Effects of Truss Mattress upon Sleep and Bed Climate

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Abstract. The purpose of this study was to examine the effects of a truss mattress upon sleep and bed climate. The truss mattress which has been designed to decrease the pressure and bed climate humidity was tested. Six healthy female volunteers with a mean age of 23.3 years, served as subjects. The experiment was carried out under two conditions: a truss mattress (T) and a futon (F) (Japanese bedding). The ambient temperature and relative humidity were controlled at 19–20°C, and RH 50–60% respectively. Sleep was monitored by an EEG machine and the rectal temperature, skin temperature and bed climate were also measured continuously. Subjective evaluations of bed and sleep were obtained before and after the recording sessions. No significant difference was observed in the sleep parameters and time spent in each sleep stage. Rectal temperature was significantly lower in T than F. Although there was no significant difference in bed climate over the T/F, the temperature under T/F was significantly higher in T. No significant difference was observed in subjective sleep evaluation. The subjective feeling of the mattress was significantly warmer in F than T before sleep. These results suggest that although T does not disturb the sleep parameters and the bed climate is maintained at the same level as with F, it may affect rectal temperature which can be due to low thermal insulation.


Keywords: sleep, bed climate, truss mattress

Introduction

Among the various kinds of bedding, the mattress has been the focus of many clinical studies as the pressure distributing mattresses is the most frequently used treatment employed for preventing and caring for decubitus (Gosnell et al., 1992). However, in spite of the increasing use of pressure redistributing mattresses, the occurrence of pressure sores has also increased (Clark and Cullum, 1992). The objective was to examine the effects of this truss mattress on sleep, body temperature and bed climate. The truss mattress was compared with Futon, since 50% of the young as well as 70% of the elderly use a Futon (Okamoto et al., 1993) in Japan.

Method

Condition and materials

Six healthy female volunteers with a mean (SD) age of 23.3 (1.8) yrs served as the subjects. Their mean (SD) physical characteristics were height 156.1 (4.10) cm, weight 49.8 (4.30) kg and Rohrel index 130.7 (7.10). The
questionnaire about sleep prior to the experiment confirmed that all the subjects did not have any sleep disturbance. After obtaining the subject's informed consent, they were tested in the laboratory for three nights. In order to avoid the effects of the menstrual cycle, subjects participated in the experiment during their follicular phase. They were asked to wake and sleep in a regular time before the experiment. Intake of alcohol, caffeine and medicine, as well as intense exercise were prohibited before and during the sessions.

The room temperature and relative humidity were controlled at 19–20°C and RH 50–60%, respectively. The experiment was carried out with either a 100% cotton futon (F) or a truss mattress (T) made of 65% polyester and 35% nylon. The properties of the mattresses are shown in Fig. 1.

A bed sheet (100% cotton) covered an experimental mattress which was placed on a 100% cotton futon. The subjects slept with a sheet, a blanket (100% Acrylic), and a futon (40% cotton/60% Polyester) wearing long sleeve pyjamas (100% cotton) and panties. In order to keep the mattress condition as stable as possible, mattresses were dried with a Futon drying machine (FD-6PR, National) for 1.5 hr from 9:00 am.

Measurements

EEG (F3, C3, C4, O1), EOG and mental EMG were recorded as objective sleep measurements using an EEG machine (EEG-4317, Nihon-kohden). Sleep recordings were scored visually every thirty seconds based on the standard manual of Reftschaffen and Kales (1968).

Rectal temperature (Tr) and skin temperature (Ts) of the arm, chest, thigh, leg and foot were recorded at the time interval of thirty seconds using a thermometer (Data collector AM7003, Anritu). Mean Ts was calculated by the four point method of Ramathan (1964).

Temperature and relative humidity inside the bedding (Bed climate) were measured using a thermometer and a hygrometer (Data stoker TRH-DM3, Shinei) continuously through the night at a time interval of thirty seconds. Three areas of bed climate were measured; waist area over T/F (waist over), waist area under T/F (waist under) and foot area over T/F.

Subjective sleep evaluations were noted after sleep using an OSA sleep questionnaire (Oguri et al., 1985). Thermal (+3; hot to -3; cold), humidity (+3; dry to -3; humid) and comfort (+3; comfortable to -3; uncomfortable) sensation were noted immediately before the lights were turned off and after the lights were turned on. At the same time, the subjective feeling about the mattress was noted.

