Effects of Two Kinds of Pillow on Thermoregulatory Responses during Night Sleep

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Abstract. We compared thermoregulatory responses during night sleep between two kinds of pillow. One has special cool medium consisting of sodium sulfate and ceramic fiber (pillow A) and the other polyester padding (pillow B). The subjects wore 100% cotton thin pajamas with short sleeves and three-quarters trousers for summer use. They lay and slept in bed with cotton sleeping mat and cotton quilt between 10:30 p.m. and 6:30 a.m. in a bed room with an ambient temperature (T_a) of 27 ± 1 °C and a relative humidity of $55 \pm 5\%$, using either of the pillow A or pillow B. When they awoke, the subjects filled out a questionnaire on how well they slept during sleep. Main results were: 1) Rectal and forehead skin temperatures and heart rate were kept significantly lower in the pillow A during the latter half of the night sleep. 2) Palm and thigh skin temperatures were significantly higher mostly in the pillow A. 3) All the subjects regarded the pillow A better for deeper sleep. It was concluded that slight cooling of the head due to the pillow A during night sleep seemed to be of significance for deep sleep.

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Key words: pillow, head cooling, night sleep, rectal temperature, skin temperature

Introduction

Although there are several scattering publications dealing with physiological parameters and pillow during sleep, systematic understanding of their physiological significance during night sleep remains to be studied from the viewpoint of physiology (Uyama, 1958a, b, c; Minezaki et al., 1972; Kodama, 1976). Heat loss from the head to surrounding air might vary depending on the kind of pillow people use during sleep, resulting probably in different thermoregulatory responses. How the level of core temperature is kept during night sleep seems to be relevant to sleep depth (Kawabata et al., 1995; Okada et al., 1994; Monroe, 1967). Thermal state of the head is of

physiological significance for the determination of tympanic membrane temperature (Midorikawa and Tokura, 1992). With these in mind, therefore, we endeavoured to compare thermoregulatory responses during night sleep between two kinds of pillow: one with special cool medium consisting of sodium sulfate and ceramic fiber (pillow A) and the other with polyester padding (pillow B).

Methods

Five female students, aged 19–20 yrs, volunteered as subjects. The anthropometric characteristics of the subjects are shown in Table 1. Each subject served twice with each pillow. The average values calculated from those obtained from two experiments were used for further analysis. The experiments were carried out in July and August 1993. They wore 100% cotton thin pajamas with short sleeves and three-quarters trousers for summer use. The subjects lay and slept in bed with cotton sleeping mat and cotton quilt between 10:30 p.m. and 6:30 a.m. in a bed room with an ambient temperature (T_a) of 27 ± 1 °C and a relative humidity of $55 \pm 5\%$, using either of pillow A or pillow B. Pillows used in the experiment are the one with special cool medium consisting of urethane (sodium sulfate, ceramic fiber) (pillow A) and the other with polyester padding (pillow B). Construction picture of pillow A and pillow B is shown in Fig. 1. Rectal temperature, skin temperatures at forehead, shoulder, chest, palm, and thigh, heart rates and clothing microclimate (temperature, humidity) at neck, chest and thigh were continuously measured during night sleep. When they awoke at 6:30 a.m., the subjects filled out a questionnaire on how well they slept during sleep. The questions consist of two: (a) Did you fall asleep easily? (b) Did you sleep well? The subjects had to select one answer among very easily, considerably, normally, difficult and not at all to (a) and among very much, considerably, normally, slightly and not at all to (b).

Student paired *t*-test was employed to know the differences of physiological and other parameters statistically.

Table 1 Anthropometric characteristics of the subjects

Subject	Age (yrs)	Height (cm)	Weight (kg)	B.S.A. (m ²)
S. 1	19	161.8	57.0	1.558
S. 2	19	158.7	51.5	1.471
S. 3	19	157.4	48.0	1.417
S. 4	20	152.0	54.0	1.459
S. 5	20	155.3	50.0	1.431
Mean	19.4	157.0	52.1	1.467
S.E.	0.24	1.64	1.56	0.024

B.S.A.: Body surface area was calculated by the formula of Fujimoto et al (1968).

Fig. 1 Construction picture of the pillow A (top) and the pillow B (bottom).

Results

Figure 2 shows a comparison of rectal temperatures during the night sleep under the influences of two types of pillow. The level of rectal temperatures during the night sleep was kept significantly lower during the latter half of sleep period from 2:00 a.m. to 6:00 a.m. in the pillow A.

