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Changes in human trunk circumferences during different breathing styles in different positions

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Abstract: Patient positioning can have multiple effects on respiratory mechanics and gas exchange. A motion capture system was used to calculate changes in thoracic and abdominal circumferences during three different body positions (sitting, standing and lying). The circumferential changes in three different breathing styles were compared in these positions. Abdominal breathing with higher abdominal circumferential changes predominates in supine position and in shallow breathing.

I. Introduction

Changing positions frequently is a typical part of daily life for most people, even while they sleep at night. The study of body position's effects has always piqued the curiosity of respiratory physiologists and medical professionals alike. For instance, Milic-Emili et al. documented the distribution of ventilation in humans in various situations in the early 1960s [1]. The impact of different positions under general anesthesia on respiratory mechanics, lung volume, and gas exchange in diverse surgical settings, such as thoracic, abdominal, and spine surgery, has been extensively researched by anesthesiologists for many years [2]. According to the patient demographics, a change in body position can have a variety of effects [3]. Tucker et al., observed a decrease in the breathing volume due the progressive elevation of the diaphragm in abdominal region during laying position [4]. The effects of different patient positioning are manifold – e. g. prone positioning can be beneficial, for a short time as it requires less ventilator support and can provide optimal oxygenation by improving gas exchange.

Many studies investigated the distribution into abdominal and thoracic breathing. In this study, this distribution was further verified by examining circumferential changes at different heights on the upper body during three different breathing styles (shallow, normal, and deep), during each of the three body positions (sitting, standing, and lying). This provided a deeper insight into the effects of body position on breathing, which may help to understand more precisely the multiple effects of positioning on respiratory mechanics and gas exchange.

II. Material and methods

A camera-based motion tracking system MoCap (Bonita, VICON, Denver, CO) was used to capture respiration-induced changes in circumferences. Therefore, nine infrared motion tracking cameras (VICON Bonita B10, Firmware Version 404) were employed to record the movements of 102 MoCap markers, fixed to a body-fit T-shirt. A schematic sketch of the MoCap system and the used shirt with MoCap markers is shown in figure 1 (a) and (b). The markers were arranged and categorized into seven distinct levels, which were uniformly distributed over the upper body. The first level was in height of the collarbone and level 7 was slightly below the belly button.

Two healthy volunteers, subject 1 (female, 1.4 m, 50 kg, 23 years) and subject 2 (male, 1.6 m, 67 kg, 35 years), took part in this study. They performed different breathing styles (shallow, normal, and deep) for about one minute in each body position (sitting, standing, and lying). The distribution into chest and abdominal breathing was made intuitively by the subjects themselves.

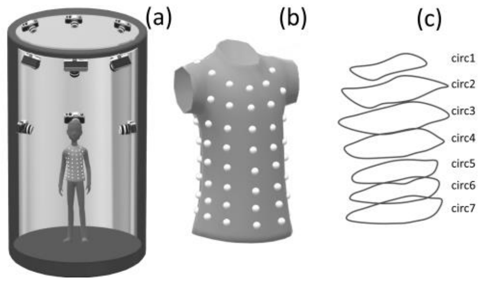

Figure 1: Sketch of the MoCap System (a) and the used compression shirt with MoCap markers (b). In (c) the circumferences are illustrated (based on the data of subject 1).

The extracted data were processed using (MATLAB 2021b). By using spline functions (according to Laufer et al. [5]), all markers in each level were connected to each other to form closed shapes that represent the circumference (figure1 (c)) of the addressed level. Finally, the changes in circumferences *Δcirc* of all seven levels were calculated, as the changes in length of the according spline curve, and analyzed during different breathing styles in sitting, standing and laying (supine position).

III. Results and discussion

The arrangement of the MoCap markers fixed to the shirt was done to form circumferences in 7 different levels (Figure 1(c)) along the human trunk. During lying in supine, the markers at the back were hidden and therefore, closed spline curves couldn’t be obtained. However, it can be assumed that the changes in circumference correspond to the changes in the visible markers, since the subjects were lying on a mattress and friction effects kept the shirt on the mattress in position.

