Effect of Posture on Ventilatory Muscle Strength

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Abstract. The purpose of this study was to investigate whether body positioning would bring about any change in inspiratory and expiratory muscle strength expressed in terms of maximal negative inspiratory pressure ($P_{\text{Imax}}$) and maximal positive expiratory pressure ($P_{\text{Emax}}$). The $P_{\text{Imax}}$ and $P_{\text{Emax}}$ measurements were carried out on 20 participants in sitting, half lying, 'slumped' half lying, supine lying, right side lying, and left side lying. The one-way analysis of variance showed that $P_{\text{Imax}}$ and $P_{\text{Emax}}$ values were within normal range for all positions. It was hypothesized that a significant change in $P_{\text{Imax}}$ and $P_{\text{Emax}}$ would occur with alteration of the body position in healthy persons, but this was proven negative. The findings were similar to those found for people with chest pathologies; that is, the highest $P_{\text{Imax}}$ and $P_{\text{Emax}}$ values were evident in the more erect positions than recumbent positions. Possible reasons and implications for such findings are discussed in terms of the force of gravity acting on the thoracic cage in various body positions and the length-tension relationship of both the inspiratory and expiratory muscles.

Key words: Inspiratory pressure, Expiratory pressure, Body position, Cardiopulmonary physiotherapy.

INTRODUCTION

The musculoskeletal system is constantly under the influence of gravitational force, including the organs of the body. The respiratory system is no exception, particularly the lungs. This is reflected in preferential perfusion of the lowermost portions of the lung, hence the altered ventilation-perfusion ratio\(^1\). So we pose the question: does the influence of gravitational force also affect ventilatory muscle performance? Like other skeletal muscles, ventilatory muscle power is assessed in terms of strength. This is generally determined by measurement of inspiratory and expiratory pressure at the mouth and usually conducted with the person sitting.

Many researchers have reported significant changes in pulmonary function with positioning\(^2\)–\(^5\); reductions of 12% for forced vital capacity and 15% for forced expiratory volume in one second have been observed in normal individuals between the different body positions of sitting and ‘slumped’ half lying\(^2\). Vital capacity has been found to be at its lowest in the foetal position compared to the body positions of Trendelenburg, supine, lean-standing and high-grasp-standing\(^3\). Other researchers have stated that vital capacity decreased more than 6.25% following a change of position from sitting to supine lying\(^4\),\(^5\).

The objectives of this study were to measure the value of the maximal negative inspiratory pressure ($P_{\text{Imax}}$) and maximal positive expiratory pressure ($P_{\text{Emax}}$), in centimetres of water ($cm H_2O$), of normal individuals in each of six body positions:
sitting, half lying, ‘slumped’ half lying, supine lying, and right/left side lying, and to investigate any possible relationship between data collected from these results. The objective of this study was the collection of information so as to be able to utilize the best possible body position for ventilatory muscle training. The null hypothesis was that there would be no significant change in P_{Imax} and P_{Emax} values with alteration of body position.

METHODS

Participants

The participants consisted of 20 physiotherapy students with an equal number of males and females. The mean (SD; range) age of this convenience sample was 22.8 (2.14; 21–28) years old with a mean (SD; range) body mass index of 20.53 (3.15; 16.80–27.55) kg/m^2. None of the participants had been engaged in any regular athletic training, nor had they had any cardiopulmonary dysfunction or musculoskeletal disorder of the thoracic cage and trunk. All the participants were non-smokers.

Measurement

The Vitalopower KH-101 (Chest M.I. Inc., Japan) was used for the measurement. The P_{Imax} was defined as the maximal negative pressure expressed in cm H₂O that could be measured at the mouth when participants performed a maximal static inspiratory effort against an occluded airway, which is taken as a measure of inspiratory muscle strength. Likewise, the P_{Emax} was defined as the maximal positive pressure expressed in cm H₂O that could be measured at the mouth when participants performed a maximal static expiratory effort against an occluded airway, which is taken as a measure of expiratory muscle strength.

Procedure

The participants were given an explanation of the purpose and procedures for this experiment. Selection of the order of the various body positions for testing was randomised, but the positions themselves were standardised as described below:

1. Sitting in a straight-backed chair with hips and knees flexed as near as possible to a right angle. The mouthpiece was held in one hand and the other arm rested on the thigh.

