Evaluation of Comfort and Health of Mattresses from Mechanical Standpoint

Teruko TAMURA, Utako SHIMANE, * Sunsuku HOU and Makoto YOSHIDA**

Faculty of Home Economics, Bunka Women's University, Tokyo 151, Japan
*Faculty of Home Economics, Wayo Women's University, Chiba 272, Japan
**Teijin Co. Ltd., Osaka 567, Japan

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Introduction
Mattresses are a textile end use that directly effect human health. The mechanical properties are essential for comfort and health of mattresses because they support a person's posture in a good position during sleep.

Figure 1 shows three aspects of the evaluation of the mechanical comfort and health of mattresses: psychological evaluation, kinematical evaluation and physiological evaluation. Concerning psychological evaluation, a big project on the comfort of mattresses was carried out by McCullough1) and the characteristics of mattresses that consumers preferred best was clarified. Concerning kinematical evaluation, the pressure distribution between the body and various mattresses were examined by Kohara,2) Newell et al.,3) Krous-kop et al.4) and McCullough.1) Also body movement during sleep was measured by Kohara,3) Kusunoki5) and Wallace et al.6) However, little attention has been given on physiological responses such as electroencephalogram by which the quality of sleep can be explored.

In this study, the physiological responses of sleeping subjects on different types of Japanese mattresses were examined with psychological and kinematical evaluations. Japanese mattresses are traditionally used directly on a Tatami floor. A typical Japanese bed consists of one pillow, one comfortor or quilt and two types of mattresses, fiberfilled and of rubber foam. In this study, three types of fiberfilled mattresses in Table 1, soft and thick, medium, and hard and thin, were tested. The fiber composition and the thickness of the mattresses were a little different for the physiological tests from the other two tests.

Psychological evaluation
As a psychological evaluation, a sensory test was conducted. The statistical method used was Nakaya's Modification of Sheffe's paired test. The subjects consisted of 10 female students aged from 20 to 21 years old with a variety of body types.

Two types of paired tests were conducted. A subjective scale is shown in Fig. 2. One test evaluated sensation and comfort when the subjects touched the mattress with their hands. This corresponded with the evaluation consumers make at a store. The second test evaluated sensation and comfort the subjects felt after laying on the mattresses for 2 min. This corresponded to the consumer's first impression after going to bed.

The results were shown in Fig. 3. The mattress that was the most preferred by the subjects was No. 5 polyester mattress. The characteristics of the mattress were rated as medium in touch feeling, sinkability, hardness, fluffiness, warmth and cushiony. A little higher rating was given in a resiliency.

Physiological evaluation
For the physiological evaluation, EEG, EMG, ECG, respiratory rate, metabolic rate and body movement during sleep were measured. The subjects were 5 healthy female students aged from 20 to 29 years old. The experiments were conducted from 9:30 pm to 7:00 am in the climatic
chamber at Bunka Women's University. The thermal conditions were 25°C, 70% RH and <.15 m/sec air velocity. Figure 4 shows the scene of the experiment and the locations of electrode monitors. An example of the chart record was shown in Fig. 5. For every 20 sec interval of the chart like this, the quality of sleep was rated. The categories of the sleep included awake, REM, and 4 stages progressing from drowsy to deep sleep. In this case, the sleep stage was judged as REM.

Fig. 1. Evaluation of the comfort and health of mattresses from mechanical standpoint

Table 1. The mattresses tested

<table>
<thead>
<tr>
<th>Test</th>
<th>Hard</th>
<th>Medium</th>
<th>Soft</th>
<th>Thick</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psycol.</td>
<td>P(8) No. 3</td>
<td>P(13) No. 4</td>
<td>C(15) No. 1</td>
<td></td>
</tr>
<tr>
<td>Kinem.</td>
<td>P(6) No. 2</td>
<td>P(13) No. 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physiol.</td>
<td>P(4)</td>
<td>C(12)</td>
<td>P/C(15)</td>
<td></td>
</tr>
</tbody>
</table>

P: polyester, C: cotton (Thickness, cm).

