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The Effects of Employing Pillows for Postural Changes on Ventilation: An Investigation Using an Ultrasonic Imaging Device

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Abstract. [Purpose] We investigated the effects of compression on the posterior surface of the thorax caused by a pillow used for postural changes on the respiratory function. [Subjects] The subjects were 22 healthy males with no history of ailments of the respiratory and circulatory organs. [Methods] With the subjects placed in the supine position, a half-lateral position with a pillow supporting the posterior surface of the thorax (pillow-supported position (1)), and a half-lateral position with pillows supporting the shoulder girdle and the pelvic band (pillow- supported position (2)), the ventilatory volume per breath (hereinafter TV) and expiratory reserve volume (hereinafter ERV) were measured based on the respiratory function, and at the same time, the distanced moved by the diaphragm was measured using an ultrasonic imaging device. [Results] Significantly lower values for TV were observed in the pillow-supported position (1) in comparison to the other postures. Significantly higher values for ERV were observed in the pillow-supported position (1) in comparison to the other postures. Significantly lower values for the distance moved by the diaphragm were observed in the pillow-supported position (1) in comparison to the other postures. [Conclusion] Ventilation decreased in pillow-supported position (1). We therefore consider that the movement of the diaphragm was reduced due to an expanded state caused by increase in residual air in the lungs.
Key words: Pillow, Respiratory function, Distanced moved by the diaphragm

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INTRODUCTION

In medical and nursing situations, postural changes are implemented for the purposes of preventing decubitus ulcers and performing postural drainage, and it is recommended that the position be switched between the supine position and the two lateral positions every two hours[1)]. Regarding the lateral positions, because the supporting base area is narrow and the position is unstable, it is common to see the use of a half-lateral position in which a pillow supports the posterior surface of the thorax to prevent disruptions of the posture. Such measures to maintain the posture are implemented out of necessity for patients whose ability to control their own movements are limited, such as patients requiring postoperative anesthetic management, weak elderly patients, and patients whose voluntary movements are impeded by severe physical disabilities. These actions are considered extremely important for management, but the selection of the posterior surface of the thorax as the region for fixing the pillow has become a habitual choice and related problems have rarely been

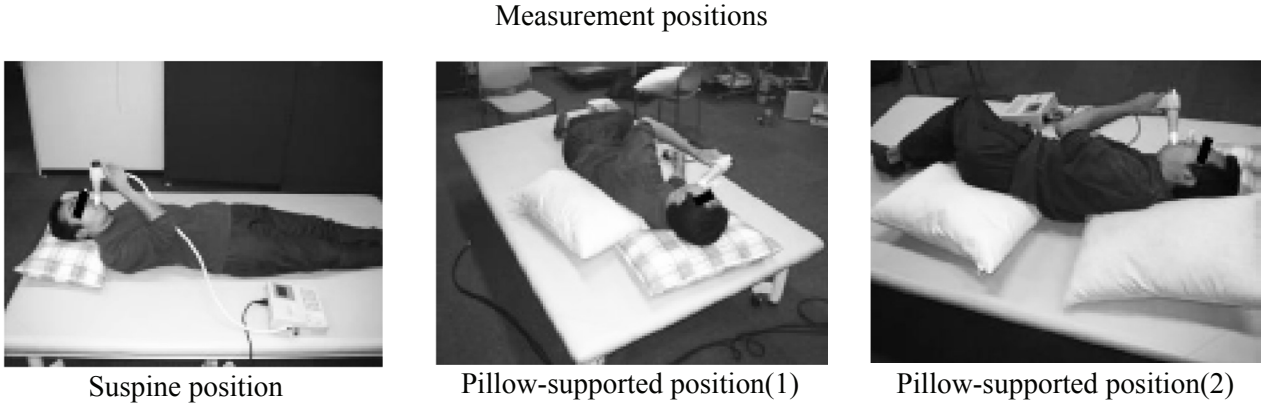
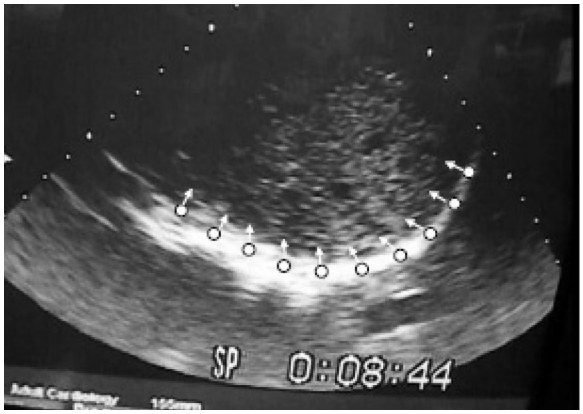


Fig. 1. Details of the measurement positions.



