Sitting Comfort of Office Chair Design

Goroh Fujimaki, Kageyu Noro
Graduate School of Human Sciences, Waseda University
2-579-15 Mikajima, Tokorozawa, Saitama, 359-1164 Japan. Noro Ergonomics Laboratory
fujimaki@ruri.waseda.jp

Abstract

Recent studies pay considerable attention to body movements, mobility, and stability to measure sitting comfort or discomfort in dynamic conditions. Reviewing the literatures revealed that most of the studies discuss the relations between subjective comfort/discomfort and objective measurements (e.g., body pressure distribution, body movement, and EMG) in short-term sitting, and only several papers reported the studies related to seat comfort during prolonged sitting. The purpose of this study is to investigate the changes in sitting conditions and describe the relationships to sitting discomfort in prolonged sitting. The pattern change of body pressure distribution, and discomfort experience were studied during VDU tasks. The subjects comprised three males and three females; two different office chairs were used in the study. The different characteristics during 60 minutes sitting were described and compared with each other in time. It appeared that after a while the discomfort increased. When it reached a certain level, macro movement occurred and the pattern repeated. The cycle shortened until the continuous macro movements were observed, and this pattern also repeated. This knowledge could help in understanding the mechanism of discomfort during prolonged sitting.

1 Introduction

The widespread use of computers has been accompanied by a heightened interest in the ergonomics of office seating (Gross, Goonetilleke, Menon, Banaag, & Nair, 1994). It is considered that comfortable office chairs help workers to maintain their health and may also improve their quality of work. Many of the recent office chairs have original functions especially on the backrests (e.g., flexible backrests, tilting mechanisms, lumber supports, pelvis supports). They all have their original theories on the mechanisms on their backrests to share or to reduce the spinal load. The functions can be classified into two major categories. One of them is the function that supports (or more accurately fixes) the lumbar region or pelvis to maintain the spine in its natural S shape; the purpose is to reduce the load on the spine by helping to maintain it in its correct position. The other function supports natural human motion; the purpose of this function is to share the load by allowing movement of the spine and avoiding a fixed body posture. Focusing on the first case, there is an advantage in posture stability; however, this might disturb natural human motion. In the second case, natural human motion is not disturbed and there is an advantage in mobility; however, this may pose a disadvantage in maintaining stable posture. Though, either of these theories and methods is acceptable, the issues regarding how people experience comfort and discomfort and how these functions affect seat comfort still need to be addressed.

Recent studies pay considerable attention to body movements, mobility, and stability to measure sitting comfort or discomfort in dynamic conditions. Vergara & Page (2002) reported the relationship between comfort and back posture and mobility, and Fenety, Putnam & Walker (2000) measured discomfort by tracking the center of pressure (COP) on buttocks and verified the reliability of the method. Cholewicki, Polzhofer & Radebold (2000) developed a method for quantifying the postural control of the lumbar spine in unstable sitting. COP is also used in this study. Some models related to seat comfort in dynamic conditions are also reported. Ebe & Griffin (2000) described qualitative models of seat discomfort to include both static and dynamic (vibration) seat characteristics for automobile seat cushions. Furthermore, Brosh & Arcan (2000) modelled body/chair interaction for the mechanism of sitting down by a numerical approach (e.g., contact stress, contact moduli).

Some papers reported the studies related to seat comfort during prolonged sitting (Fernandez & Poonawala, 1998, Vergara & Page, 2002); however, since most of the studies deal with sitting comfort for a period of few seconds or few minutes, the studies concerned with seat comfort for long-term are less in number. According to the survey held by Ministry of Health, Labour and Welfare, of the Japanese Government in 1999, more than 50 percent of the office
workers work on their computers for one to four hours a day, and only 18 percent work on the computer for less than one hour.

Reviewing the literatures revealed that most of the studies discuss the relations between subjective comfort/discomfort and objective measurements (e.g. body pressure distribution, body movement, and EMG) in short-term sitting, and only several papers reported the studies related to seat comfort during prolonged sitting.

Regarding short-term sitting, the adjustability and suitability (e.g. size, shape, and stiffness of the chair) to the body are important (Jianghong & Long, 1994, Kolich, 2003). These factors also affect seat comfort for long-term sitting; however, physical, physiological, and psychological state of a human being and the physical state of the chair (especially seat cushions and tilting functions) change as time progresses. Changes in the state and body movements (i.e. posture stability, posture mobility) seem to be the important factors in long-term sitting (Fenety et al., 2000, Vergara & Page, 2002, Yukawa, Kawaguchi, Yamamoto & Fukui, 2002).

