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EFFECT OF SITTING POSTURE ON THORACIC CONFIGURATION AND CHANGES IN VOLUME OF HEMITHORACES

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ABSTRACT

Background: Poor posture is detrimental to breathing. Our purpose was to investigate the effect of upright and hunchbacked sitting on thoracic configuration and changes in the volume of the thorax during quiet and volitional deep breathing.

Methods: The participants were 11 healthy men with a mean age of 21.6 years, mean body mass of 59.8 kg, mean height of 169.7 cm and a body mass index of 20.7 kg/m2. Eighty-four reflective markers were placed on the trunk. Three-dimensional motion analysis measured the volume within the hemithoraces. To calculate upper and lower thoracic volumes, six imaginary hexahedra were visualized using four reflective markers for each on both aspects of the thorax. Each hexahedron was divided into three imaginary triangular pyramids to calculate positional vectors. Finally, the volume for the hexahedra and triangular pyramids was calculated. Upper thoracic volume encompassed a space from the sternal notch to a midpoint on the ventral aspect of the third rib and the lower thoracic volume from the xiphoid process to the midpoint on tenth rib's dorsal aspect.

Results: In hunchbacked sitting during quiet breathing the left lower hemithorax yielded a significantly larger volume (p=0.003), and both breathing patterns during inspiration and expiration yielded a significantly greater change in thoracic configuration (p=0.01, p=0.016).

Conclusion: Findings suggested that, in a hunchbacked sitting, there was decreased thoracic asymmetry with re-establishment of thoracic vertebral alignment, consequently stabilizing the sitting position, but breathing was suppressed and tidal volume decreased. Physiotherapy should aim at ensuring correction of hunchbacked posture and maintenance of thoracic symmetry.

Keywords: thoracic volume, hemithorax, three-dimensional motion analysis, hunchbacked sitting, quiet breathing, volitional deep breathing.

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INTRODUCTION

In clinical practice, physical therapists encounter patients with poor posture that may lead to changes taking place in the mechanics of thoracic excursion with accompanying abnormal breathing patterns. Improvement in a patient's posture has been found to alleviate shortness of breath [1]. Patients with either obstructive or restrictive disease of the lungs commonly have some respiratory symptoms that are derived from a combination of pathophysiological changes in the respiratory organs themselves, together with possible changes in the mechanics of thoracic excursion [2]. A great number of the ventilatory muscles are also found to play a part in postural control, especially those muscles of the neck and trunk. Therefore, the alignment of the body may consequently affect respiratory function. A change in posture may affect thoracic excursion and, subsequently, respiratory function, especially vital capacity and inspiratory reserve volume, which reflects on inspiratory capacity [3]. The thoracic cage principally consists of the thoracic vertebrae, ribs, and sternum. If an incongruity, albeit a small one, occurs in this structure, its mechanics will be affected, resulting in a significant impact on respiratory function. Women with thoracic kyphosis were found to have a decrease in their respiratory function with a negative correlation evident between the degree of kyphosis and vital capacity/maximum inspiratory volume [4]. Therefore, it was considered significant to clarify the relationship between changes in thoracic configuration and respiratory function.

Studies have already been carried out on the effects of changes in chest volumes at specific locales within the thorax in upright and hunchbacked sitting positions [1,5]. However, during the assessment of patients with fatigue and dyspnoea, it was frequently observed that right-left asymmetry of respiratory muscle activity occurred. This asymmetrical movement included abnormal alignment of the thorax on a sagittal plane, changes in thoracic configuration about the pelvis on a frontal plane and right-left discrepancy in chest expansion. Further, in a study carried out on the thoracic configuration about the alignment of the pelvis on a frontal plane right-left discrepancy in chest expansion was observed [6]. The specific purpose of the present study was, therefore, to investigate the effect of two sitting positions, especially hunchbacked sitting, on thoracic configuration and, in particular, noting any changes in the volume of the upper and lower hemithoraces.

METHODS

Participants

The participants were 11 sedentary non-smoking healthy men with no history of the respiratory or spinal condition. They had a mean (SD) age of 21.6 (1.6) years (range: 20-26), mean (SD) body mass of 59.8 (10.0) kg (range: 48-76), mean (SD) height of 169.7 (4.8) cm (range: 162-176) and a mean (SD) body mass index of 20.7 (2.7) kg/m^2 (range: 17.30-24.53). The investigators explained to the participants the purpose and procedures of the study and obtained their written consent for participation. This study was conducted in the Kinematics Laboratory at Bunkyo Gakuin University.