The procedure of the experiment is shown in Table 1. The subjects were asked to sleep from 23:00 p.m. to 7:00 a.m. Bed climate, Tr, Ts and polysomnographic recordings were measured continuously during the eight hours. The subjects slept three nights continuously, the first night of which was an adaptation night. The subjects were not informed about the order of the two conditions from the second night and these conditions were set at random.

In order to test the statistical significance of the data, two-way ANOVA was used to analyse the subjective feelings and sleep parameters. The factors were condition (T and F) and subjects. Two-way ANOVA for

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![Fig. 1 Properties of the truss mattress.](image-url)
repeated measures was used to analyse bed climate, Ts and Tr. The factors were condition and time. The level of significance was considered to be \( P<0.05 \).

**Results**

**Sleep characteristics**

The results of the sleep parameters are shown in Table 2. There was no significant effect of the condition on sleep parameters and the time spent in each sleep stage through the night. Sleep efficiency index was more than 90% for both conditions.

**Rectum temperature and skin temperature**

Fig. 2 shows the result of Tr through the night in an average of six subjects under the two conditions. The Tr was significantly affected by time \( (F_{31,310}=1.75; p<0.01) \) and interaction \( (F_{31,310}=1.94; p<0.01) \). F sustained a significantly higher level from 0:45 to 1:15 (\( P<0.05 \)). In local and mean Ts, only the effect of time was significant. Mean Ts was maintained at 35~35.5\(^\circ\)C for both conditions.

**Bed climate**

The bed climate of the waist over and waist under through the night is shown in Fig. 3. In the bed climate temperature of the waist over, only the effect of time was significant \( (F_{31,310}=48.39; P<0.001) \). In waist under, a significant effect of time \( (F_{31,310}=68.25; P<0.001) \) and interaction was observed \( (F_{31,310}=2.16; P<0.001) \). The temperature was significantly lower in F than T at 0:15~1:15 a.m. The difference in bed temperature of waist over and waist under was significantly affected by time \( (F_{31,310}=5.94; P<0.01) \) and interaction \( (F_{31,310}=2.18; P<0.01) \) which was greater in F than T at 23:00~0:30 \( (P<0.05) \). In relative and absolute humidity of the bed climate, no significant effect of condition nor any interaction was observed. All the conditions maintained RH 35~50% level.

No significant effect of condition nor any interaction

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**Table 1** Procedure of the experiment

<table>
<thead>
<tr>
<th>Time</th>
<th>2230</th>
<th>2300</th>
<th>7:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EMG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EOG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rectum temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bed climate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal sensation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humidity sensation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comfort sensation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep evaluation</td>
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<td></td>
</tr>
</tbody>
</table>

Asterisk indicates the measuring point.

**Table 2** Sleep parameters under two conditions

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>TST</td>
<td>448.0 (11.1)</td>
<td>451.0 (11.9)</td>
</tr>
<tr>
<td>Onset of Sleep</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 2</td>
<td>6.8 (4.8)</td>
<td>4.7 (2.4)</td>
</tr>
<tr>
<td>Stage 3</td>
<td>22.8 (13.3)</td>
<td>17.9 (3.8)</td>
</tr>
<tr>
<td>Stage 4</td>
<td>30.6 (14.3)</td>
<td>27.7 (5.6)</td>
</tr>
<tr>
<td>REM</td>
<td>67.3 (16.1)</td>
<td>84.0 (24.0)</td>
</tr>
<tr>
<td>SEI (%)</td>
<td>93.3 (2.3)</td>
<td>94.1 (2.5)</td>
</tr>
<tr>
<td>WASO</td>
<td>17.4 (6.6)</td>
<td>17.5 (9.2)</td>
</tr>
<tr>
<td>Time of Wake</td>
<td>31.9 (11.1)</td>
<td>28.4 (12.1)</td>
</tr>
<tr>
<td>Stage 1</td>
<td>37.7 (15.3)</td>
<td>32.3 (10.3)</td>
</tr>
<tr>
<td>Stage 2</td>
<td>240.0 (19.7)</td>
<td>247.0 (18.1)</td>
</tr>
<tr>
<td>Stage 3</td>
<td>26.2 (6.0)</td>
<td>27.6 (10.4)</td>
</tr>
<tr>
<td>Stage 4</td>
<td>39.0 (16.0)</td>
<td>30.2 (16.3)</td>
</tr>
<tr>
<td>Stage 3+4</td>
<td>65.2 (18.2)</td>
<td>57.8 (7.2)</td>
</tr>
<tr>
<td>REM</td>
<td>105.0 (10.4)</td>
<td>114.0 (11.3)</td>
</tr>
</tbody>
</table>

Average (S.D.) min.
Average of six subjects. TIB; Time in bed, SOL; Sleep onset latency, SPT; Sleep period time=TIB-SOL, WASO; Wake after sleep onset, TST; Total sleep time=SPT-WASO, SEI; Sleep efficiency index.

