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Effect of Posture on Maximal Expiratory Pressure

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ABSTRACT

The purpose of this study was to investigate whether body position would bring about change in expiratory muscle strength expressed in terms of maximal positive expiratory pressure (P_{Emax}). The P_{Emax} measurement was carried out on 20 subjects in half lying, sitting, supine lying, 'slumped' half lying, right side lying, and left side lying. The one-way analysis of variance revealed that P_{Emax} values were within normal range for all positions. This finding was similar to that for people with chest pathologies ; that is, the highest P_{Emax} values were in the more erect positions than recumbent positions. It was hypothesized that a significant change in P_{Emax} would occur with alteration of body position in, persons for example, with respiratory abnormalities, but this was not the case. Possible reasons and implications for these findings are discussed in terms of gravity acting on the thoracic cage and the length-tension relationship of the expiratory muscles.

KEY WORDS

maximal positive expiratory pressure, body position, cardiopulmonary physiotherapy

INTRODUCTION

Like other skeletal muscles, respiratory muscle performance is assessed in terms of strength. This is generally determined by measurement of inspiratory and expiratory mouth pressures and usually conducted with the person in sitting.

Many researchers have reported significant changes in pulmonary function with positioning; reductions of 12 % for forced vital capacity and 15 % for forced expiratory volume in one second have been observed in normal individuals between the positions of sitting and 'slumped' half lying[1]. Vital capacity has been found to decrease by 15 % between the 'foetal' position and extension[2]. Other researchers have stated that vital capacity decreased more than 6.25 % following a change of position from sitting to supine lying[3-4].

The objectives of this study were to measure th value of the maximal positive expiratory pressu (P_{Emax}), in centimetres of water, of normal individua in each of six body positions : half lying, sitting, su pine lying, 'slumped' half lying, and right/left sid lying, and to investigate possible relationships b tween data collected from these results. The null hy pothesis was that there would be no significa change in P_{Emax} values with alteration of position.

METHODS

Participants

The test subjects consisted of 20 physical thera students who were divided into two groups of equ number. The mean (SD ; range) age of this conve ience sample was 20.2 (0.7 ; 19-22) *years old,* me (SD ; range) height 164.4 (6.8 ; 153 to 180) *cm,* a

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mean (SD ; range) body mass 58.6 (9.2 ; 47 to 80) *kg*, respectively. 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_{Emax} was defined as the maximal positive pressure expressed in $cm\ H_2O$ that could be measured at the mouth when participants performed a maximal static expiratory effort against an occluded airway, which is regarded as a measure of expiratory muscle strength[5].

Procedure

The participant was given an explanation of the purpose and procedures for this experiment. Selection of the order of positions for testing was randomised, but the positions themselves were standardised as follows :

1. *Half lying* with the head of the bed elevated to 45 degrees and knees supported at approximately 30 degrees. The mouthpiece was held in one hand and the other arm rested on the bed.
2. *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.
3. *Supine lying* on the bed with a pillow under the head, limbs relaxed and the mouthpiece held in one hand.
4. *'Slumped' half lying* with the head of the bed elevated to 45 degrees, a conical pillow supporting the head and thorax, and a pillow beneath the knees with the mouthpiece held in one hand.

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

Participants rested in the appropriate test position for approximately 10 minutes prior to each measurement. P_{Emax} was measured at total lung capacity after a maximal inspiration with a nose clip in situ in the positions described above. 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. The measurement was repeated three times with an interval of one minute between each measurement and the highest reading was taken as the participants' P_{Emax}. Maximum expiratory effort lasting less than one second was discarded. Instead of assigning all the participants randomly into the different body positions, they themselves were the control throughout the testing. The participant was instructed in the use of the equipment and was allowed to perform several 'trial' tests in different positions 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 expiratory muscle fatigue brought about by the previous session. The participants were prohibited from drinking coffee, or other caffeine containing beverages on test days.

