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Biomechanical influences on head posture and the respiratory movements of the chest

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Purpose. The head represents 6% of total body weight, therefore it can significantly affect the biomechanics of human posture control, movements and activities. When set out of vertical body axis, head position interferes with the work of the other links in the kinematic chain. The aim of our study was to evaluate the effect of head posture on the breathing activities of the chest. Material and methods: The research was conducted on a group of 65 patients (51 years ± 9.8 years), including 48 women and 17 men. Head posture and chest movements were assessed using a photogrammetric method. Results: The results confirmed the existence of a negative correlation between head position in the sagittal plane and movements of lower ribs. Forward head posture resulted in lower amplitude of costal arch motion: for the transverse plane Spearman's $R = -0.296$, for the frontal plane; –0.273, –0.289. Tilting the head in the frontal plane also influenced the change in the biomechanics of breathing and contributed to a reduction of respiratory movements of the lower ribs Spearman's $R = -0.260$. Conclusions: Changing the position of the head causes disturbances in the three-dimensional shape of the chest and its respiratory movements.

Key words: *chest, head, posture*

1. Introduction

Breathing efficiency is the basis for functional performance of the human body. Proper functioning of the pulmonary system is conditioned by internal factors that directly affect the lungs or bronchial tubes, as well as external factors that determine the respiratory movements of the chest. Many scientific reports confirm that a significant condition for the optimal functioning of the respiratory system is the correct body posture. Defects of the rib cage, age, scoliosis [8], [16], [11], body posture and even temporary and mild postural disturbances may alter the ability of respiratory muscles to participate in respiration [23]. Excessive forward body posture increases the thoracic kyphosis and cervical lordosis thereby impairing the main breathing muscle – the diaphragm activity. Under physiological conditions, the diaphragm lowers during inspiration and rises with exhalation. A slumped posture disturbs the proper functioning of this muscle which results in increased activity of the upper respiratory tract [6]. As the head represents 6% of body weight it can significantly affect the biomechanics of human movement. When set out of vertical body axis, head position interferes with the work of the other links in the kinematic chain [19]. Such changes in joint orientation and muscle activity/

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efficiency would be hypothesised to influence respiratory movements.The need to assess the impact of head posture on the respiratory movements of the chest is clearly justified.

The study aimed to examine the relationship between the posture of the head, and the respiratory movements of the chest.

2. Material and methods

The research was conducted on a group of 65 patients (51 years ± 9.8 yrs), including 48 women and 17 men. The subjects were assessed as healthy, meaning they did not have posture defects which could affect the test results and none of them was treated for respiratory diseases. Participants were recruited from the general population.

In order to achieve the aim of this work, a photogrammetric study in the system Photogrametrical Body Explorer (PBE) was applied. PBE is a system positioning selected points of the entire human body, which allows us to determine spatial coordinates of the selected body points, thus enabling the analysis of motion in time [15]. The measurement is entirely remote. Reflective markers were taped on the points that describe the position of the head in three dimensions and positions of the chest (Table 1, Table 2) and their 3D positions were captured with an opto-electronic system. Sections created by connection of the indicated points, including the *Y*, *X*, *Z* axis, created angles used for further analysis (Fig. 1). The *Y* axis was represented by the vertical alignment line running across the spinous process of a vertebra of the seventh cervical vertebrae [15], [25]. In the PBE system, points determined by the photogrammetric measurement represent the transfer of skeleton elements to the body surface and they are signalled by the polystyrene balls of 4–5 mm diameter. The precision of determining the spatial coordinates of the signalled body points is high and amounts to ±2–4 mm [25]. In order to limit the measurement errors, the balls were fixed by one person. The additional factor favourable for these studies was the fact that they were performed in a static position, thus, the risk of relocation of the balls was minimised. Moreover, for the assessment of head alignment in the frontal plane, pupils were used, and one of the points for the assessment of head alignment in the sagittal plane was the middle of the upper lip – these points did not require our intervention.

Table 1. The anatomical points used in the assessment of head posture

Head *YZ*	W – middle of the upper lip, G – occipital tuberosity, angle between the center part of the upper lip and occipital tuberosity), the position of the head in the sagittal plane.
Head *XY*	EL – left eye, EP – right eye (angle between the left and right eye), the position of the head in the frontal plane.
Head *XZ*	EL – left eye, EP – right eye, BP – right acromion process, BL - left acromion process (the ratio of the position of the head at the eye line to the position of the shoulder), the position of the head in the transverse plane).

The task of the subjects was to keep a casual, habitual standing position with their weight evenly on both feet and looking straight ahead.

Measurements were made at three positions: (1) relaxed position, (2) position with the maximum inhale, and (3) position with the maximum exhale.