**Fig. 2** Changes of rectum temperature. Average of six subjects.

**Fig. 3** Changes of bed climate temperature of the waist over and waist under. Average of six subjects.
was observed in bed climate of the foot area and the temperature and relative humidity was maintained at 28~32°C, and RH30~45%, respectively.

Subjective evaluation

No significant difference was observed in OSA subjective sleep evaluation and all the conditions obtained a good evaluation of over 50 points. The comfort sensation also was appraised as comfortable under both conditions (F=2.2 ± 0.51; T=1.9 ± 0.71). The main difference in the subjective evaluation was observed in regard to the subjective feeling of the mattress (Fig. 4). F was significantly warmer (F1,10=10.0; P<0.05) and stable (F1,10=8.18; P<0.05) before sleep and was more spongy (F1,10=5.29; P<0.05) in the morning.

Discussion

No significant difference was observed in sleep parameters and bed climate of the waist over between T and F. These results indicate that T does not disturb sleep and bed climate of the waist over can be maintained at the same level as F.

The most interesting finding in this study was observed in Tr. Tr decrease sharply following sleep onset and this sleep-evoked decrease show a greater effect in the evening than in the morning (Barrett et al., 1993). A significant difference was observed during this decreasing period which was lower in T than F. One possibility for a significant difference in Tr might have been the different thermal properties of F and T. Inagaki et al. (1995) compared T with F and found about two times greater heat transfer and 12 times greater air permeability in T. Results from bed climate have also shown a clear difference in thermal property between F and T. Although there was no significant difference in waist over, waist under showed a significantly higher temperature in T, indicating that heat transfer is higher in T. Considering that the subjective evaluation of the bed was significantly warmer before sleep and tended to be warmer in the morning in F than in T, it is possible that bed condition was cooler in T than F due to lower thermal insulation. Candas et al. (1978) compared sleep and body temperature under five levels of thermal neutral temperature. Although they did not find any significant difference in sleep parameters, Tr showed a significantly greater decrease as the room temperature decreased. It has been shown that Tr during sleep depends even on the slight changes of ambient temperature within thermal comfort zone (Muzet et al., 1984). These results were similar to our result, and supports the notion that a cooler condition in T is one of the reasons for the lower Tr. It is of interest to confirm the effect of T in a hot environment, as this result can be due to the ambient temperature in this study.

In spite of the significant difference in Tr, no significant difference was observed in bed climate temperature of the waist over. Candas et al. (1978) found that when the ambient temperature varied 16~25°C, the sleep parameters did not change and bed climate temperature varied only 28.6~30.9°C, while Tr clearly changed depending on the ambient temperature. He hypothesised that a sleeping man can maintain certain level of bed climate temperature during sleep by decreasing the Tr without changing any sleep parameters. It is possible that the greater Tr decrease in T had acted in maintaining the same waist over temperature as the F. Suzuki et al. (1995) pointed out that an excessive decrease in rectal temperature under a cool ambient temperature leads to sleep fragmentation. Although our result did not reach this level, it is important to note that bed condition will be cooler than F when using T for patients and bedridden elderly.

Another finding in this study was observed in the subjective feeling of the bedding before and after sleep. Although pressure concentration did not occur in T relative to F in the objective pressure measurements (Inagaki et al., 1995), the subjects felt more rigid and
unstable in T than in F. This indicates that objective pressure measurements are not always consistent with the subjective feelings. Although the pressure is reduced, a rigid and unstable feeling increases discomfort (Sugama and Sanada, 1997). Considering that the bedridden elderly have to remain in bed for almost 24 hours, it is extremely important to take the subjective feeling in account when vaulting pressure redistribution mattresses.

In conclusion, T does not disturb the sleep parameters and maintains the bed climate at the same level as F. However, careful consideration is needed in using T for patients and the bedridden elderly as it may affect Tr which can be due to lower thermal insulation. Further study on comparing these data with the elderly subjects, various ambient temperature, and longer duration including the daytime is needed.

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