Influence of Posture on Respiratory Function and Respiratory Muscle Strength in Normal Subjects

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Abstract. [Purpose] The purpose of this study was to compare the respiratory function and respiratory muscle strength in the different body positions in order to find the posture in which it is easiest to cough up secretions or endotracheal aspirate. [Subjects] Fifteen non-smoking healthy women participated. All subjects gave their written consent to the study. [Methods] We measured respiratory muscle strength and respiratory function in three postures: sitting, supine, and 45 degree rotative prone. [Results] Vital capacity, forced vital capacity, forced expiratory volume in one second, and peak expiratory flow were marginally lower in 45 degree rotative prone. Percent of forced expiratory volume in one second was significantly lower in supine compared with sitting (p<0.05). [Conclusion] Our results suggest that 45 degree rotative prone is effective for coughing up secretions and endotracheal aspirate as well as the sitting position in young female subjects.

Key words: Posture, Respiratory function, Respiratory muscle strength

INTRODUCTION

Pulmonary complications after thoracic surgery and aspiration create peripheral airway obstruction. Secretions or endotracheal aspirate are generally removed by voluntary cough. However, difficulties with cough caused by respiratory muscle weakness bring on atelectasis or pulmonary complications, which way result in the respiratory function getting worse.

To facilitate removal of secretions, we provide airway clearance1) by postural drainage and some other techniques. Several studies have reported that postural drainage, especially prone and 45 degree rotative prone were effective for acute respiratory distress syndrome or acute lung injury2–5).

Takahashi et al.6) assessed the relationship between posture and bronchial inclination angle from an anatomical angle. However, they did not clarify the effect of posture on physiological respiratory function. Vitacca et al.7) compared the respiratory function between the sitting position and supine positions in elderly subjects. They established that forced expiratory volume in one second (FEV1.0), forced vital capacity (FVC) and peak expiratory flow (PEF) were significantly lower in supine than in sitting. Vilke et al.8) showed differentiation of the respiratory functions between sitting, prone, and the supine position. In their study, the supine and prone positions were lower in FVC, FEV1.0 and maximum voluntary ventilation among healthy subjects.

Expired flow is also important for expectoration of sputum and intrabronchial secretions. Badr et
al.\(^9\) reported that maximal expiratory pressure and flow were changed by body positions. However, whether or not 45 degree rotative prone is a useful position for the coughing has not previously been examined.

The purpose of this study was to compare the respiratory muscle strength and respiratory function in the sitting, supine and 45 degree rotative prone positions in order to find out the posture in which it is easiest to cough up secretions or endotracheal aspirate.

**SUBJECTS AND METHODS**

Fifteen non-smoking healthy women (22.7 ± 2.3 y.o.) participated. None of the subjects had chronic respiratory disorder, cardiovascular disease, neuromuscular disease or acute respiratory disease within the previous six weeks. All participants gave their written consent to the study.

The participants underwent measurement of maximum mouth pressure, which is deemed the respiratory muscle strength, with Micro RPM 01 (Micro Medical Ltd, UK). The maximal inspiratory mouth pressure (PImax) was defined as the maximal negative intraoral pressure that could be measured at the mouth when participants performed a maximal static inspiratory effort against an occluded airway. This was taken as a measure of inspiratory muscle strength. Similarly, the maximal expiratory mouth pressure (PEmax) was defined as the maximal positive intraoral pressure that could be measured at the mouth when participants performed a maximal static expiratory effort against an occluded airway. This was taken as a measure of expiratory muscle strength. The respiratory function tests were performed with a hand-held spirometer (AutoSpiro AS-7, Minato Medical Science Co., LTD, Osaka, Japan). Vital capacity (VC), FVC, FEV\(_{1.0}\) and peak expiratory flow (PEF) were recorded. Percent of forced expiratory volume in one second (FEV\(_{1.0}\%\)) was calculated as FEV\(_{1.0}\)/FVC × 100%.

Measurements were performed in the sitting, supine and 45 degree rotative prone positions. Selection of the order of the body positions was randomized. The position themselves were standardized as described below and are shown in Fig. 1:

1. Sitting: sitting in a chair with the trunk extended and the hips and knees flexed as near as possible to a right angle.
2. Supine: lying on a bed with a pillow supporting the head. Both legs were extended.
3. Forty-five degree rotative prone: left side lying with the trunk tilting forward at 45 degrees. Right hip and right knee were bent at 90 degrees. The left arm was at the back of the trunk. Pillows were set under the right thigh and right arm to maintain the body position without effort.

Each measurement was done three times, and the maximum value was used for analysis. Mean and standard deviations were used to describe the population studied. The results were analyzed using SPSS 11.0J for Windows (SPSS Japan Inc., Japan). A one-way analysis of variance was used. A p-value <0.05 was considered statistically significant.

**RESULTS**

None of participants were excluded because their spirometry results were in the normal range (Table 1).

There were no significant differences in PImax and PEmax among the three positions (Table 2).

VC in sitting, supine and 45 degree rotative prone was 3.46 ± 0.58 L, 3.45 ± 0.60 L, 3.31 ± 0.51 L, respectively. FVC in sitting, supine and 45 degree rotative prone was 3.16 ± 0.66 L, 3.18 ± 0.62 L,
7.02 ± 0.66 L, respectively. FEV₁₀ in sitting, supine and 45 degree rotative prone was 2.90 ± 0.55 L, 2.74 ± 0.45 L, 2.64 ± 0.54 L, respectively. VC, FVC and FEV₁₀ showed no significant difference among the three positions, although they were marginally lower in 45 degree rotative prone position than in the sitting and supine positions. FEV₁₀% in sitting, supine and 45 degree rotative prone was 92.0 ± 6.3%, 86.6 ± 5.8*, 88.8 ± 5.9%, respectively, and its value in the supine position was significantly lower than that in the sitting position (p<0.05). These results are shown in Table 3. PEF in sitting, supine and 45 degree rotative prone was 6.00 ± 1.69 L/s, 5.70 ± 1.56 L/s, 5.55 ± 1.48 L/s, respectively with no significant differences among the three positions.