Fig. 2. Subjective scale

Fig. 3. Subjective ratings for five mattresses (No. 1–No. 5)
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Fig. 4. The locations of electrode monitors and the scene of the experiment

Fig. 5. An example of chart record (REM)

Fig. 6. Physiological responses during sleep

(707)
sleep because the electroencephalograph was fast and small, typical eye movement and no response of electromicogram were observed. Figure 6 shows the data for every 20 sec interval for the sleep for one subject for one night on a hard type polyester mattress. The typical progression of the sleep stage was shown here. The subject fell into a deep sleep in 30 min after going to bed, remained in a deep sleep for about 1.5 hr, and then the sleep stage changed into light sleep. After that, REM sleep appeared four times until the subject woke up in the morning. During each REM sleep period both the heart rate and respiratory rate increased. The metabolic rate declined gradually through the night. Body movements occurred in response to each change in the sleep stages.

From the experimental data the total sleep time, sleep latency, REM latency, percent of each sleep stage time to total sleep time, number of times awaken were calculated by computer.

The graphs in Fig. 7 compared the three mattresses tested. The highest quality of sleep resulted from the polyester mattress which was the hardest and the thinnest of all.

**Kinematical evaluation**

For the kinematical evaluation, a plaster mold method was developed to evaluate the posture in the lying position (Fig. 8). In this method, plaster was applied subject's back, they lay on the mattress for 30 min, and then the dried plaster mold was removed. A line was drawn on the plaster to correspond with the original level of the mattress surface.

The plaster molds were measured using moire topography. The center picture in Fig. 8 shows the moire topography equipment. The right picture is the contour map from the moire topography. In this picture, each moire contour line represents about 1 cm vertical depth. So the depth of each body region from the original surface of the mattress could be calculated from the photograph. The subjects were female students aged from 20 to 21 years old with a variety of body types.

The graph in Fig. 9 shows distance of the different body regions from the plane of the small of the back. The graph represents the averages of the data from the 9 subjects. The laying position graphs were straighter than the standing position graph. In the case of the most preferred mattress, the posture was 3 cm below the waist plane at the scapula, 4 cm at the sacrum and the same level with the waist plane at the thigh and heel. In the case of the mattress that was the most uncomfortable by the psychological test but the most healthy by the physiological test, the posture was the straightest of all as the thin solid line in the figure showed.

Using compression depths derived from the moire topography, the pressure of the subject's body on the mattress was estimated by the compression-pressure curve of each mattress. Figure 10 shows examples of the body pressure distribution. Relatively higher pressure was observed on all mattresses at areas such as the scapula, sacrum, head and heel. These regions are all bony prominent areas. It is in these areas that patients tend to get pressure sores in long term care units.
The body pressure increased with the hardness of the mattresses. The lowest pressure was resulted from the soft mattress. The medium pressure was observed on the medium mattress and the highest pressure on the hardest mattress. The contact area between the body and the mattresses changed with each mattress and each body type. With the softer mattresses and with the obese subjects, the contact area increased (Fig. 11).

**Conclusion**

1. The results of the psychological test showed...
that the subjects preferred the medium type mattress. In contrast, the physiological test suggested that the highest quality sleep resulted from the hardest mattress. The mattress that was perceived as the most comfortable when awake was not necessarily physiologically the most healthy during sleep.

2. The plaster mold method was developed to examine the postures and the body pressure distributions on the mattresses.

The posture on the most preferred mattress was 3 cm below the waist plane at the scapula, 4 cm at the sacrum and the same level with the waist plane at the thigh and heel. The highest quality of sleep resulted from the straightest posture. The body pressure was the lowest on the soft mattress.

3. The mechanical properties of Japanese mattresses need to be examined on further more people in future to satisfy both the comfort and health of the consumers.

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① 石膏包帯法による背面形状の採取は、寝姿勢・体圧分布を把握する上で有用な方法である。
② 最も好まれた敷布団は、W.Lを基準にすると、肩甲部で3 cm、仙骨部で4 cm沈み、大腿・踵部は、W.Lと同じ沈みであった。最も良い眠りは、直線的な寝姿勢をもつものであり、体圧は柔らかい布団で最も低い値を示した。
③ 官能検査結果より得られた最も適当な敷布団は、生理的反応に基づく健康な評価とは、必ずしも一致しなかった。敷布団の機能的な特性は、今後さらに多くの人を対象として、消費者の快適性と健康性の両面から検討していく必要がある。

キーワード：敷布団、健康性、快適性、脳波、官能検査、体圧分布。