Design of pillows in view of breathing frequency and range of head motion

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Abstract. In an effort for designing pillows in view of breathing frequency and range of head motion, effect of difference in head motion and pillow shape on respiratory characteristics was investigated in an attempt to get fundamental knowledge. Thirteen healthy adults (4 males and 9 females) served as subjects. Two types of pillows, a conventional flat type and a roll-type, were used for the experiment with head angles and respiratory characteristics measured on two head positions; one with extended head and the other with flexed one. As a result, regardless of pillow type, a significant increase ($p<0.01$) tended to be seen in the head angle in the extended-head position compared with in the flexed-head position, with breathing frequency decreasing. The roll-type pillow revealed a significantly larger range of head motion ($p<0.05$) than the flat-type. The roll-type pillow provided a weak negative correlation recognized between head angle and breathing frequency, along with a weak positive correlation between head angle and breathing amplitude, as well as with breathing frequency significantly negatively correlated with breathing amplitude ($r=-0.462$, $p<0.05$). The aforementioned findings led to the reasoning that roll-type pillows would provide a wider range of head motion with the respiratory tract released, making smooth or deep breathing easier.

Keywords: pillow, range of head motion, breathing

1. Background and objectives

The major functionality a pillow performs during sleep is to keep the cervical region in a neutral position and to serve as a pivot point for the upper half of a human body when it turns over in bed. Since biomechanical stress to the cervical spine could produce waking symptoms such as cervical pains and stiffness, headache, and scapular or arm pain, some supporting functions would be needed to minimize the cervical stress (Gordon, 2010).The reason for our rolling over in bed is the need for getting back good blood circulation in the compressed underside of the body and avoidance of heat damage from sweating, though the rolling action is taken unconsciously. Yanase et al (1972) showed in a report on their polygraphy-based research that sleeping depth is affected by bed width, demonstrating a narrower bed width tends to cause a shallower sleep. High-frequency body motions or situations in which body motion is restricted would presumably lead to a shallower sleep, being linked to difficulty in having a restful sleep. The important factors for the restful sleep to require of a pillow consist of the optimum height, size, shape, and material (Hanaoka, 1993). In another word, it is necessary to facilitate roll-overs as well as to adjust the height of a pillow to fit lying in both lateral and dorsal positions (Yamada, 2011).

Meanwhile, it is known that breathing during sleep is affected by swelling of mucosal membrane in nasal passage and respiratory tract blockage caused by muscular relaxation among others. From an anatomical viewpoint, lying in the dorsal position with the cervical region inflected would get the respiratory tract narrower. With the cervical part appropriately extended, however, the respiratory tract would become wider to possibly promote nasal breathing. The pillows that support cervical extensive position would include a cylinder type pillow. Since old times in Japan, there has been a stuffed-bag type pillow, which was sometimes dubbed cylinder pillow or priest pillow. There has been another kind of cylinder-type pillow as well that deals with those suffering from whiplash injury or being so-called straight-necked. However, there has been no such research ever found in our survey as investigated into relationships between cylinder-type pillows, head motion, and breathing.

We are trying to develop a pillow that does not restrict body movement, especially the one that does not obstruct head motion, thereby aiming to finally attain a high-quality sleep. This paper describes part of its process, referring to the development of a pillow that enables its users to adjust their own head position best fit for breathing with their heads kept free to move.

2. Method

The effect of head motion and difference in pillow shape was investigated on characteristics of breathing curve. Thirteen healthy adults (4 males and 9 females) served as subjects.

2.1 Measurement of head motion

In this research, head motion was represented by variation of head angle that is defined as an angle formed between a line that connects the gnathion of midsagittal plane with the tragion and the horizontal line. The head angles were measured by means of an angle scale under two head positional conditions; one with head on a relevant pillow in its extensive position and the other in its inflective one. The maximum extension angle (θ_A) and the maximum flexion angle (θ_B) were defined as the head angle with chin lifted utmost and the one with chin lowered downmost, respectively, while their difference (θ_A-θ_B) was defined as the range of head motion (Figure 1).