Figure 3(A) shows a comparison of forehead skin temperatures during the night sleep under the influences of two types of pillow. Skin temperatures of forehead were significantly lower from 3:40 a.m. to 5:20 a.m. in the pillow A than in the pillow B. Figure 3(B) shows a comparison of thigh skin temperatures under the influences of two types of pillow. Thigh skin temperatures during night sleep tended and kept to be significantly higher from 1:30 a.m. to 5:20 a.m. in the pillow A. Figure 3(C) shows a comparison of palm skin temperatures between the pillow A and pillow B. Palm skin temperatures in the two types of pillow continued to rise equally from the beginning till midnight. However, the palm skin temperatures in the pillow B began to decrease after midnight, while those in the pillow A were kept higher constantly. The difference between the two types of pillow was significant from 3:40 a.m. to 6:30 a.m. Figure 3 (D) shows a comparison of sole skin temperatures between the pillow A and pillow B. Due to a technical failure the data were obtained only from two subjects. Clearly, the sole skin temperatures were mostly higher in the pillow A than in the pillow B.

Figure 4 shows a comparison of heart rate between the two types of pillow. The heart rate in the pillow A tended to be lower mostly and significantly lower partly than in the pillow B.

Figure 5(A) shows a comparison of the clothing microclimate temperatures near the frontal chest under the

Fig. 2 A comparison of rectal temperature during night sleep between the pillow A and pillow B. Open circle: pillow A. Closed circle: pillow B. Mean $\pm$ S.E.M. (n=5). *: $p < 0.05$, **: $p < 0.01$.

Fig. 3 A comparison of skin temperature in forehead (A), thigh (B), palm (C) and sole (D) during night sleep between the pillow A and pillow B. Open circle: pillow A. Closed circle: pillow B. Mean $\pm$ S.E.M. ($n=5$). *: $p<0.05$, **: $p<0.01$.

Fig. 4 A comparison of heart rate during night sleep between the pillow A and pillow B. Open circle: pillow A. Closed circle: pillow B. Mean $\pm$ S.E.M. ($n=5$). *: $p<0.05$, **: $p<0.01$.

Fig. 5 A comparison of clothing microclimate temperature near the front of the chest (A) and between the pillow and sleeping mat (B) during night sleep between the pillow A and pillow B. Open circle: pillow A. Closed circle: pillow B. Mean $\pm$ S.E.M. ($n=5$). *: $p<0.05$, **: $p<0.01$.

influences of two types of pillow. They tended to be lower during night sleep in the pillow A than in the pillow B. The difference between the two was significant from 0:20 a.m. to 1:40 a.m. and from 4:20 a.m. to 5:00 a.m. Figure 5(B) shows a comparison of clothing microclimate temperatures between pillow and sleeping mat between the pillow A and pillow B. Again, due to a technical failure, the data were obtained from two subjects. Clearly seen in the figure, they were lower in the pillow A than in the pillow B.

Figure 6 shows an individual comparison of the easiness of falling asleep (a) and sleep depth sensation (b) between two types of pillow. All the subjects could fall asleep easier in the pillow A than in the pillow B, and they answered that they obtained deeper sleep in the pillow A than in the pillow B.

Discussion

What physiological mechanisms could account for the most interesting findings that the rectal temperature was kept lower in the pillow A (Fig. 2), the skin temperatures in the extremities were higher in the pillow A (Fig. 3) and all the subjects could fall asleep more easily and sleep well in the pillow A? The clothing microclimate temperature between pillow and sleeping mat was clearly lower in the pillow A (Fig. 5), suggesting that the dry heat loss from the head to the pillow might have been greater in the pillow A, and hence, resulting probably in the reduced brain temperature in the pillow A. In fact the forehead skin temperature, reflecting the relative brain temperature, was clearly lower in the pillow A (Fig. 3). The probable lower level of brain temperature in the

Fig. 6 An individual comparison of the easiness of falling asleep (a) and sleep depth sensation (b) between two kinds of pillow. Open circle: pillow A. Closed circle: pillow B.

pillow A might be responsible for the increased skin temperatures in thigh, sole and palm, since the close linkage between lowered core temperature and increased extremities skin temperatures could exist (Aschoff and Heise, 1972). However, the detailed physiological mechanisms for these remain to be systematically studied.

The reason why all the subjects could fall asleep more easily and sleep well in the pillow A is surely related to the reduced core temperature during the sleep period in the pillow A, confirming our previous reports (Kawabata and Tokura, 1995; Kawabata et al., 1995) indicating that the reduced core temperature could induce deeper sleep. Heart rate was clearly lower in pillow A than in pillow B, suggesting that the sympathetic nervous system innervation heart was less excited in pillow A. Higher skin temperatures in the lower extremities might be related with less excitement of the sympathetic nervous system.

The china pillow, called "Tochin" and the stone pillow were preferred as favourable pillow in old China and Japan (Kawabata, 1990, 1992). Presumably, the china pillow and stone pillow can conduct heat from head to the pillow effectively, resulting in a low of brain temperature and high of the extremity skin temperatures, and hence, deep sleep. People have known since old times that cooling the head is important for deep sleep. Our present results suggest why cooling the head is significant from the viewpoint of thermal physiology.

Thus, it is concluded that the moderate cooling of the head by the pillow during night sleep is of physiological significance for deep sleep.

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