Analysis

Statistical analysis was done on the lap-top computer (akia Tornado 510V) with Microsoft Excel 7.0, using a one-way analysis of variance. The level of statistical significance was set at 0.05.

RESULTS

Comparative values of P_{Emax} among the different positions are shown in Table 1. None of the results yielded any statistical significance (Table 2 and Figure).

DISCUSSION

In a study employing 16 chronic asthmatics with an age range from 30-55 years, it was found that their P_{Emax} in a sitting leaning forward position was significantly higher than that for supine lying (79.3125 ± 22.057 vs. 69.8750 ± 25.211 $cm\ H_2O$, $p<0.001$)[6]. According to Jenkins, et al.[7], the functional residual capacity is highest in sitting, followed by left side lying, right side lying, half lying, 'slumped' half lying, and supine lying. Similar results were expected for this study, but the expiratory muscle strength showed no change with alteration of body positions, hence support of the null hypothesis. This finding suggests

Table 1. Comparison of the difference in P_{Emax} values for each position. (HL, half lying ; S, sitting; SHL, 'slumped' half lying ; SL, supine lying ; RSL, right side lying ; LSL, left side lying).

Position 1	*vs. position 2*	*mean 1*	*vs. mean 2*	*Difference*	*p*
HL	S	100.745	101.760	-1.015	0.8802
	SHL		95.715	5.030	0.4557
	SL		97.460	3.285	0.6259
	RSL		90.005	10.740	0.1127
	LSL		94.760	5.985	0.3750
S	SHL	101.760	97.460	6.045	0.3702
	SL		95.715	4.300	0.5235
	RSL		90.005	11.755	0.0829
	LSL		94.760	7.000	0.2997
SHL	SL	95.715	97.460	-1.745	0.7956
	RSL		90.005	5.710	0.3972
	LSL		94.760	0.955	0.8872
SL	RSL	97.460	90.005	7.455	0.2696
	LSL		94.760	2.700	0.6886
RSL	LSL	90.005	94.760	-4.755	0.4806

Table 2. One-way analysis of variance for measure of mean absolute error by body positions. (*SS*, sum of squares ; *df*, degree of freedom ; *MS*, mean squares ; p, probability of no difference between relevant effects at significant level $p \leqq 0.05$)

Source of Variance	*SS*	*df*	*MS*	*F*	*p*
Between body positions	1841.801	5	368.3603	0.815811	0.5408
Within body positions	51474.050	144	451.5267		
Total	53315.850	112			

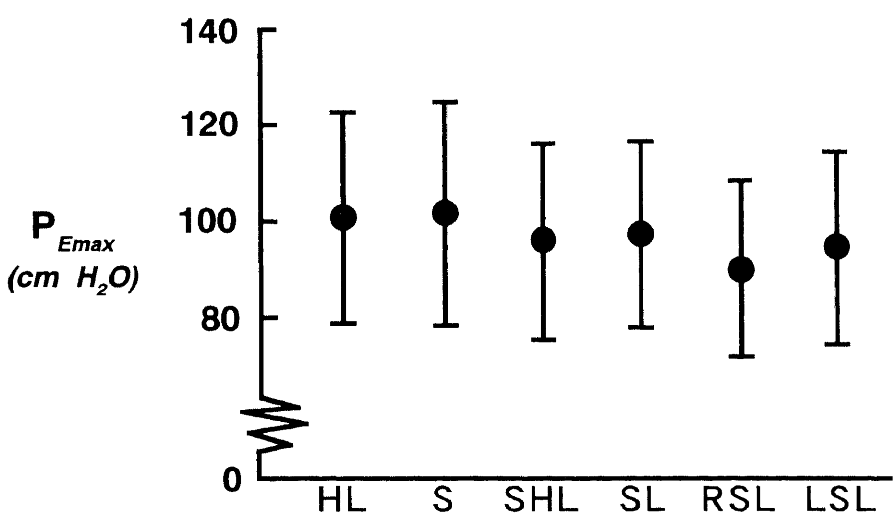

Figure. Mean P_{Emax} values in six positions. (Abbreviations as for Table 1).

that the expiratory muscles of healthy individuals seem to work efficiently in any posture. However, P_{Emax} values tended to be at their highest when the body was in the more upright positions, i.e. sitting and half lying, than in 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 lying[8]. The upright position also gives better mechanical advantage to the oblique abdominal muscles when they contract during the forced expiratory manoeuvre.