2.2 Measurement of breathing curves

Conventional methods for measurement of breathing include an impedance method, a method based on detecting temperatures and/or sounds with a sensor mounted on subject’s nose and mouth, and a method using a hand-type sensor

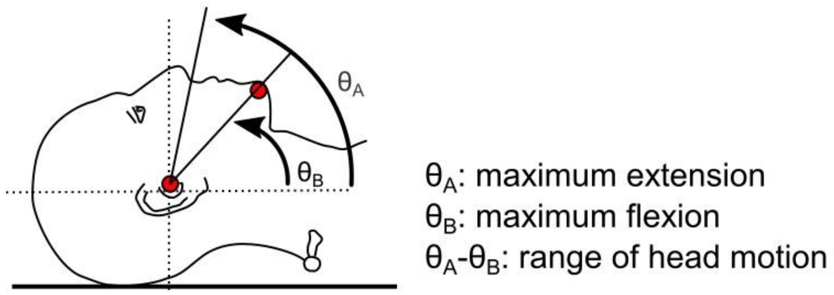


Figure 1. *Definition of head angle and range of head motion*

equipped on subject's breast region. Most recently, a sleep evaluation device (Sleep EYE GD700, DENSO) has been developed with a pressure-sensor built in a mattress serving to detect biosignals that undergo frequency analysis before being used for estimation of the corresponding breathing curve. Part of its function was used for recording continuous breathing curves from subjects lying in the mattress. Data of 40 seconds was analyzed to obtain the frequency of breathing along with respective amplitudes (Figure 2). The frequency of breathing refers to the count of wave forms in the breathing curve appearing in the analysis section of 40 seconds. The amplitude of a wave form is defined as the distance from trough to peak of the wave, while the amplitude of breathing is represented by the mean value of the amplitudes averaged over the wave forms concerned.

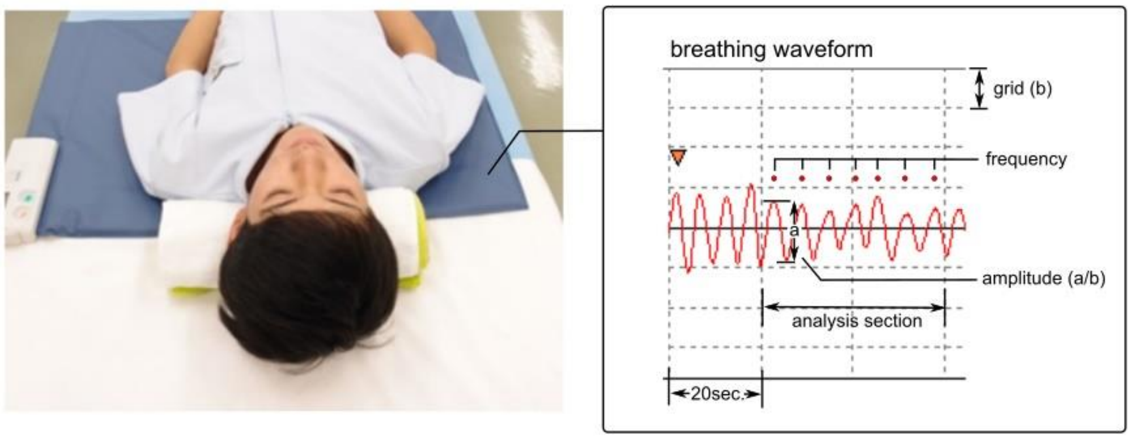


Figure 2. *A picture of respiratory measurement and its analysis method*

2.3 Experimental condition

The measurements were conducted on two types of pillow; one on a roll-type pillow of cylindrical form and the other on flat, large one (conventional form), under the extended and inflected head conditions.

2.4 Analysis method

All the results are given in the form of mean value± standard deviation. The statistical processing of head angle, breathing frequency, and breathing amplitude was handled by the two- way repeated measure ANOVA with the type of pillow (roll and flat types) and the head angle (maximum extension θ_A and maximum flexion θ_B)