Table 2. The anatomical points used in chest mobility assessment

The sternum *YZ*	The forward movement of the breastbone (the spinous process of the 7th cervical vertebra and incisura jugularis).
The spine *YZ* The spine *XY*	The synkinesis of the spine in the sagittal and frontal plane (the spinous process of the 7th cervical vertebra and the point marked on the sacrum)
The left costal *XY* The right costal *XY* The left costal *YZ* The right costal *YZ*	The movement of the left costal margin in the frontal plane The movement of the right costal margin in the frontal plane The movement of the left costal margin in the sagittal plane The movement of the right costal margin in the sagittal plane (the xiphoid process and the point marked on the costal margin of the 10th left rib).
The costal *XZ*	The movement of costal margins in the transverse plane
The right sholuder *XY* The left shoulder *XY*	The synkinesis of the right shoulder in the frontal plane The synkinesis of the left shoulder in the frontal plane (the acromial end of the clavicle and the 7th cervical vertebra).
The shoulders *XZ*	The movement of shoulders in the transverse plane.

r – relaxed position; in – inhale, ex – exhale.

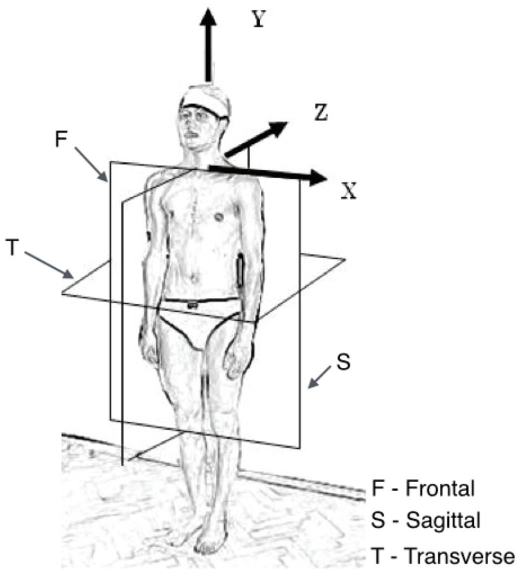

Fig. 1. The planes and axes taken into account in the evaluation of head posture and chest mobility

To evaluate the head posture, the following standards were applied: sagittal plane: 60 +/–1°, frontal plane: 90 +/–1° (values over 90° indicated head bend to the right, while values below 90° – to the left), the, the transverse plane 360 +/–1° (when the values exceeded 360°, they indicated head rotation to the right, whereas values below 360° – to the left) [15].

To eliminate the effect of fatigue tests were carried out between 9.00 am to 10.00 am.

The research report was approved by the Bioethics Committee (No. 36/KBL/OIL/2011). Tests were carried out with the written consent of each study participant.

The study was conducted at the Center for Medical Rehabilitation "Health" in Kraków.

Methods of statistical analysis

To compare the results obtained Spearman method was used taking into account the correlation coefficient *R* (rho). The coefficient determines the strength of the relationship between variables, the closer it is to 1 or –1, the greater the strength of correlation. In addition, the coefficients obtained were compared with the coefficient level of significance $p = 0.05$. This means that if the p value was less than 0.05 a given correlation can be considered statistically significant.

3. Results

The obtained results of the studies, describing the head alignment in the frontal and transverse plane, showed distribution compliant with the standard distribution. For that reason, they were subject to further statistical analysis, by means of: Student's *t*-test for a single sample, in which the results obtained were compared to the generally applicable standard (frontal plane: 90° ± 1, transverse plane: 360° ± 1), Student's *t*-test for two independent variables, where, due to the compliance of the results obtained with the standard distribution, variances of the averages were compared, describing the head bend and twist to the right and to the left. Due to the fact that the results obtained indicated no differences between the right and the left-hand side ($p > \alpha$, where $\alpha = 0.05$), no division into the right and left-hand side was taken into account in further analysis.

Descriptive statistics for the measurements of head posture are provided in table 3.

Table 3. Descriptive Statistics of the Head Measurements

	N	Standards	Position	Mean	SD	Min	Max
Head *YZ*	65	60+/–1°	relaxed	71.44	6.5	46.72	84.22
			max inhale	73.87	4.98	60.64	87.08
			max exhale	69.94	6.77	47.38	85.41
Head *XY*	65	90+/–1°	relaxed	91.02	2.48	83.26	96.61
			max inhale	90.95	2.66	81.19	97.9
			max exhale	90.99	2.57	84.43	97.73
Head *XZ*	65	360+/–1°	relaxed	359.17	7.09	332.64	381.87
			max inhale	358.85	6.16	347.24	385.36
			max exhale	358.43	4.91	342.34	368.08

3.1. Does a change of head position in the sagittal plane affect the mechanics of the chest?

The results showed that while the position of the head in the sagittal plane was not determined by the settings of the chest, in the relaxed position significantly, the relationship becomes important during inspiration. This means that the forward head posture causes limited movement of lower ribs both in the sagittal, frontal and transverse planes. This dependence is noticeable mainly during inspiration.