Procedure

The participants were tested in two sitting positions. These were an upright sitting position with a pelvic tilt of zero degrees and a hunchbacked sitting position with a pelvic tilt of 20 degrees. For both positions the feet were flat on the floor and the hip and knee joints in 90° of flexion. The pelvic angle was defined as an angle created by intersecting imaginary lines formed by infrared reflective markers attached to the skin over the anterior and posterior superior iliac spines. This was in conjunction with an imaginary spatial horizontal line, which was determined by using a spirit level.

A total of 84 infrared reflective markers each with a diameter of 9.5 mm were placed at specific points on the skin over the anterior and posterior aspects of the trunk. Any changes in their movement recorded changes in thoracic volume. The precise positioning for both the anterior and posterior markers was determined from six midline markers placed vertically in line on six levels, these being the sternal notch, third rib, xiphoid process, eighth rib, tenth rib, and umbilicus, all of which are commonly used as a guide for Palpation of chest movement. About the six midline markers on the trunk an additional 78 markers, in order of their proximity to them, were placed medially, centrally and laterally on the anterior and posterior aspects of the trunk. Specifically, three markers were placed on either side of a midline marker, totaling seven markers in all. The distance between each marker was based on the participant's physique and set at 15% of the distance between the left and right acromion processes. This procedure was repeated on the posterior aspect of the trunk at each of the corresponding six levels.

The anterior half was encompassed within the space of the upper thorax demarcated by the sternal notch and third rib, and the posterior half of the space of the lower thorax demarcated by the xiphoid process and tenth rib. Using a three-dimensional motion analyzer Vicon MX (Vicon, Inc.), the difference in volume within the upper and lower hemithoraces was measured in the two sitting positions during quiet breathing and deep volitional breathing, each with five or more consecutive breaths. An average value of three consistent breaths was taken for the calculation. By previous studies [7,8,9,10,11], the changes in thoracic volume were calculated from the amount of change in the movement of the infrared reflective markers attached to the body surface. For the recording of this movement, seven infrared cameras were used, and the data were stored on a personal computer with a sampling frequency of 100 Hz.

The thoracic volume was calculated by the method developed by Ferrigno and Carnevali [7] and Nakabo and Yamamoto [9]. Specifically, six imaginary hexahedra were visualized for the upper thorax with three for the right and three for the left using four markers for each on the anterior and posterior aspects of the thorax at the levels of the sternal notch and third rib (Figure 1a). Similarly, this was repeated for the lower thorax at the levels of the xiphoid process and tenth rib (Figure 1b). Further, each of these imaginary hexahedra was, then, divided into three imaginary triangular pyramids to calculate positional vectors using the data obtained from the position of each marker by the method employed by Ferrigno and Carnevali [7]. Finally, the volume of both the hexahedra and triangular pyramids was calculated, culminating in any change of thoracic volume on the whole.

To measure for any changes in the thoracic volume imaginary midpoints were established between the ventral and dorsal markers with the upper thorax encompassing the anterior space between the ventral markers and their midpoints. Similarly, the lower thorax encompassed the posterior space between the dorsal markers and midpoints. This measurement method was based on the model originally developed by Shōbo and Kakizaki for analysis of thoracic movement (Figure 1) [1]. Thereby, the volume change in each hexahedron could be calculated. Accordingly, four thoracic volumes were measured: a) the upper right and left hemithoraces' volumes emanating from a midpoint on an imaginary line connecting from the sternal notch to the third rib, and b) the lower right and left hemithoraces' volumes emanating from a midpoint on an imaginary line connecting from the xiphoid process to the tenth rib. The Vicon Body Builder and MATLAB (MathWorks, Inc., Natick, U.S.A.) were used for calculation of the thoracic volumes.

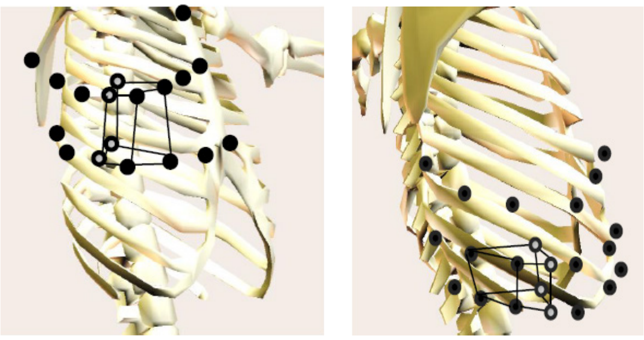
a) b)

Figure 1: Illustration of imaginary hexahedra

a) One of six hexahedra on the upper thorax is seen demonstrated within the anterior markers and midpoints.
b) One of six hexahedra on the lower thorax is seen demonstrated within the posterior markers and midpoints.

Dots indicate markers from which the hexahedra were constructed.