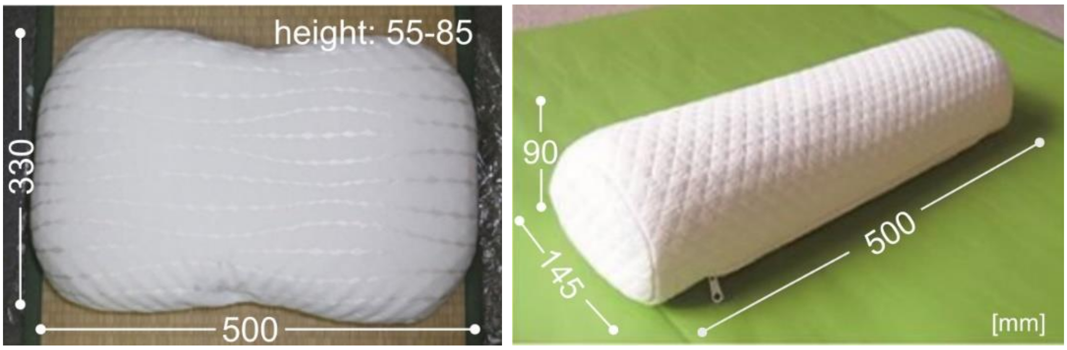


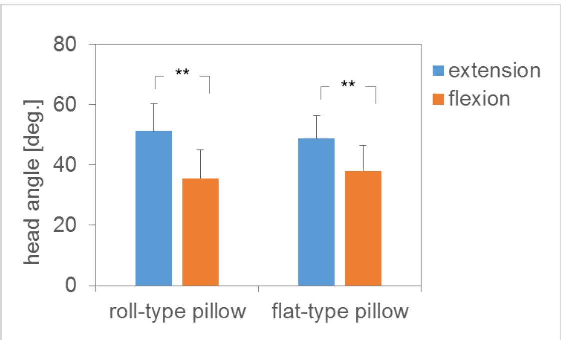
Figure 3. *Pillows used in the experiment (Left : Conventional flat type, Right : Roll type)*

set for the two factors. The results from range of head motion were evaluated by means of t-test in relation to the types of pillow. Pearson product-moment correlation coefficients were calculated corresponding to head angle, breathing frequency, and breathing amplitude, to investigate into relationships between head angle and breathing characteristics (breathing frequency, breathing amplitude).

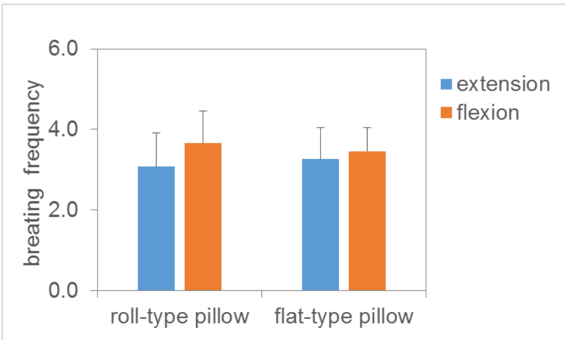
A significance level of 5 % was employed in the aforementioned statistical operations.

3. Results

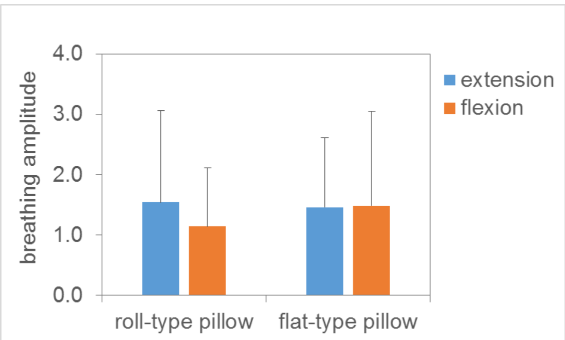
As for head angle, the major effect of head motion was significant (p<0.01). The head angle increased more in the extensive position compared with the inflective one



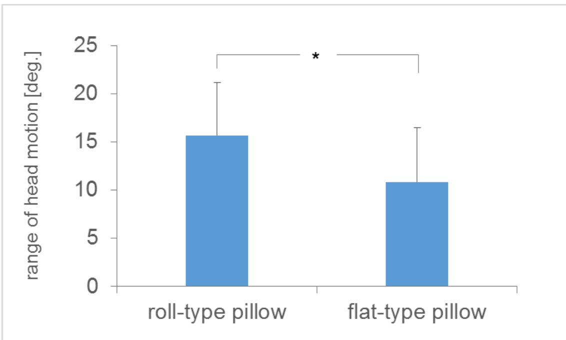
a. Head angle



b. Breathing frequency



c. Breathing amplitude



d. Range of head motion

Figure 4. *Comparison in head motion, head angle and breathing characteristics between two types of pillow (P-value: * p < .05; ** p < .01)*

(Figure 4a). With regard to breathing frequency, compared with the head inflective position, its extensive position tended to provide an increase of breathing frequency for either type of pillow (p=0.073)(Figure 4b).

With regard to the breathing amplitude, there was no remarkable variance recognized among different positional conditions. There still appeared a tendency for the roll-type pillow that the head extensive position brought an increase in the breathing amplitude compared with the head inflective position (Figure 4c).

The ranges of head motion on flat and roll type pillows were 10.8±5.6°and 15.7±5.5°, respectively, resulting in recognition of significant difference between the two types of pillow (p<0.05)(Figure 4d).

