair. The posture of the human part of the model is controlled by adjusting the parameters of the chair such as seat and backrest angles. The model provides as output all forces in individual joints and muscles and the force between the human body and the chair. This allows for investigation of properties such as the muscle effort of the seated posture, i.e. how much does the chair enable the occupant to relax, the spinal compression force, and the shear forces on the soft tissues under the buttocks. The latter causes discomfort in static postures.

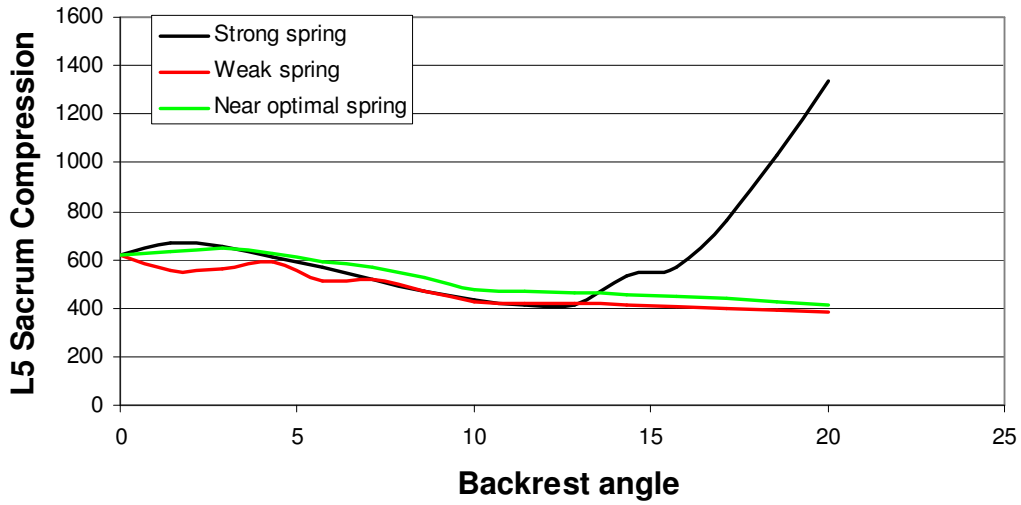

Figure 1. Force between L5 and sacrum as a function of chair inclination.

As an example, consider the standard RBM series 800 office chair. It is equipped with a spring arrangement that allows the occupant to incline the seat and the backrest backwards while maintaining some level of support. To accommodate occupants of

different weight and stature, the spring has an adjustment feature and can be tightened more or less. A too tight spring will require force beyond gravity from the occupant to incline the seat. A too loose spring will give inadequate support during the inclination and force the occupant to use active muscle force to prevent falling backwards. It is obvious that the spring should be adjusted for each user, but how will a poor adjustment affect the spinal force?

Figure 1 shows a simulation of the spinal compression between the fifth lumbar vertebra and the sacrum. The compression generally drops off as the chair is inclined, but is the spring is too tight, the larger inclination angles will cause a significant increase of the spinal pressure due to the necessary muscle activity.

4 Experiences from Field Studies

A final aspect to consider is the long time follow-up at actual work places. Questions must be raised such as:

- Are the chairs used as intended after delivery?
- Can any change be seen in measurable production or employment health data?
- Do the usage of chairs change over time?

An example of a minor pilot study focussing on such questions was performed by RH Form AB from June 2006 to March 2007 at a call centre workplace in Newcastle, UK. The main objective of the study was to test the method itself, to record productivity data together with user behaviour in the chairs. A population of 19 subjects were originally involved in the study and were provided with new office chairs that were predicted to possess higher ergonomic ratings compared to the earlier company standard. During the study, health and productivity data from the group were recorded. In order to record the handling of the chairs, five of these chairs were equipped with data loggers. The loggers recorded the position of a specific handle every second during a 9 months period, thus providing insight into the daily use of the chair.

Table 1: Productivity related data collected at half-year assessment.

Collection date:	*Mean value - NCI [minutes] (Net Communication Income – telephone)*	*Mean value - cross selling of insurances [%]*
1st May 2006	37.1	46.0
25th Sept 2006	20.9	48.6
19th April 2007	15.5	50.4

Table 2: Summary of logger data

Collection date:	*Users working mainly with chair in LOCKED position*	*Users working mainly with chair in OPEN position*
1st Sept 2006	3	2
25th Oct 2006	0	5
19th March 2007	0*	4*

**One logger not available for read-out at last data collection.*

During the test period some users left the group due to organisational changes. Among the users that kept their original work tasks, the mean values for some productivity-related parameters are shown in Table 1. Read-outs for the loggers were collected three times during the test period and a summary is shown in Table 2.

As seen in Table 1, the NCI-value decreases with 58% over the period of the study which means that incoming calls were handled faster (less waiting time for customers). During the same period the sales went up with more than 9 % for the group. The data logger information (Table 2) shows a tendency that all users eventually were using the chair in opened position, providing the dynamical sitting recommended by the manufacturer. However, the majority was not using the chair in the recommended way during the first recording period.

The main objective of the pilot study was to evaluate the methodology and this was found to work successfully without interfering with the call centre day-to-day business.

5 Discussion and Conclusion

Measurements of discomfort can provide quantitative or qualitative data from actual users, but some physical parameters can not be measured directly. Furthermore, many of the measurements can only be performed in a laboratory setting. Computer modelling of the musculoskeletal system can indeed provide insight into a number of internal forces and load situations. Still, when trying to analyse the calculated data, it is important to exactly know what to look for. The most successful way is probably to combine different approaches to the work place evaluation, and computer simulations should of course be validated over and over again by measurements and physical experiments. It is also important to be aware of the limitations of computer models. Even if such models are amazing in their complexity, it is important to understand what they can not predict.

Evaluating the outcome of environment interventions in real-world workplaces often means problems due to unforeseen changes (Lindbeck et al. 2006). From a scientific viewpoint it is hard to draw conclusions and for example connect a productivity increase to a specific design of a chair. Still, case-studies can provide excellent feed-back into the product development process, and the unexpected changes in themselves can give raise to new ideas. In the example described in this paper, RH Form was encouraged to continue to use this kind of field studies. A similar project was started up in the Netherlands and is also planned to start in Finland.

In conclusion; the possibilities today to obtain and validate sitting ergonomics are very promising. However, a wide perspective and an interdisciplinary approach are very much needed in the product development.

6 Acknowledgement

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