The Effects of Air Mattress upon Sleep and Bed Climate

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Abstract. The purpose of this study was to investigate the effects of an air mattress upon sleep and bed climate. This air mattress, which employs a pump and timer to increase or decrease the inflation pressure in order to cure and prevent decubitus was tested. Six healthy female volunteers, aged 18 to 23, served as subjects. The experiments were carried out under three conditions: using regular Futon (Futon), the air mattress with pump and timer activated (Air+) and the same mattress without pump and timer activated (Air-). Room temperature and relative humidity were controlled at 22-23°C and RH 50-60% respectively. Subjects' sleep was monitored by using EEG machine throughout the night, and subject's body temperature and bed climate were also continuously checked. Subjective estimation of bed and sleep were obtained before and after the recording sessions. Sleep onset latency and wake after sleep onset tended to be reduced in Air+ compared to Futon and Air-. The time and percentage of Stage 3 was increased significantly in the middle one third of the night in Air+. A significant difference was observed in bed climate of the waist area. Temperature tended to be higher in Futon than in Air+ and Air-, while relative and absolute humidity were significantly higher in Air+ and Air-. Significant difference between Air+ and Air- was observed only during one hour after sleep recordings started. Thermal sensation in the morning was cooler and comfort sensation tended to be better in Air+ and Air-. Subjective sleep estimation was somewhat good under all conditions. These results suggest that although these air mattresses do not affect sleep, we have to be cautious in using these mattresses as relative and absolute humidity were kept higher than with Futon. Further study on materials and construction of these air mattresses to decrease the humidity is needed.

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Introduction

Recently, it has been reported that 21% of the population in Japan will be elderly in 2010 (Health

Welfare Statistics Association, 1993a). According to this rapid increase, bedridden elderly has also increased (Health Welfare Statistics Association, 1993b) and 13% of them are said to suffer from decubitus (Mizunoe, 1985). Various factors are considered as the cause of decubitus but preventive interventions between bedding and body are said to be based on eliminating four major risk factors such as pressure, moisture, shear and force (Spoelhof and Ide, 1993). In order to eliminate these factors, stocks of pressure redistributing mattresses has increased over these 4 years (Clark and Cullum, 1992) and the usage of these mattresses is the most common treatment taken for preventing decubitus (Gosnell et al., 1992). But on the other hand, occurrence of pressure sores has also increased according to the increase of the stock in these mattresses. One of the reasons is considered to be total lack of comparative data on effectiveness of available mattresses and incorrect usage. (Clark and Cullum, 1992). This is due to the fact that efficiency of many of these special mattresses is not supported by scientific data (Levine and Totols, 1995). Considering the rapid increase of elderly in our country, scientific and comparative data for these special mattresses are necessary.

Air mattress is one of these special mattresses which have been reported to be effective in reducing pressure and increasing blood flow compared to usual hospital beds (Allen et al., 1994; Stewert et al., 1990; Xakellis et al., 1993; Feldman et al., 1993). On the other hand, risk scores, incidence, severity and healing duration when used by patients are not always effective especially when it is compared with other pressure redistributing mattresses (Sidrenko et al., 1992; Daechsel and Conine, 1985). But in these previous studies, the measurements for vaulting these mattresses are limited on pressure, blood flow and observation of the patients during daytime. Although reducing pressure is one of the most important factors, other factors such as moisture, shear and force should not be neglected. Furthermore air mattresses are used 24 hours a day. As far as the authors know, there is no study which focuses on effect upon neither sleep nor bed climate. The intention of this study was to confirm fundamental effect of air mattress upon sleep and bed climate in healthy young subjects. Air

mattress was compared with *Futon*, as 50% of young as well as 70% of the elderly use traditional Japanese bedding namely "*Futon*" (Okamoto et al., 1994) in Japan.

Method

Properties of the air mattress

The properties of the air mattress are shown in Fig 1. Mattress is made from 100% vinilon. It consists of twenty-four air cells, timer and pump. Air cells are connected in three separate series. The pump increases or decreases inflation pressure in each of the series in constant time of twenty minutes and constantly changes areas of support. The air comes out from the central area of the mattress between the air cells when the pump increases or decreases inflation pressure, in order to prevent the increase of the humidity inside the bedding. Most of the subjects did not feel these movements of the cells and air.