The purpose of this study is to investigate the changes in sitting state and describe the relationships to sitting discomfort in prolonged sitting.

2 Methodology

2.1 Experimental procedure

The subjects comprised three males and three females (table 1); two different office chairs were used in the study (figure 1). Chair A was a chair that supports pelvis and avoid its backward rotation. Chair B was a chair that supports natural human motion and avoid a fixed posture. Seat heights of the office chairs were adjusted to the subjects’ popliteal heights, and desk heights were adjusted to the subjects’ preferences. The subjects were free to move their body and change their posture during the experiment. Subjective evaluation on sitting discomfort and body pressure distribution was measured during 60 minutes of VDU tasks. Subjective evaluation of sitting discomfort was conducted at the beginning and after every 15 minutes during 60 minutes of VDU tasks. Subjective evaluation was measured on a five-point scale in questionnaire form. Seat and Back System of Force Sensitive Applications (Vista Medical Ltd., Canada) was used for measuring body pressure distribution, and it was measured in sampling frequency of 1Hz.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>167.8</td>
<td>58</td>
</tr>
<tr>
<td>2</td>
<td>172.5</td>
<td>61</td>
</tr>
<tr>
<td>3</td>
<td>182.0</td>
<td>84</td>
</tr>
<tr>
<td>4</td>
<td>152.8</td>
<td>49</td>
</tr>
<tr>
<td>5</td>
<td>160.2</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>163.0</td>
<td>-</td>
</tr>
</tbody>
</table>
2.2 Analysis method using Self-organizing Map

General method to analyze body pressure distribution were, 1) Divide the pressure maps into several areas (e.g. buttock area, thigh area, upper back area, lower back area) and calculate average pressure and pressure variation in each area (Ng, Csar, & Gross, 1995, Park & Kim, 1997), 2) Analyze the pressure on the major region of body (e.g. underneath the ischial bones, lumber region) (Kamijo, Tsujimura, Obara & Katsumata, 1982). It was difficult to understand the pattern change of body pressure distribution by current methods. In this study, measurement values of body pressure distribution were analysed by a method using Self-organizing Map. By using this method, the result could be represented in the same array as they were measured, and the pattern change of body pressure distribution could be understood.

Figure 2 shows the concept of analysis method using Self-organizing Map. Neurons at the competitive layer learn the measurement value of body pressure distribution, and as a result, learned neurons those have similar distribution profile will be located nearby, and those have dissimilar distribution profile will be located far away. Weight vector of a learned neuron shows the approximate distribution pattern of the pressure distribution those were classified as that neuron. By investigating the transition of ignited neurons, pattern change of body pressure distribution is understandable (figure 3).

**Figure 2:** Concept of the analysis method using Self-organizing Map.

**Figure 3:** Transition of an ignited neuron and pattern change of body pressure distribution.
3 Results

3.1 Subjective evaluation

However, the figure has varied among the subjects, discomfort increased by time. Most of the subject experienced much discomfort in the case of chair A compared to chair B. Figure 4 shows an example of discomfort experienced by subject 1. In this case, there was a characteristic change between 30 minutes to 45 minutes, and the decrease of discomfort was observed at that time interval.

![Figure 4: Discomfort experienced by subject 1 during 60 minutes sitting.](image)

3.2 Pattern classification by Self-organizing Map

The measurement values of body pressure distribution were learned by Kohonen’s Self-organizing Map. 5 times 6 neurons were prepared and it was learned for 1000 times. Figure 5 shows the array of neurons and the weight vectors of the learned neurons.

![Figure 5: Weight vector of the learned neurons.](image)
3.3 Pattern change of body pressure distribution

Figure 6 and figure 7 shows an example of ignited neurons during 60 minutes sitting for subject 1. Neuron numbers stated in the figures refer to the neuron numbers in figure 5. In the case of chair A, several neurons were observed as a basing point, and there was a transition between those neurons. In the case of chair B, a certain neuron was observed as a basing point, and there was a transit to various neurons. These trends were common among all the subjects.

![Figure 6: Change of ignited neurons during 60 minutes sitting on chair A (subject 1).](image)

![Figure 7: Change of ignited neurons during 60 minutes sitting on chair B (subject 1).](image)

Figure 8 shows the change of sitting condition, which was based on the ignited neurons during 60 minutes sitting. When ignited neurons were same for more than 10 seconds, it was defined as stable condition. When an ignited neuron transit to the neighbouring neuron or ignited neurons were same for less than 10 seconds, it was defined as unstable condition. When an ignited neuron jumps to non-neighbouring neuron, it was defined as macro movement.