○ : Diaphragm markers.
↑ : Distanced moved by the diaphragm.

Fig. 2. Measurement of the distanced moved by the diaphragm.

reported. A number of advanced studies on posture and respiratory function have been conducted[2–4] and an extremely close relationship has been reported to exist between the two. Physical therapists also provide intervention for many patients with respiratory diseases and patients who are required to remain in a lying position.

While there have been verifications of the effects of changes in posture on the respiratory function and early ambulation[5,6], to the best of our knowledge, there have so far been no investigations on the common method of posture maintenance implemented by fixing a pillow to the posterior surface of the thorax. The purpose of the present study was to investigate the effects on the respiratory function of posture maintenance in a half-lateral position which is implemented on a routine basis by fixing a pillow to the posterior surface of the thorax for the purpose of inducing postural change. Moreover, this study also aimed to enable the selection of regions for pillow fixation that result in few adverse effects.

SUBJECTS AND METHODS

The subjects comprised 22 healthy males. Their mean age was 21.3 ± 1.4 years old, their mean height was 172.4 ± 4.1 cm, and their mean weight was 69 ± 5.6 kg. Subjects with no history of ailments of the respiratory and circulatory organs and no deformations of the spinal column and the thorax were selected. They received thorough explanations regarding the main points of the study and measurements were performed after obtaining consent with the understanding that they could freely withdraw from the study at any time. Moreover, as an ethical consideration, we obtained approval from the ethics committees of our universities and medical facilities.

Respiratory measurements were made in three positions: The supine position; a half-lateral position with a pillow supporting the posterior surface of the thorax (pillow-supported position (1)); and a half-lateral position with pillows supporting the pelvic band and the shoulder girdle (pillow-supported position (2)) (Fig. 1).

The ventilatory volume per breath (TV) and the expiratory reserve volume (ERV) were measured to examine the respiratory function. Measurements were performed using a Minato Autospiro AS302. A nose clip was attached to each subject before performing the measurements and 2 minutes were

Table 1. Measurement results

	Supine position	Pillow- supported position (1)	Pillow- supported position (2)
TV (*l*)	0.4 ± 0.12	0.3 ± 0.13*	0.4 ± 0.21
ERV (*l*)	1.2 ± 0.51	1.8 ± 0.53*	1.3 ± 0.22
Distance moved by the diaphragm (mm)	4.7 ± 2.21	2.4 ± 0.82*	4.2 ± 1.83

Mean ± SD. (n=22). *: $p<0.05$.

spent on quiet breathing with a mouthpiece in place. As the respiratory conditions were unfamiliar, measurements were started after the subjects became accustomed to the measurement conditions. For the distance moved by the diaphragm, the distance moved in the craniocaudal direction of the posterior wall of the right diaphragm was measured by scanning the eighth intercostal space using an ultrasonic diagnostic imaging device. The measurement method was based on the method established by Houston, et al.[7,8] A Hitachi EUB-5500 was used with an EUP-S50 sector array transducer (2.75 MHZ) as the measuring probe, measurements were performed for each breath. To calculate the distance moved, images acquired by the ultrasonic imaging device were captured on a personal computer and an image analysis software program (DARTFISH) was used to mark measurement points at 10 equally spaced locations throughout the diaphragm (Fig. 2). The measurement points marked on the diaphragm were monitored over 10 breaths of quiet breathing and the distance moved during contraction was automatically measured by the image analysis software. The marker with the greatest distance moved was used as the maximum value. The subjects drew cards in advance to randomize the sequence of measurements and eliminate effects any sequence. For the measurements of respiratory function, a 2-minute rest was provided before and after each measurement to prevent the effects of respiratory muscle fatigue.

For statistical analysis of the respiratory function and the distance moved by the diaphragm, one-way analysis of variance was used to investigate the differences among the measurement positions, and we examined the main effect through a multiple comparison (Tukey's method). The significance level was less than 5%. We performed the examinations using the statistical software Dr. SPSS II for Windows.