Conditions

Six healthy female volunteers, aged 19 to 23, served as subjects. Mean (s.d.) physical characteristics of the subjects were height 156.2 (4.9) cm, weight 51 (4.4) Kg and Rohrer index 133.75 (6.76). They were informed before the experiment and agreed to sleep and be tested in the laboratory for four nights. In order to avoid the effects of the menstrual cycle, subjects participated in the experiment when they are in follicular phase. They were asked to wake and sleep in a regular schedule one week before the experiment. Intake of alcohol, caffeine and medicine, severe exercise were forbidden during the experiment.

Room temperature and relative humidity were controlled at 22 to 23°C and RH 50-60% respectively. The experiment was carried out under three conditions, that is: using air mattress with air pump and alternating the cells activated (Air+), air mattress with air filled without alternating the cells activated (Air-) and Japanese traditional Futon (Futon). Futon was made of 100% cotton stuffing covered with 100% cotton material.

Bed pad (100% cotton) and sheet covered the air mattresses. A cotton sheet covered the Futon. Bed pad was used in air mattress condition to minimise the effect of different contact surface, as it was very different between Futon and air mattresses. Bed pad which is as thin as possible was selected so as not to disturb the function of the air coming out from the air mattress. They were placed on a urethane mattress which was placed on the *tatami* (traditional Japanese flooring). Subjects slept on the sheet (100% cotton), using a blanket (100% acrylic) and wearing short-sleeve pyjamas (100% cotton) and shorts.

Measurements

EEG (F3, C3, C4, O1), EOG and mental EMG were

recorded all through the night as objective sleep measurement by using EEG machine (EEG-4317, Nihon-kohden). Recordings were scored visually every twenty seconds by standard criteria of Rechtschaffen and Kales (1968).

Skin temperature of the forehead and dorsal hand were recorded in interval of one minute by using a thermocouple (CTM205, Core Temp).

Bed climate was measured by using data stoker (TRH-DM3, Shinei) continuously through the night in time interval of twenty seconds. Sensors were attached on the bedding under the bed sheet. Foot and waist area were measured as decubitus is said to occur most frequently on sacrum and heel (Meehan, 1994; Gosnell et al., 1992).

Subjective sleep estimations were asked after sleep by using a seven ranked scale (-3 to +3) for five factors: satisfaction, sleep depth, refreshed feeling, sleep onset and sleep time. Thermal (+3; hot to -3; cold), humidity (+3; dry to -3; humid) and comfort (+3; comfortable to -3; uncomfortable) sensation were asked before entering the bed, just after entering the bed and after final awaking.

Procedure of the experiment is shown in Table 1. Subjects were asked to sleep from 23:00 to 7:00. Bed climate, skin temperature and polysomnographic recordings were measured continuously during these eight hours. Subjects slept four nights continuously and slept on air mattress with air pump and alternating the cells activated for the first adaptation night. The order of the three conditions from the second night were untold to the subjects and were at random.

For analysing the statistic significance of the data, one way analysis of variance (condition: Air+, Air- and Futon) were used for subjective feelings and sleep variables. Two way analysis of variance for repeated measures (time and condition) were used for bed climate and skin temperature. The level of significance was considered as less than $P < 0.05$ after the Greenhouse-Geisser correction for repeated measures. After significance was observed in analysis of variance, paired t-test was calculated.

Results

Sleep characteristics

The results of the sleep parameters are shown in Table 2. There was no significant difference among the condition in time and percentage spent for each sleep stages all through the night. Sleep efficiency index tended to be highest in Air-. Sleep onset latency and wake after sleep onset tended to be shorter in Air+ and Air- than Futon.

In order to compare the difference depending on time course of the sleep, total time in bed was divided into three blocks for 160 min each. The time and

Fig. 1 Properties of the air mattress and measuring points of bed climate.