As shown in figure 2 and figure 3, both subjects were instructed to breathe shallow, normal and to their maximum capacity in sitting, standing and laying positions.

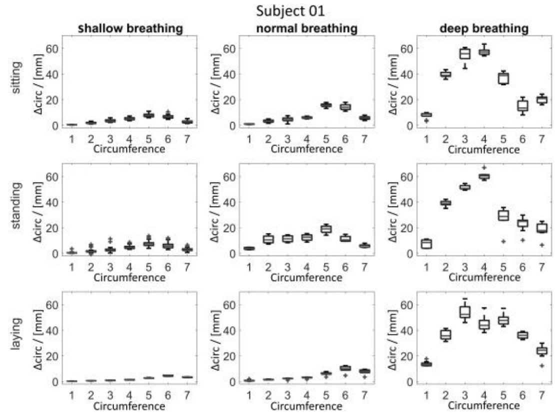

Figure 2: Box plots (subjects 1) - the change in circumference of all levels for corresponding breathing styles and body position.

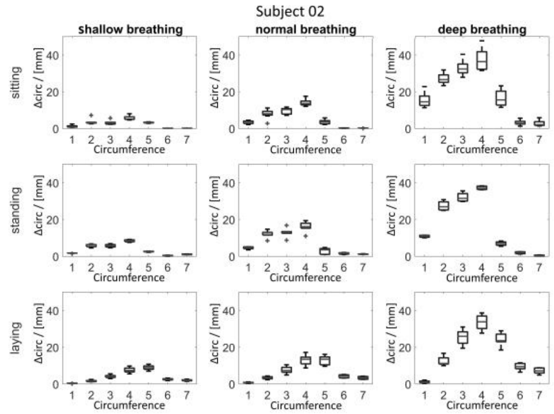

Figure 3: Box plots (subjects 2) - the change in circumference of all levels for corresponding breathing styles and body position.

As expected, it can be observed that the overall change in circumference during shallow breathing and the variance of circumferential changes are lower, compared to the other breathing styles. In accordance to Tucker et al. [4], the movement of the thoracic and abdominal cavities appears to be less in subjects in the lying / supine position. This could be due to the lower activity of the body in the supine position and the associated relaxing position. It is also evident that in the lying position the subjects tended to breathe more abdominally (corresponding to levels 4 through 7) and the chest moved less than in the other body positions, which might be caused by a lower breathing effort. Lifting the thoracic ribcage up against gravity during breathing might be more demanding as lifting up the abdomen. It also appears that in lying position the upper part of the thorax (level 2) expanded less than in sitting or standing position, which could be related to the subject’s individual breathing styles. A further study with more subjects should confirm these assumptions.

The largest changes in volume and the largest deviations are observed in both subjects during deep breathing. During maximum breaths, the subjects used all breathing capacity and the deviation in chest and abdominal breathing was not affected so much by the posture. The maximum thoracic circumferential changes show that the capacity of the thorax was utilized to the fullest during maximum breathing. As a result, circumferential changes especially in the range from *circ2* to *circ4* are up to 6 times higher than during normal breathing. The higher variance in maximum breathing could be explained by the motivation of the subjects. Although the subjects were instructed to breathe maximally, they were not specifically motivated to go to the limit during the maneuver, because achieving the maximum filling of the lungs was not essential for this study. The subjects may have felt that they were breathing to the maximum, but they might have had some reserve.

Further measurements with more subjects of different ages, genders, and body shapes may allow deeper insight into the effects of postures on respiration and confirm the results of this study. Additional studies with patients, suffering from various lung diseases could be performed to get a deeper insight in the nature of circumferential changes in different body positions and the impact of the respective disease on circumferences and respiration, which in turn could potentially support more sophisticated diagnoses.

IV. Conclusions

This study proves that the breathing volumes and therefore the trunk circumferences of a person can change based on his/her body position or posture. This work offers up several avenues for future research into the influence of various other parameters on breathing patterns and how those parameters affect the human body.

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