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Ergonomic approach for pillow concept design

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ABSTRACT

Sleep quality is an essential factor to human beings for health. The current paper conducted four studies to provide a suitable pillow for promoting sleep quality.

Study 1 investigated the natural positions of 40 subjects during sleep to derive key-points for a pillow design. The results suggested that the supine and lateral positions were alternatively 24 times a night, and the current pillows were too high for the supine position and too low for lateral positions.

Study 2 measured body dimensions related to pillow design of 40 subjects to determine pillow sizes. The results suggested that the pillow height were quite different in supine position and lateral position and needed to take into consideration for a pillow design.

Study 3 created a pillow design based on the results of above studies. The pillow was a U-form in the front of view in which the pillow height in the middle area was lower for the supine position, and both sides were higher for the lateral positions.

Study 4 assessed sleep quality of 6 subjects by using the proposed pillows and the current pillows. The results showed that the newly designed pillow led to significantly higher sleep quality, and the new design received an innovation patent.

1. Introduction

Sleep is essential to human beings for health and development. It occupies as much as one-third of human's live span. The major functions of sleep included physical restoration (Opp, 2009; Schütz et al., 2009; Zager et al., 2007), energy conservation (Amaranath, 2015; WebSciences International, 2015), preservation and protection (Amaranath, 2015; WebSciences International, 2015), memory processing and learning (Gradisar et al., 2008; Turner et al., 2007), and brain development (Morrissey et al., 2004).

Sleep duration is one of the most important factors to maintain sleep quality. Many studies related to sleep duration have been reported such as the association between sleep duration and sleep quality (Mesas et al., 2011), the association between sleep duration and health, quality of life (Magee et al., 2011), the association between sleep duration and obesity (Sahlin et al., 2009; Marshall et al., 2010; Itani et al., 2011), the association between sleep duration and mortality (Heslop et al., 2002; Allen, 2002; Kripke et al., 2002), and dynamic sleep duration (Xue et al., 2012).

Many methods have been used to improve sleep quality including sleep hygiene education and behavioral therapy (Nishinoue et al., 2012; Kaku et al., 2012), doing a short afternoon nap (Kaida et al., 2012), using a suitable pillow with appropriate support to reduce neck and shoulder pain (Lavin et al., 1997), and keep in a certain sleep positions (Gordon et al., 2011; Leung et al., 2003). For this topic, Gordon et al. (2011) reported that lateral positions produce significantly lower diastolic, systolic, and mean arterial blood pressure than does the supine position. Furthermore, Leung et al. (2003) pointed out that patients with congestive heart failure avoid the left lateral position during sleep to prevent discomfort from an enlarged apical heart.

Theoretically, using a pillow to maintain spine in a natural position during sleep, the pillow height in the supine position should be referred to the distance between the hindbrain and upper back in the sagittal plane, and pillow height in the lateral position should be referred to the distance between the ear and shoulder in the crown plane. A pilot study (Chen and Cai, 2012) had pointed out that these two distance were significantly different. Furthermore, humans change their position continuously during sleep. The

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supine and lateral positions occupied large part of the entire sleep process. Therefore designing a suitable pillow to provide good support for both supine and lateral positions is important.

The current paper aims to provide a suitable pillow for promoting sleep quality. Study 1 investigated the proportions of the four sleep positions and unnatural postures during sleep to derive key-points of pillow design. Study 2 measured body dimensions related to pillow design of subjects to determine suitable pillow sizes. Study 3 proposed a suitable pillow concept according to design key-points. Study 4 tested sleep quality of subjects by using the newly designed pillow and the current pillow to validate the new concept design.

2. Sleep position investigation

2.1. Methods

2.1.1. Participants

Forty participants (20 males and 20 females; age, 17–36 years; mean age, 25.7 ± 7.1 years) were recruited for the sleep-position study. The participants claimed that they were healthy, had no sleep disorders, and did not have important work to do the next day, so they were able to sleep without stress. In this way, all sleep positions could be recorded for further analysis. All participants were voluntary subjects and were paid the equivalent of 35 USD for participation.

2.1.2. Apparatus and procedures

An Infrared video was used to record the head and neck positions during sleep regardless of the brightness of the bedroom. The sleep positions were recorded in the participant's bedrooms with their own bedding. All settings were according to the participants' habits to prevent interference with sleep. When the participants were ready for bed, they first set up the video to focus on the location of their head, neck, and shoulder from a side position. Then, they pressed the video switch and went to bed. The following day, they turned off the video to complete the recording process. The recorded video files were then observed by the researches and analyzed using Noldus Observer V. 4.1.