Table 4. Spearman's *R* values between the position of the head in the sagittal plane, and the setting of the chest in relaxed position; with maximum inhale, with maximum exhale

	Head *YZ* r	Head *YZ* in	Head *YZ* ex
The sternum *YZ*	0.223	0.243	**0.475**
The left shoulder *XY*	0.210	0.196	**0.487**
The right shoulder *XY*	0.150	0.151	**0.304**
The shoulders *XZ*	0.004	0.241	0.064
The left costal *YZ*	–0.198	–0.155	–0.102
The right costal *YZ*	–0.165	–0.241	–0.201
The left costal *XY*	–0.154	**–0.273**	–0.158
The right costal *XY*	–0.169	**–0.289**	–0.148
The costal *XZ*	0.204	**–0.296**	0.165
The spine *XY*	–0.097	0.093	0.101
The spine *YZ*	–0.051	–0.09	0.048

r – relaxed position; in – inhale, ex – exhale.

3.2. Is there a difference between the head position in the frontal plane, and the movements of the chest?

The obtained results show a relationship between the position of the head in the frontal plane, and movements of the chest (Table 5). The increase in the value of the angle of side head tilt caused an increase in the value of the angle describing the movement of the upper chest during inspiration. Also noticeable is a negative correlation between head position and movements of the lower ribs in the transverse plane.

Table 5. Spearman's *R* values between head position in the frontal plane, and chest setting in relaxed position; with maximum inhale, with maximum exhale

	Head *XY* r	Head *XY* in	Head *XY* ex
The sternum *YZ*	0.029	**0.247**	0.129
The left shoulder *XY*	0.189	0.226	0.110
The right shoulder *XY*	–0.010	0.031	–0.002
The shoulders *XZ*	–0.014	–0.026	–0.088
The left costal *YZ*	**0.245**	0.201	**0.261**
The right costal *YZ*	**0.255**	**0.272**	**0.262**
The left costal *XY*	**0.273**	**0.251**	0.227
The right costal *XY*	0.223	**0.281**	0.226
The costal *XZ*	–0.191	**–0.260**	–0.172
The spine *XY*	–0.121	–0.075	–0.183
The spine *YZ*	0.086	0.171	0.128

r – relaxed position; in – inhale, ex – exhale

This means that with the side tilt of the head, subjects decreased their respiratory movements of the lower chest and increased the amplitude of respiratory movements of the upper tract.

3.3. Is there a difference between head position in the transverse plane, and chest movements?

The results show a relationship between head position in the transverse plane and chest respiratory movements. The increase in the angle of the head which characterizes head position in rotation induced a decrease in the angle describing the movement of the lower ribs in both the relaxed position and at maximal expiration.

Table 6. Spearman's *R* values between head position in the transverse plane, and chest setting in relaxed position; with maximum inhale, with maximum exhale

	Head *XZ* r	Head *XZ* in	Head *XZ* ex
The sternum *YZ*	–0.159	0.019	0.098
The left shoulder *XY*	–0.011	0.078	0.018
The right shoulder *XY*	–0.010	0.031	–0.002
The shoulders *XZ*	0.037	0.020	–0.070
The left costal *YZ*	0.025	–0.014	0.028
The right costal *YZ*	–0.054	–0.161	0.031
The left costal *XY*	0.202	0.167	0.190
The right costal *XY*	0.203	0.171	0.242
The costal *XZ*	–0.232	–0.183	**–0.257**
The spine *XY*	0.020	–0.005	–0.101
The spine *YZ*	0.182	0.179	0.065

r – relaxed position; in – inhale, ex – exhale.

The statistical analysis also covered the distribution of lower angles of the ribs – the right and the left rib, in order to indicate the differences occurring between them. Due to the lack of compliance between the distribution of the angles describing the position of lower ribs (right and left), the Mann–Whitney *U* test was used to assess the differences between the distributions. As a result of the test, the value of $p = 0.83$ was obtained, which, in accordance with the testing rules ($p > \alpha$, where $\alpha = 0.05$) confirmed the lack of differences between the results obtained.