2. Half lying with the head of the bed elevated to 45 degrees and knees semiflexed and supported with pillows at approximately 30 degrees. The mouthpiece was held in one hand and the other arm rested on the bed.

3. ‘Slumped’ half lying with the head of the bed elevated to 45 degrees, a butterfly pillow supporting the head and thorax, and a pillow supporting the knees in semiflexion with the mouthpiece held in one hand.

4. Supine lying on the bed with a pillow supporting the head with the limbs relaxed unsupported and the mouthpiece held in one hand.

5 and 6. Alternate right and left side lying with both knees and hips in semiflexion with weight distributed anteriorly with one pillow under the head and the mouthpiece held in the uppermost hand.

Participants rested in the appropriate test position for approximately 10 min prior to each measurement. After a maximal expiration with a nose clip in situ in the positions described above, P_{Imax} was measured at the point of residual capacity. An orifice with an internal diameter of 0.6 mm in the Vitalopower permitted an air leak to minimise the pressure artefact secondary to facial muscle contraction. The verbal command remained constant by the use of a pre-recorded cassette tape to prevent inter- and intra-tester variability. The measurement was repeated three times with an interval of one minute between each measurement, and the highest reading was taken as the participant’s P_{Imax}. Maximal inspiratory effort lasting less than one second was discarded. Similarly, P_{Emax} was measured at the point of total lung capacity after a maximal inspiration with a nose clip in situ in the positions described above. The rest of the procedure was the same as that for the P_{Imax} measurement.

The order of measurement of P_{Imax} and P_{Emax} in the six body positions was randomised. Instead of assigning all the participants randomly into the six body positions, they themselves were the control throughout the testing. The participant was instructed in the use of the equipment and allowed to perform several ‘trial’ tests in each body position before the actual test was carried out.

Only one test position per day was used. Each measurement session was separated by approximately 24 hours so as to take into account the participant’s biorhythm and to nullify the
possible effect of ventilatory muscle fatigue brought about by the previous session. Measurements were avoided within one hour of having a meal, and also the participants were prohibited from drinking coffee or other caffeine containing beverages on test days because caffeine is known to cause an increase in muscle contraction\(^4, 5\).

**Statistics**

Statistical analysis was done on a computer (Sharp PC-FJ30) with Microsoft Excel for Windows 98, using a one-way analysis of variance (ANOVA). An alpha level of 0.05 was selected for statistical significance in this study.

### RESULTS

Mean (SD; range) \(P_{Imax}\) in sitting, half lying, ‘slumped’ half lying, supine lying, right side lying and left side lying was 100.98 (30.36; 56.0–166.7), 95.48 (31.74; 51.2–177.5), 95.84 (30.40; 52.7–162.7), 91.77 (25.33; 52.0–140.2), and 96.09 (31.57; 45.2–151.5), 93.81 (31.08; 45.2–146.5) cm \(H_2O\), respectively. Likewise, mean (SD; range) \(P_{Emax}\) was 126.42 (42.29; 55.7–200.7), 119.08 (42.13; 52.0–187.2), 115.43 (39.34; 52.7–181.2), 112.58 (37.91; 62.5–194.7), 111.70 (35.27; 71.0–172.5), 108.07 (34.92; 74.2–186.7) cm \(H_2O\), respectively. None of the results yielded any statistical significance. These results are shown in Figs. 1 and 2, together with ANOVA tables (Tables 1 and 2).

### DISCUSSION

This study revealed that change of position did not significantly alter ventilatory muscle strength, though the sitting position tended to produce a
higher chronic asthmatics in age range from 30–55 years, it was found that their $P_{E_{max}}$ in a sitting leaning forward position was significantly higher than that for supine lying (79.3125 ± 22.057 vs. 69.8750 ± 25.211 cm H2O, p<0.0017). According to Jenkins and her associates8), the functional residual capacity was found to be highest in sitting, followed by left side lying, right side lying, half lying, ‘slumped’ half lying, and supine lying. Similar results were predicted for our present study, but both the inspiratory and expiratory muscle strength showed no change with alteration of body positions, hence support of the null hypothesis. This finding suggests that the ventilatory muscles of healthy individuals seem to work efficiently in any posture. However, $P_{I_{max}}$ and $P_{E_{max}}$ values tended to be highest when the body was in the more upright positions of sitting and half lying than for the horizontal positions. This can be validated by the fact that, in these positions, gravity assists in the compression of the upper thoracic cage more easily than in the horizontal positions. Further, activity of the diaphragm has been known to increase three to five times more in sitting and standing than in supine lying9). The upright position also gives better mechanical advantage to the oblique abdominal muscles when they contract during the forced expiratory manoeuvres.