The results from the correlation analysis are summarized in the following: for roll type pillows, there exist a weak negative correlation between head angle and breathing frequency, a weak positive correlation between head angle and breathing amplitude, and a significant negative correlation between breathing frequency and breathing amplitude (r=-0.462, p<0.05)(Figure 5).

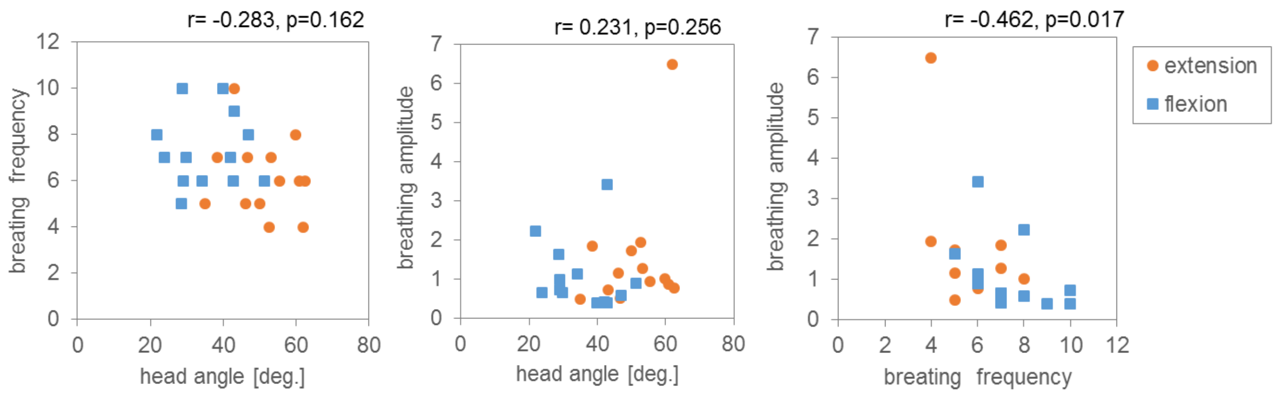


Figure 5. *Relationships between head angle and breathing properties (condition of roll-type pillow)*

4. Discussions

It was made clear regardless of the pillow type that there was a difference in head angle between head extensive and inflective positions. Although no significant correlation was found between head motion and breathing characteristics (breathing frequency, breathing amplitude), an increase in head angle tended to produce a decrease in breathing frequency along with an increase in breathing amplitude. The finding that a negative correlation existed between breathing frequency and breathing amplitude suggested the head extensive position in which head angle increased would create a smooth breathing, facilitating a deep breathing. With two types of pillow compared with each other, there was no remarkable difference in breathing characteristics. Compared with a conventional flat type pillow, however, a roll type pillow, with its larger range of head motion, was considered to easily get the respiratory tract wider resulting in the pillow characteristics that would induce easy and comfortable breathing in the dorsal position.

5. Conclusion

The measuring experiments this time revealed that a roll type pillow would be able to produce a larger range of head motion. Based on this finding, a developmental principle for an easy-to-breath pillow would be proposed as shown in Figure 6. Its fundamental rule is that its user can easily adjust the pillow position, and that the pillow should equip a supporting function for the back of head. Although necessity of the supporting function for the back of head was drawn from another collection of ideas, an extreme extension of head would cause pain to the cervical region. Hence the support is considered to serve as a stopper to prevent such a risk. It is most likely that such principle-based design of pillow shape could create easy breathing to its users.

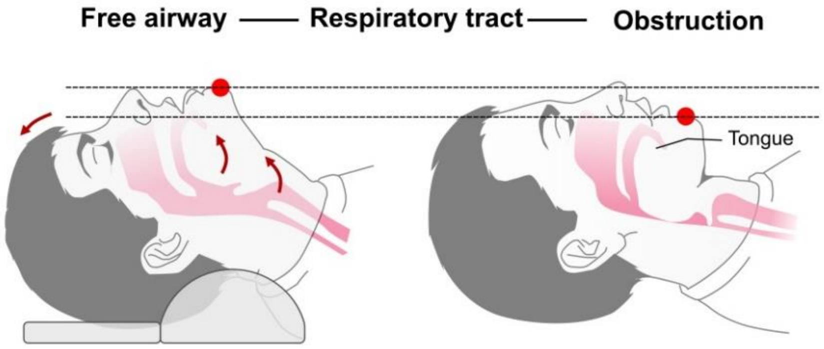


Figure 6. *Developmental principle for an easy-to-breath pillow*

6. References

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