**DISCUSSION**

Our study had two major findings. First, respiratory muscle strength was not changed in the sitting, supine and 45 degree rotative prone positions. Second, FEV₁₀% declined in the supine position.

Ogiwara and Miyachi⁹) reported that respiratory muscle strength did not change in sitting, half lying, ‘slumped’ half lying, supine lying, right side lying and left side lying in twenty young subjects. Our study was similar to their investigation, and similarly indicated that respiratory muscle strength was not influenced by the body position.

Regarding the second finding, some researchers have established a relationship between respiratory function and posture. Vilke et al.⁸) showed differences among the sitting, prone and supine position. They reported that FVC, FEV₁₀ and maximum voluntary ventilation were lower in the supine and prone positions compared to the sitting position in 18-year-old to 50-year-old healthy male subjects. In our study, we compared 45 degree rotative prone and two other positions in young female subjects. The differences of position, age and gender might influence the results.

Generally, pressure caused by the intra-abdominal organ to diaphragm is larger than in supine than in sitting, and it’s larger at dorsal than at ventral. In the supine, the dorsal side of the chest wall is limited its mobility by weight. VC and FVC were not lower in the supine position in this study. This indicates that the effect of the pressure caused by the intra-abdominal organ to diaphragm or limitation of the dorsal chest wall might be small in young healthy subjects.

Jenkins et al.¹¹) reported that lung capacity is smaller on the side of lying than in supine and it causes from limitation of the chest wall. Based on this result, we presumed that limitation of the chest wall would be greater in 45 degree rotative prone than the other positions, and that VC and FVC would decrease in 45 degree rotative prone. However, the results of this study indicated no statistically significant differences, suggesting that limited chest wall motion caused by posture did not have an effect on VC and FVC in healthy young

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**Table 1. Characteristics of all subjects**

<table>
<thead>
<tr>
<th>Characteristics (n=15)</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>22.7</td>
<td>2.3</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>158.7</td>
<td>4.6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>50.7</td>
<td>5.3</td>
</tr>
<tr>
<td>BMI</td>
<td>20.1</td>
<td>1.2</td>
</tr>
<tr>
<td>%VC at sitting (%)</td>
<td>111.5</td>
<td>16.9</td>
</tr>
<tr>
<td>FEV₁₀% at sitting (%)</td>
<td>92.0</td>
<td>6.2</td>
</tr>
</tbody>
</table>

**Table 2. Mean positional respiratory muscle strength (cmH₂O)**

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Sitting</th>
<th>Supine</th>
<th>45° rotative prone</th>
</tr>
</thead>
<tbody>
<tr>
<td>PImax</td>
<td>68.1 ± 21.1</td>
<td>66.2 ± 22.4</td>
<td>66.5 ± 22.2</td>
</tr>
<tr>
<td>PEmax</td>
<td>67.9 ± 19.6</td>
<td>68.3 ± 17.6</td>
<td>69.3 ± 17.3</td>
</tr>
</tbody>
</table>

All data are shown as mean ± S.D.

PImax: maximal inspiratory mouth pressure; PEmax: maximal expiratory mouth pressure. There were not significant differences in one-way ANOVA.

**Table 3. Effects of posture on VC, FVC, FEV₁₀ and FEV₁₀% in subjects with normal respiratory function.**

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Sitting</th>
<th>Supine</th>
<th>45° rotative prone</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC (L)</td>
<td>3.46 ± 0.58</td>
<td>3.45 ± 0.60</td>
<td>3.31 ± 0.51</td>
</tr>
<tr>
<td>FVC (L)</td>
<td>3.16 ± 0.66</td>
<td>3.18 ± 0.62</td>
<td>3.02 ± 0.66</td>
</tr>
<tr>
<td>FEV₁₀ (L)</td>
<td>2.90 ± 0.55</td>
<td>2.74 ± 0.45</td>
<td>2.64 ± 0.54</td>
</tr>
<tr>
<td>FEV₁₀% (%)</td>
<td>92.0 ± 6.3</td>
<td>86.6 ± 5.8*</td>
<td>88.8 ± 5.9</td>
</tr>
</tbody>
</table>

*Significantly lower than sitting (p<0.05). VC: vital capacity; FVC: forced vital capacity; FEV: forced expiratory volume in one second; FEV₁₀%; percent of forced expiratory volume in one second.
female subjects.

To assess FEV$_{1.0}$ or FEV$_{1.0\%}$, fast forced expiration is required. The expiratory muscles, mainly the abdominal rectus muscle, act in forced expiration. In the sitting position and 45 degree rotative prone, one or both hip joints are bent. Therefore the lower FEV$_{1.0\%}$ in supine suggests that hip extension is a disadvantage for fast forced expiration like coughing.

In the case of gravity-dependent atelectasis, prone or 45 degree rotative prone are effective for improving oxygenation and for transfer of the intrabronchial secretions to the proximal airway. We conclude that 45 degree rotative prone is effective for coughing up secretions and endotracheal aspirate as well as the sitting position in young female subjects.

ACKNOWLEDGMENT

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REFERENCES