The tendency for $P_{I_{max}}$ and $P_{E_{max}}$ to be at their highest in sitting for this study can also be explained by the change in the length-tension relationship of the ventilatory muscles. For example, in the upright position the scalene, sternocleidomastoid and parasternal intercostal muscles are readily activated, raising and enlarging the upper thoracic cage, thereby increasing in length the expiratory muscles and, therefore, the potential recoil of them, so the thoracic cage becomes more easily compressed, hence gaining higher $P_{E_{max}}$. A similar explanation can be given for inspiratory muscles.

In side lying the underside of the body becomes compressed by the individual’s own body weight, restricting movement of the hemi-thorax both during maximal inspiration and the forced expiratory manoeuvre. This may explain why the $P_{E_{max}}$ values tended to be at their lowest for side lying. However, this finding may contradict with Jenkins and her associates’ statement8) that lying on the side with the hips and knees flexed is helpful in encouraging expiratory manoeuvres such as huffing and coughing. We believe that Jenkins and her associates may mean expiratory manoeuvres taking place at low lung volume in this case.

Bed-ridden persons who are propped up in half lying can frequently be seen to have slid down the bed into a ‘slumped’ half lying position. In this posture the upper thoracic spine becomes forcibly flexed, so that the thoracic cage, especially the upper part, cannot fully expand anteriorly, which may prevent the thoracic cage from providing a more appropriate length-tension relationship for contraction of both the inspiratory and expiratory muscles. Also inhibited in excursion is the descent of the diaphragm due to compression of the abdominal viscera and, in addition, that of lateral thoracic expansion due to the flexed and adducted upper limbs on the rib cage. This may be why $P_{I_{max}}$ tended to be at its lowest in this position. Physiotherapists, therefore, must be acutely aware of this body position whenever visiting wards, and appropriate instruction given to the client and nursing staff.

The limitation of extension of the spine beyond the neutral position in supine lying may account for not gaining a higher $P_{E_{max}}$ because of the prevention of any potential recoil of the thoracic cage. In addition, full activity of the accessory muscles of respiration is inhibited in this posture compared to the increase of activity which occurs in the upright position.

In a clinical situation such as performing coughing and FET or forced expiration technique clients often prefer to perform these manoeuvres in the upright position. This suggests that compromised chest mechanisms and/or ventilatory muscle weakness cannot generate sufficient expiratory force in positions other than sitting, although this may not be the case for young healthy individuals. However, Gouden’s study showed that the sitting leaning forward position in 57 normal university students produced a significantly higher $P_{E_{max}}$ compared to that of supine lying7). Thus, Gouden’s and our results seem to contradict, but there are some slight variations in the studies, specifically, concerning the fact that the majority of Gouden’s participants were female (48 vs. 9)7), and the sitting leaning forward position was not used, suggesting the possible existence of a sex difference and the need for further studies involving this latter position.

The implications resulting from this and other
researchers’ studies show that, whenever possible, coughing and/or FET should be carried out in an upright position for persons with chest pathologies, such as chronic obstructive pulmonary disease, who need to be energy efficient for their bronchial hygiene. In addition, training of both the inspiratory and expiratory muscles should also be done in this position for a better length-tension relationship. When assessment of maximal ventilatory muscle strength is required, it is important to consider various factors, one of which is the body position.

CONCLUSION

One can deduce from the results of this study that healthy college-age students have ventilatory muscles that work efficiently in any body position. Specifically, the length-tension relationship of these muscles seems to remain constant regardless of any change in body position. However, the effect of change in body position may become highly significant for the elderly and persons with chest pathologies who are likely to have compromised chest mechanics together with possible ventilatory muscle weakness. Therefore, additional studies will be required to know $P_{Imax}$ and $P_{Emax}$ of young adults with a compromised respiratory system and that of both a healthy and an ailing elderly population. These studies will further aid in clarifying the effect of body position on ventilatory muscle performance.

REFERENCES