Table 1. Procedure of the experiment

Time	2230	2300	700
EEG			
EMG			
EOG			
Skin temperature			
Bed climate			
Thermal sensation	*	*	*
Humidity sensation	*	*	*
Comfort sensation	*	*	*
SSS	*		*
Sleep estimation			*

Asterisk indicates the measuring point.

percentage spent for each stage was calculated. Stage 3 showed significant increase in the middle one third of the night in Air+ ($P<0.01$). Gross body movements analysed from video recordings tended to decrease in Air+ and Air-.

Bed climate and skin temperature

Figure 2 shows the bed climate of the waist area through the night in average of six subjects under three conditions. Temperature tended to be higher in Futon than in Air+ and Air-. On the other hand, relative humidity was significantly effected by the condition ($F(2,14)=9.69$, $P<0.01$). It was higher in Air+ and Air- and increased gradually in the first three hours of the night while Futon kept the same level all through the night ($P<0.05$). Significant difference between Air+ and Air- was observed during only one hour after sleep recordings ($P<0.01$). Absolute humidity was also significantly effected by condition ($F(2,14)=4.69$, $P<0.05$). It was also higher in Air+, Air- than Futon and the significant difference between Air+ and Air- was also observed during only 30 minutes after sleep recordings

($P<0.01$). In bed climate of the foot area, no significant effect of condition was observed.

Skin temperature of the forehead and the dorsal hand tended to be highest in Air+ but no significant effect was observed between the conditions.

Subjective evaluation

Thermal sensation in the morning tended to be cooler and comfort sensation was higher in Air+ and Air- but no significant difference was observed. Humidity sensation showed no significant difference. Among all the conditions, comfort sensation in the morning was on the comfortable side.

Subjective sleep estimations which were asked just after waking up tended to be better in Air- and Air+ compared to Futon. But no significant difference were observed among the three conditions.

Discussion

Although a significant increase of stage 3 in the

Table 2. Sleep parameters under three conditions

	Average (S.D.) min		
	Air mattress (+)	Air mattress (-)	Futon
TST	446.79 (19.28)	456.75 (13.59)	421.07 (50.20)
Onset of			
Sleep	7.95 (4.44)	13.30 (10.46)	10.52 (7.13)
Stage 2	7.73 (4.72)	4.56 (2.51)	6.07 (2.26)
Stage 3	19.69 (4.72)	16.46 (5.83)	16.92 (3.25)
Stage 4	25.14 (4.98)	26.64 (6.47)	21.76 (2.65)
REM	93.54 (35.04)	102.14 (36.84)	72.66 (8.18)
WASO	37.49 (29.11)	9.57 (7.25)	41.79 (36.79)
SEI (%)	90.48 (6.70)	95.16 (2.83)	87.72 (10.46)
Total time of			
Wake	32.83 (19.28)	22.83 (13.97)	58.83 (50.05)
Stage 1	43.50 (12.39)	28.83 (11.41)	37.00 (15.92)
Stage 2	217.83 (25.33)	244.67 (15.13)	210.17 (37.14)
Stage 3	29.83 (14.53)	24.33 (6.50)	27.67 (9.55)
Stage 4	59.17 (21.84)	59.00 (15.03)	55.17 (13.07)
REM	96.50 (15.44)	99.50 (25.31)	91.00 (22.65)
Total time of first 160 min			
Wake	13.00 (7.23)	14.83 (11.51)	12.67 (7.78)
Stage 1	11.00 (5.39)	7.33 (3.54)	9.00 (5.60)
Stage 2	66.50 (11.07)	65.83 (4.81)	55.33 (10.21)
Stage 3	15.33 (9.94)	16.00 (6.14)	22.50 (9.95)
Stage 4	44.00 (11.93)	49.00 (12.75)	46.17 (13.33)
REM	9.83 (6.52)	6.83 (5.81)	14.50 (5.41)
Total time of middle 160 min			
Wake	7.50 (8.94)	5.50 (6.68)	24.67 (33.79)
Stage 1	14.67 (9.53)	9.83 (6.41)	10.17 (3.34)
Stage 2	73.50 (23.06)	94.67 (11.43)	84.83 (16.85)
Stage 3	11.17 (8.35)	3.00 (3.21)	1.83 (2.54)**
Stage 4	15.00 (17.08)	7.17 (10.59)	9.00 (11.46)
REM	38.33 (12.47)	39.83 (8.41)	29.33 (20.23)
Total time of last 160 min			
Wake	12.67 (11.47)	2.50 (1.26)	21.67 (37.16)
Stage 1	17.83 (5.24)	11.50 (4.11)	18.00 (10.25)
Stage 2	77.83 (12.63)	84.33 (19.11)	69.67 (26.09)
Stage 3	3.50 (5.16)	5.67 (4.68)	3.33 (4.96)
Stage 4	0.17 (0.37)	2.83 (6.34)	0.17 (0.37)
REM	48.33 (5.99)	52.67 (24.25)	47.17 (22.04)