Circles indicate imaginary midpoints.

For statistical analysis, the Wilcoxon rank-sum test was employed for comparison of the changes in the volume of the bilateral hemithoraces. The level of significance was set at p<0.05, and, for the data analysis, the Statistics Package for Social Sciences version 23.0 (SPSS Japan Inc, Tokyo, Japan) for Windows was employed. This study was approved by the Bunkyo University Medical Ethics Review Board (Approval No. 2016-0034).

RESULTS

In upright sitting during quiet breathing mean tidal volume was 660.9±682.7 ml and during volitional deep breathing 1270.9±369.3 ml. In hunchbacked sitting during quiet breathing mean tidal volume was 608.8±417.8 ml and during volitional deep breathing 1081.1±429.6 ml.

In upright sitting, during quiet and volitional deep breathing the left upper hemithorax yielded a significantly larger volume compared to the right upper hemithorax (p=0.003 and p=0.002, respectively) (Table 1). However, this was reversed for the lower hemithoraces for both breathing patterns (p=0.002 and p=0.001, respectively). During quiet breathing in hunchbacked sitting the left lower hemithorax yielded a significantly larger volume compared to the right lower hemithorax (p=0.003) (Table 1).

Table 1: Changes in the mean (SD) volume of the right and left upper and lower thoraces during quiet and volitional deep breathing in two sitting positions.

N=11

		Change in the thoracic volume (ml)							
		Upright sitting				Hunched-back sitting			
		Quiet breathing	p-value	Volitional deep breathing	p-value	Quiet breathing	p-value	Volitional deep breathing	p-value
Upper thorax	Right	17.5±10.7	0.003	57.7±28.0	0.002	26.7±16.8	0.075	55.5±28.0	0.248
	Left	26.3±16.8		97.5±46.5		31.1±15.4		63.3±35.7	
Lower thorax	Right	55.6±16.3	0.002	146.7±60.7	0.001	60.3±27.6	0.003	108.7±47.3	0.286
	Left	46.6±13.7		104.8±42.6		71.2±29.8		117.1±44.1	

For both breathing patterns in upright sitting during expiration and inspiration, the left upper hemithorax yielded a significantly larger volume compared to the right upper hemithorax (p=0.003 and p=0.003, respectively) (p=0.003 and p=0.003, respectively). However, this was reversed for the lower hemithoraces (p=0.003 and p=0.003, respectively) (p=0.003, p=0.003, respectively) (Table 2). For both breathing patterns in hunchbacked sitting during inspiration and expiration the left upper hemithorax yielded a significantly larger volume compared to the right upper hemithorax (p=0.03 and p=0.03, respectively), and the left lower hemithorax yielded a significantly larger volume compared to the right lower hemithorax (p=0.01 and p=0.016, respectively) (p=0.008, p=0.026) (Table 2).

Table 2: Changes in the mean (SD) volume of the upper and lower thoraces during inspiration and expiration in two sitting positions.

N=11

			Change in the thoracic volume (ml)							
			Upright sitting				Hunched-back sitting			
			Quiet breathing	p-value	Volitional deep breathing	p-value	Quiet breathing	p-value	Volitional deep breathing	p-value
Upper thorax	Inspiration	Right	768.0±162.4	0.003	791.6±100.5	0.003	966.7±337.6	0.062	898.2±156.4	0.03
		Left	1049.0±175.0		1118.4±145.5		1046.4±168.5		1093.2±175.5	
	Expiration	Right	750.5±155.7	0.003	733.9±97.0	0.003	940.0±328.1	0.062	842.7±139.7	0.03
		Left	1022.8±164.9		1020.9±139.1		1015.3±168.5		1029.9±161.1	
Lower thorax	Inspiration	Right	1420.1±365.2	0.003	1439.6±366.3	0.003	1360.8±428.9	0.01	1419.8±469.1	0.008
		Left	1200.0±287.0		1227.0±318.4		1494.0±439.6		1553.7±476.8	
	Expiration	Right	1364.5±358.3	0.003	1292.9±336.3	0.003	1300.6±408.8	0.016	1311.1±442.3	0.026
		Left	1153.2±280.3		1122.2±296.9		1422.8±423.2		1436.6±456.8	

In hunchbacked sitting during inspiration and expiration for both breathing patterns the left lower hemithorax yielded a significantly larger volume compared to the right lower hemithorax (p=0.003 and p=0.003, respectively) (Table 3).

Table 3: Mean (SD) thoracic volume as a result of change in thoracic configuration in two sitting positions during quiet and volitional breathing.