2.1.3. Position identification and criteria

Sleep positions were classified into four types for further analysis: the supine position, left lateral position, right lateral position, and prone position. Because position changes continuously during sleep, the sleep positions were included in the analysis when they could be clearly identified as one of these four positions. For example, if a participant began to sleep in the supine position, the supine position would begin at that moment and would end when the next identifiable position was observed, which also marked the beginning of the second position. The duration and frequency of the four positions were recorded.

2.2. Results and discussion

2.2.1. Sleep durations of the four sleep positions

Table 1 shows the statistics of sleep duration each time for the four sleep positions. The average sleep durations in the supine, left lateral, right lateral, and prone positions were 21.5, 15.8, 13.7, and 6.8 min, respectively. The longest sleep duration occurred in the supine position, followed by the left lateral position, the right lateral position, and the prone position. Sleep duration in the supine position was longer than that in the left lateral position ($t = 3.301$, $p = 0.001$). The difference in sleep durations between the left lateral and right lateral positions was not significant ($t = 1.506$, $p = 0.133$). Sleep durations in the left and right lateral positions were longer than that in the prone position ($t = 2.336$, $p = 0.02$). The longest sleep duration occurred in the supine position, which was maintained for 176 min (2.93 h), whereas the shortest duration was in the left lateral position, which was maintained for only 2 s.

2.2.2. Rotation frequencies of the four sleep positions

Table 2 shows the frequency of the four sleep positions by the 40 participants. The frequencies of sleep in the supine, left lateral, right lateral, and prone positions were 481, 244, 221, and 22, which occupied 49.7, 25.2, 22.8, and 2.3 percent of the total frequency, respectively. The frequency in the supine position was the greatest, whereas that in the prone position was the lowest. The sum of frequencies in the left lateral and right lateral positions was 465 sleep episodes, which was approximately equivalent to the frequency in the supine position (465/481 = 96.7%). This result indicated that both the supine and lateral positions were significantly important during sleep. The mean frequencies of sleep in the supine, left lateral, right lateral, and prone positions of one subjects one night were 12.03, 6.10, 5.53, and 0.55 times, respectively. The total rotation frequency was 24.2 times (SD = 7.99 times) for a person a night (Table 2). The minimum rotation frequency was only eight times and the maximum was 48 times.

2.2.3. Proportions of sleep duration of the four positions

Table 3 shows the mean durations of the 40 subjects in the supine, left lateral, right lateral, and prone positions were 258, 96, 76, and 4 min, respectively. The proportions of sleep time in the supine, left lateral, right lateral, and prone positions were 59%, 22%, 18%, and 1%, respectively. This result was different from that of a previous study (Sahlin et al., 2009), which concluded that Swedish women spent 41% of their sleep time in the supine position, 50% in the lateral position, and 9% in the prone position. Comparing the two studies, Taiwanese spend more time in the supine position, whereas Swedes spend more time in the lateral position. This difference may be attributed to the difference in the curvature of the back of the head; Taiwanese have a flatter rear skull, and Swedes have a more curved one. Additionally, the ages of the two groups were different; the mean age of the Taiwanese subjects was 25.7 years, and that of the Swedes ranged from 20 to 70 years.

Table 4 shows that the average sleep duration of the 40 participants was 7.23 h (434 min, SD = 76 min). The longest duration was 11.88 h (713 min), and the shortest was 5.67 h (340 min). Total sleep

Table 1
The statistics of duration of the four sleep positions (min).

Positions	N	Min	Max	Mean	SD
Supine position	481	0.07	176.00	21.47	24.50
Left lateral position	244	0.03	90.68	15.78	15.67
Right lateral position	221	0.17	88.23	13.72	13.65
Prone position	22	0.05	27.83	6.83	6.58
Total	968	0.03	176.00	17.93	20.43

Table 2
The rotation frequency of the four sleep positions (times).

Positions	Mean frequency	Frequency	Percent	Cumu. Percent
Supine position	12.0	481	49.7	49.7
Left lateral position	6.1	244	25.2	74.9
Right lateral position	5.5	221	22.8	97.7
Prone position	0.6	22	2.3	100.0
Total	24.2	968	100.0	