TST, total sleep time; WASO, Wake after sleep onset; SEI, Sleep efficiency index.

**P<0.01

middle one third of the night was observed in Air+ and somewhat good score in subjective sleep estimation, there was no significant difference in time and percentage spent for each sleep stage through the night. Considering tendency of short sleep onset latency and wake after sleep onset, movement of the cells in Air+ did not affect sleep. This result can not be reflected directly on either patients or elderly people. But the main result that sleep was not disturbed has a very important meaning and encourage us to use these air mattresses for the patients and elderly people during sleep.

The most important findings in this study were observed in our results of bed climate. Relative humidity of the waist area was significantly higher in Air+ and Air-

where the highest level reached almost 70%. According to Miyazawa et al. (1974) the comfort zone of the relative humidity inside the bed is said to be around 45-55%. Futon showed the nearest value and Air+ and Air- were over this zone. Absolute humidity was also significantly higher in Air+ and Air-. Although there were no significant difference among the three conditions in subjective humidity and comfort sensation in the morning, this result is noteworthy as air mattresses are used in bedridden people or patients to prevent and cure decubitus. It has been reported by many previous studies that reducing moisture and friction is one of the important factors to prevent decubitus (Low, 1990). Biesecker et al. (1995) has compared the coefficients of

Fig. 2 Changes of waist area bed climate under three conditions. Average of six subjects. Asterisk indicates the significant level between Air+ and Air- (** $P < 0.01$).

friction of wet cotton and wet cotton-polyester sheets and found two times greater friction than those of comparable dry sheets. It has also been concluded in previous studies that hydration accelerates the aborting action on the skin by increasing the friction force and decreasing the sheerer resistance of the skin (Flam, 1990; Hoshowsky and Schramm, 1994; Kemp, 1994). Therefore, under pads recommended for preventing decubitus are those designed to absorb moisture and present a quick drying surface to the skin (Kemp, 1994). Our result indicates that Futon absorbs moisture inside the bedding more rapidly and keep the bedding drier than these air mattresses during sleep. Futons are generally made of cotton stuffing. When the subjects get inside, the amount of moisture is immediately absorbed by the inside coverlet and Futon, keeping warm and dry micro climate inside the bedding through the night (Tada, 1994). Two factors can be considered as reasons for the high level of

relative and absolute humidity in Air+ and Air-. First, these air mattresses are made of vinilon which has very poor ability in absorbing the moisture. Second, the construction of these mattresses does not allow moisture absorption. Tada (1994) has compared Futon and raft structure mattress which has very similar construction to our air mattress, and found that the moisture was absorbed very effectively through spacing between body and the ditch of the mattress. It can be considered that an opening between body and the ditch was not enough in our air mattress, although the air cells had made an opening by decreasing inflation pressure. But from our results, it is not clear whether the increase of the humidity was due to the material or the construction of the air mattresses.

Another interesting finding in this study was the difference between Air+ and Air-. Generally, it has been believed that the air coming out of the waist area in Air+ will decrease the bed humidity in using air mattresses. But surprisingly, this was effective only during the first one hour after sleep recording started, indicating we could not expect this function to avoid the humidity increase all through the night.

In conclusion, these results suggest that although these air mattresses will not disturb sleep parameter, we have to be cautious in using these mattresses as relative and absolute humidity was kept higher than with Futon. Further study on materials and structure of the air mattresses to prevent the increase of the humidity are needed. Furthermore, it is important to obtain these data by using elderly as subjects or bedridden people who are likely to suffer from decubitus.

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