Comparing chair A with chair B, less macro movements, less stable condition, and more unstable condition were observed. Increases of unstable condition were observed at the time interval when discomfort increased (table 2).

![Figure 8: Sitting condition during 60 minutes sitting (subject 1).](image)
Table 2: Total time of sitting conditions in seconds (subject 1).

<table>
<thead>
<tr>
<th>Chair type</th>
<th>sitting condition</th>
<th>0-15 minutes</th>
<th>15-30 minutes</th>
<th>30-45 minutes</th>
<th>45-60 minutes</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chair A</td>
<td>stable condition</td>
<td>589</td>
<td>545</td>
<td>573</td>
<td>513</td>
<td>2219</td>
</tr>
<tr>
<td></td>
<td>unstable condition</td>
<td>297</td>
<td>344</td>
<td>318</td>
<td>370</td>
<td>1329</td>
</tr>
<tr>
<td></td>
<td>macro movement</td>
<td>13</td>
<td>11</td>
<td>9</td>
<td>18</td>
<td>52</td>
</tr>
<tr>
<td>Chair B</td>
<td>stable condition</td>
<td>743</td>
<td>785</td>
<td>744</td>
<td>597</td>
<td>2868</td>
</tr>
<tr>
<td></td>
<td>unstable condition</td>
<td>132</td>
<td>85</td>
<td>134</td>
<td>219</td>
<td>570</td>
</tr>
<tr>
<td></td>
<td>macro movement</td>
<td>26</td>
<td>30</td>
<td>23</td>
<td>84</td>
<td>163</td>
</tr>
</tbody>
</table>

4 Discussion

In former study, macro movements were considered as a good indicator of discomfort, and if the time interval between two consecutive changes is less than 5 minutes, probability of being uncomfortable is high (Vergara & Page, 2002). It was a valid conclusion, but macro movements also have a meaning of reducing discomfort. Actually, discomfort decreased between 30 to 45 minutes in the case of chair A for subject 1, which had macro movements with the time interval less than 5 minutes. It was considered that when discomfort increases, unstable condition increase. Increase of continuous macro movements is considered that presently discomfort is high, and after discomfort is low. Increase of stable condition may be the cause of discomfort (Vergara & Page, 2002), but macro movements will reduce discomfort and the combination of these sitting conditions may maintain the discomfort level. Figure 9 is a theoretical model of sitting condition and discomfort on prolonged sitting, which was considered from the results.

During the stable condition the feeling of discomfort increases by a certain degree. When the discomfort reaches a certain level, the sitting condition will shift to the unstable condition and discomfort will increase rapidly. When the discomfort further increases to reach a certain level, macro movement occurs and the feeling of discomfort will be reduced. At this conjuncture, discomfort will not be reduced completely, and a certain level of discomfort will be stored. The pattern repeats and the cycle shortens. The reduction of discomfort by a macro movement becomes less effective as the stored discomfort increase, and to reduce the stored discomfort, continuous macro movements will occur. And this pattern also repeats.

According to this theory, chair A had a shorter cycle and the first cycle ends around 30 minutes. Chair B had a longer cycle compared to chair A and only one cycle was observed during 60 minutes of sitting. It was considered chair A, which supports pelvis and prevent backward rotation, had less macro movements and reduction of discomfort was low, and as a result unstable condition increased and the cycle was shorter. Chair B, which supports natural human motion, had more macro movements and reduction of discomfort was high, and as a result stable condition increased and the cycle was longer. In prolonged sitting, discomfort increase by time in any chair. To reduce discomfort it is important not to disturb macro movements.

Figure 9: Theoretical model of sitting condition and discomfort on prolonged sitting
5 Conclusion

The pattern change of body pressure distribution, and discomfort experience were studied during VDU tasks. The different characteristics during 60 minutes sitting were described and compared with each other in time. It appeared that after a while the discomfort increased. When it reached a certain level, macro movement occurred and the pattern repeated. The cycle shortened until the continuous macro movements were observed, and this pattern also repeated. The cycle depends on subjects and chairs, but this knowledge could help in understanding the mechanism of discomfort during prolonged sitting. Further, effectiveness of macro movements to discomfort may be a clue to reduce discomfort.

Acknowledgement

Authors would like to thank Human Life Technology Research Institute of Gifu Prefecture, Japan, and Ms. Kiyoka Sakai for their cooperation.

References