4. Discussion

Under physiological conditions, the head should be located on the extension of the axis line of the body. Deviations from ideal head posture are often associated with different disorders in the musculoskeletal system. Kang suggests that forward head postures may contribute to some disturbance of balance [2], [9]. Several reports confirmed the existence of a relationship between head posture and cervical spine pain [22], [24]. Fernandez-de-las-Penas et al. showed a positive correlation between forward head posture and neck mobility. Increased angle of the head tilt in the sagittal plane was associated with decreased mobility of the cervical spine [3]. Furthermore, the results obtained by Quek et al. [18] show that forward head posture mediates the relationship between thoracic kyphosis and cervical range-of-motion, specifically general cervical rotation and flexion. Griegel-Morris et al. [5] argue that forward head posture can affect not only the biomechanics of the cervical spine, but also the thoracic spine and scapula position causing musculoskeletal imbalances.

Although it is logical to conclude that changes of head position should affect chest wall shape and motion distribution between compartments of the chest wall, the independent effect of position of the head has not previously been evaluated. To our knowledge, this is the first study to report the impact of head posture on the respiratory movements of the chest.

Our studies show that even subtle changes in the position of the head cause disturbances in the three-dimensional chest shape and its respiratory movements. Lima et al. [13] suggest that the forward head posture will lead to disorganization of the muscle blocks (anterior, posterior, and transverse muscles), impairing diaphragm muscle mobility. In our observations forward head posture resulted in a reduction of respiratory movements of the lower ribs in both the sagittal, frontal and transverse plane. The greatest influence on the changes in the respiration activity was a change of head position in the sagittal plane. Head tilt in the frontal plane also resulted in changes in the biomechanics of breathing. When breathing in, a significant increase in mobility of the upper chest was observed with a simultaneous reduction of amplitude of the lower respiratory movements of the chest in the transverse plane. The same situation has happened when changing the position of the head in the transverse plane. Changing position of the head most of all decreased respiratory movements of the lower chest and increased the amplitude of respiratory movements of the upper tract.

Huggare argues that changes of head position lead to accessory muscle recruitment, with increased sternocleidomastoid muscle activity, causing rib cage elevation, reducing thoracoabdominal mobility, and compromising the ventilatory efficacy of the diaphragm. This mechanical disadvantage intensifies the inspiratory effort and increases the work of breathing [7].

It was noticeable that only a small number of people met the criteria for proper head posture. Within 65 study participants being examined, only 5 patients had normal head position in the sagittal plane, 7 patients in the transverse plane and 20 in the frontal plane. Our results concerning the effect of head posture and its influence on breathing biomechanics indicate the need for further study of the subject. Due to the suggestion of Kim et al. [10] that head position is also influenced by vision, it is advisable to take into account eye assessments in future research. Moses and Skoog [16] state that as much as 50% of the population may be functional and asymptomatic with head postures that are abnormally deviated from the axis of gravity. Certainly, assessment of head posture is dependent on the sensitivity of the measurement methods. There are different methods to assess forward head posture. In clinical practice, subjective methods of head posture assessment seem to prevail (be dominant). It is believed that the majority of clinicians, especially physiotherapists make a simple examination of head posture based on their own visual determination of the alignment of the head and describe abnormal head posture with subjective descriptions [5]. Garrett et al. [4] used the Cervical Range of Motion Instrument (CROM) to measure the resting head posture.

But most investigators of cranial angulation take the angle formed by a line connecting C7 with the tragus of the ear, and the horizontal line [1], [9], [22]. They evaluate head posture using videography or photography with computer digitizing to quantify relationship between anatomical landmarks. Values for this angle relate to the position of the upper cervical spine, and increasing values are indicative of a more extended head. Salahzadeh [21] compared three angles for forward head posture: craniovertebral angle, head title angle and head position angle to measure FHP objectively. Their results showed that the photogrammetric method had excellent inter and intra rater reliability to assess the head and cervical posture. In our research, we decided to use photogrammetric methods of assessment of the head posture, as it allows the simultaneous evaluation of the position of the head and chest movement. While most of the work concerns the evaluation of the position of the head in the sagittal plane, by using PBE had the opportunity to evaluate three planes.

In the literature dealing with the phenomenon of asymmetry, a lot of attention has been paid to the performance of the motor system. Based on the analysis conducted, the lack of statistically significant asymmetry in the chest movements was found. It is compliant with the observations by Leong [12] and Ragnostóttir [20].

Study limitations

This study investigated natural positions, however in the future we would like to take into account the results of relation between the respiratory movements of the chest and maximal position of head in three planes.

5. Conclusions

These findings confirm and expand upon previous observations regarding the importance of head posture. Our findings show that, changing the position of the head causes disturbances in the three-dimensional shape of the chest and its respiratory movements. These observed data should be useful for the clinical assessment of posture and breathing movement during physical examinations.

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