N=11

			Change in the thoracic volume (ml)					
			Quiet breathing			Volitional deep breathing		
			Upright sitting	Hunched-back sitting	p-value	Upright sitting	Hunched-back sitting	p-value
Upper thorax	Inspiration	Right	768.0±162.4	966.7±337.6		791.6±100.5	898.2±156.4	
		Left	1049.0±175.0	1046.4±168.5		1118.4±145.5	1093.2±175.5	
	Expiration	Right	750.5±155.7	940.0±328.1		733.9±97.0	842.7±139.7	
		Left	1022.8±164.9	1015.3±168.5		1020.9±139.1	1029.9±161.1	
Lower thorax	Inspiration	Right	1420.1±365.2	1360.8±428.9		1439.6±366.3	1419.8±469.1	
		Left	1200.0±287.0	1494.0±439.6	0.003	1227.0±318.4	1553.7±476.8	0.003
	Expiration	Right	1364.5±358.3	1300.6±408.8		1292.9±336.3	1311.1±442.3	
		Left	1153.2±280.3	1422.8±423.2	0.003	1122.2±296.9	1436.6±456.8	0.003

DISCUSSION

Kakizaki in 2016 [12] states that, in an upright sitting, the left upper thoracic configuration is larger than the right. This is, however, reversed for the lower thoracic configurations even during deep volitional breathing. These findings were in concordance with our results. It has been suggested from results of a study by Shōbo and Kakizaki in 2016 [6] that this occurs because the anterior half is encompassed within the space of the upper thorax and the posterior half within the space of the lower thorax. However, as demonstrated in this current study, in the hunchbacked sitting position the thoracic volume was larger in the left lower hemithorax, this being in disagreement with the finding for the upright sitting position in which the right lower hemithorax showed a larger volume. However, this can be explained as follows: in hunchbacked sitting the upper ribs of the thorax rotate anteriorly with the costovertebral joints fixated anteriorly leading to posterior rotation of the ribs, consequently, limiting rib elevation. This explains why there was no right-left difference in the volume of the upper thorax. The right upper ribs in upright sitting were found to remain in the anterior rotation with the left upper ribs in the posterior rotation, but, in a hunchbacked sitting, there was no apparent right-left asymmetry in thoracic configuration as demonstrated in Kakizaki's statement 2016 [12]. Kakizaki also states that trunk flexion associated with posterior shifting of the center of pressure leads to the disappearance of right-left asymmetry in the upper thorax [12]. As for the lower thorax in the current study, hunchbacked sitting caused trunk flexion with the posterior shifting of the center of pressure, hence the center of gravity. This consequently led to a leftward rotation of the thorax with thoracic configuration regaining right-left symmetry, which was in agreement with Kakizaki's statement 2016 [12]. Consequently, due to overworking of the erector spinae, the asymmetrical configuration of the lower hemithoraces had possibly regained symmetry, leading to expansion of the left lower hemithorax.

Concerning changes in thoracic configuration during hunchbacked sitting, the center of pressure shifted posteriorly, resulting in relaxation of the erector spinae. This may have caused anterior rotation of the ribs and resulted in a decrease in the right-left asymmetry of the upper thorax. Furthermore, the left lower hemithoraces in hunchbacked sitting demonstrated a larger volume, but this asymmetry in thoracic configuration was smaller than that for quiet expiration in the upright position. Thus, a thoracic configuration may have changed. As a result of thoracic kyphosis, the right-left asymmetry in the upper thorax has been found to disappear [12]. Although hunchbacked sitting appears to stabilize the sitting posture with this regaining of alignment of the thoracic vertebrae, the right-left asymmetry of the thorax is reduced with decreased mobility of the upper thorax, suggesting a reduction of tension in the ventilatory muscles and a decrease in the tidal volume. This may lead to a reduction in thoracic mobility and a shift in the center of gravity, consequently affecting posture. This asymmetry in thoracic configuration could produce a mechanical disadvantage in the ventilatory muscles, but this was not the object of this study. Therefore, it would be of interest in the future to further investigate and verify this factor.

CONCLUSION

The results of this study suggest that, in the hunchbacked sitting position, thoracic asymmetry decreased and normal alignment of the thoracic vertebrae is re-established, stabilizing the sitting position. However, breathing was suppressed with a decrease in tidal volume. This hunchbacked posture is becoming more commonly observed because of everyday use of electronic devices such as computers and cell phones. Therefore, the physiotherapist could focus on upper thoracic mobility and correction of posture in everyday activities, especially in a sitting.

Limitations of this study were that activity of the erector spinae was not examined in this study. However, future studies are required to investigate the role of this muscle about respiratory function in various postures, together with external abdominal oblique, serratus anterior and latissimus dorsi muscles. Also, our study population was rather small.

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