Acceptance of the null hypothesis in this study can also be explained by the length-tension relationship of the expiratory 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 the potential recoil, so the thoracic cage is easily compressed, hence gaining higher P_{Emax}.

In side lying the underside of the body becomes compressed by the individual's own body weight, restricting movement of the hemithorax both during the maximal inspiration and forced expiratory manoeuvre. This may be why the P_{Emax} values tended to be at their lowest in side lying. However, this finding may contradict with Jenkins et al.'s statement[5] that lying on the side with the hips and knees flexed is helpful in encouraging expiratory manoeuvres such as huffing and coughing. The authors believe that Jenkins et al. may mean expiratory manoeuvres 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 expand fully anteriorly, which may be preventing the thoracic cage from gaining a more appropriate length-tension relationship for contraction of the expiratory muscles. Also inhibited in excursion are the descent of the diaphragm due to compression of the abdominal viscera and lateral costal expansion due to the flexed and adducted upper limbs.

The limitation of supine lying for gaining a higher P_{Emax} may be because it prevents the spine from extending beyond the neutral position, so inhibiting any potential recoil of the thoracic cage to occur, which contributes to a higher P_{Emax}. In addition, activity of the accessory muscles of respiration cannot fully take place in this posture compared to that of the upright position.

In a clinical situation such as performing coughing and FET or forced expiratory technique people often naturally prefer to perform these manoeuvres in the upright position. This suggests that compromised chest mechanics and/or ventilatory muscle weakness cannot generate sufficient expiratory force in positions other than sitting, although this may not be the case in young normal individuals. However, Gounden's study showed that the sitting leaning forward position in 57 normal university students produced a significantly higher P_{Emax} compared to that of supine lying[6]. Thus, Gounden's and our results seem to contradict, but there are some slight variations in the studies, specifically, the majority of Gounden's participants were female (48 vs. 9)[6], and we did not use the sitting leaning forward position, 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 require efficient bronchial hygiene. In addition, training of the expiratory muscles should also be done in this position for a better length-tension relationship. When assessment of maximal expiratory 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, unlike persons with chest pathologies who are likely to have compromised chest mechanics including possible ventilatory muscle weakness, healthy college-age students have ventilatory muscles which work efficiently in any body position. Specifically, the length-tension relationship of these muscles seems to remain constant regardless of change in body position.

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最高呼気圧に対する姿勢の影響

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要　　旨

20名の健常大学生の最高呼気圧を椅座位，半臥位，ずり落ち半臥位，仰臥位，右側臥位，および左側臥位で測定し，姿勢による最高呼気圧の差異があるか否かを検証した。一元配置の分散分析による解析の結果，最高呼気圧に有意差は認められなかった。しかしながら，最高呼気圧の高低の傾向は，姿勢の変化による肺活量を代表とする肺機能の差異に酷似していた。すなわち，椅座位や半臥位では最高呼気圧が比較的高く，臥位では低い傾向が認められた。本所見は，重量および姿勢の変化による呼息筋群の長さ・張力関係によって説明できる。すなわち，椅座位や半臥位など，直立位またはそれに近い姿勢では，吸息筋群の収縮が臥位時に比べると容易であり，したがって呼息筋群は伸ばされやすくなる。これが呼息筋群の収縮力を大きくし，最高呼気圧に反映されるものと考えられる。しかし健常大学生では，上記の機序が顕在化せず，いかなる姿勢でも呼息筋群が高率良く収縮するようである。