RESULTS

The measured values of the respiratory function are shown in Table 1 along with the distances moved by the diaphragm. TV was 0.42 ± 0.12 *l*, 0.35 ± 0.14 *l*, and 0.44 ± 0.21 *l* for the supine position, pillow-supported position (1), and pillow-supported position (2), respectively. The pillow-supported position (1) exhibited lower values than the other postures and significant differences were observed. The ERV was 1.2 ± 0.5 *l*, 1.8 ± 0.4 *l*, and 1.3 ± 0.2 *l* for the supine position, pillow-supported position (1), and pillow-supported position (2), respectively. The pillow-supported position (1) exhibited higher values than the other postures and significant differences were observed. The distance moved by the diaphragm was 2.8 ± 0.8 mm, 5.2 ± 2.1 mm, and 3.2 ± 0.7 mm for the supine position, pillow-supported position (1), and pillow-supported position (2), respectively. The pillow-supported position (1) exhibited higher values than the other postures and significant differences were observed.

DISCUSSION

We investigated the effects of the half-lateral position with a pillow supporting the posterior surface of the thorax, which is a posture that is habitually used for maintaining a lateral position during a postural change, on respiratory function. The results show that TV decreased in the pillow-supported position (1) compared to the supine position and the pillow-supported position (2). In our previous study[9], we reported that while abdomen-dominant breathing patterns were observed in the supine position and the pillow-supported position (2), the pattern changed to a chest-dominant breathing pattern in the pillow-supported position (1). Also, regarding thoracic expansion, the mobility of the lower thorax was limited in the pillow-supported position (1) compared to the other postures. In the present

study, in order to directly observe the respiratory movements of the diaphragm that determine the TV, we measured the distanced moved by the diaphragm during the respiratory movements using an ultrasonic imaging device. The distance moved by the diaphragm decreased in the pillow-supported position (1) compared to the other postures. This may indicate that diaphragm activity during respiration is decreased. Furthermore, based on the increase in ERV in the pillow-supported position (1), we infer that the alveoli were expanding. Burioka, et al.[10] have reported that when blocked, part of the alveolar respiratory system is unable to provide effective ventilation during quiet breathing. In patients with chronic obstructive pulmonary disease and other conditions in which ventilation is limited, a phenomenon in which the amount of residual air increases is observed, and while most measurements are performed through measurements of the functional residual capacity (FRC), because measurements of FRC were considered difficult for the present study, we measured ERV as an indicator of relative changes in FRC. The result that ERV exhibited high values only in the pillow-supported position (1) suggests that in addition to the effects of the lying position on the closing capacity exceeding FRC, the main cause of the high ERV may have been due to the fixing of the pillow to the posterior surface of the thorax that limited the thoracic movement necessary for performing respiratory movements. In our previous study[9], in the pillow-supported position (1), ventilation was limited and the breathing pattern changed into a chest-dominant breathing pattern. As the pleural space created a state of overexpansion and made diaphragm movements difficult ,we believe that this was disadvantageous for ensuring ventilatory volume. In this study, we used healthy subjects, but greater decreases may be observed in elderly patients and other cases in whom the respiratory function becomes limited due to degeneration. In order to prevent pulmonary atelectasis and other complications of the respiratory system in perioperative patients and patients requiring bed rest, it is necessary to ensure the ventilatory volume. In this respect, pillow-supported position (1), in which TV decreases, is a disadvantageous posture as the ventilation decreases. On the other hand, in pillow-supported position (2), there were no significant differences with the supine position in terms of TV, ERV, or distanced moved by the diaphragm. Based on the small area of contact between the supporting thorax and both the pillow and the pillow surface, we believe this result is due to the lack of limitation on expandability despite being another half-lateral position. The results suggest that the use of pillow-supported position (2) is desirable for postural changes and other cases requiring the use of the lateral position. We speculate that is not limited in pillow support(2)because of the empty space provided at the back, and think this is the reason why no significant difference was found with the supine position even though the support side is different, and there is no contact with pillow. As advancements continue to be made in medical instruments, it is becoming more common to provide respiratory management for patients with serious injuries, from newborns to elderly patients, requiring bed rest. We therefore believe it is necessary to recognize the effects of the habit of using pillow to support the posterior surface of the thorax on respiratory function and to reconsider methods of posture maintenance.

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