Assessment of breathing patterns in the context of physical performance in young people

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Abstract

Introduction: Breathing requires the involvement of accessory muscles, which can result in their overactivity and lead to the occurrence of neck pain, abnormal posture, or impaired mobility and scapular alignment. Abnormal breathing mechanics lead to significant changes of the body posture and functioning by affecting biochemical parameters.

Aim: The aim of this study was to examine whether the mechanics of breathing can affect the level of physical performance of healthy individuals under the age of 30.

Materials and methods: 40 adults under the age of 30 with no respiratory diseases (20 women, 20 men) were recruited for the study. Chest and abdominal circumference and respiratory rate were measured. Furthermore, the Body Oxygen Level Test (BOLT) and Cardiac stress test were conducted, and the respiratory pattern was evaluated.

Results: At rest, an upper-costal breathing pattern prevailed among women, while during activity, most both men and women were breathing in a thoracic pattern. Breathing frequency was, on average higher, and BOLT was shorter in women than in men. Physical performance varied by gender. The diaphragmatic breathing group had a lower average number of breaths taken per minute and a longer BOLT than the upper-costal breathing group. Individuals with shorter BOLT times breathed significantly more often. The average physical performance of diaphragmatic and upper-costal breathing subjects was similar. No significant correlations between age and any of the examined parameters were found.

Conclusions: The breathing pattern was not directly related to physical performance in adults under the age of 30. The breathing pattern at rest was gender-related. Individuals breathing in the diaphragmatic pattern breathed less frequently, and their control pauses were longer than those breathing with the upper-costal pattern.

Key words

efficiency, cardiac stress test, diaphragm, respiration, breathing pattern, BOLT, control pause.

Introduction

Breathing is an activity performed without pause – it consists of inhalation, an active process, and exhalation, a passive process (at rest) [1]. There are two ways of breathing – the upper-costal pattern or the diaphragmatic (lower-costal) pattern. The former refers to a breathing pattern in which there is initially intense movement of the upper part of the chest, followed by movement of the lower part and the abdominal area. It requires the involvement of accessory muscles, which can result in their overactivity and lead to the occurrence of neck pain, abnormal posture, or impaired mobility and scapular alignment. It also promotes the deterioration of diaphragmatic activity, which can reduce lumbar stability but can also disrupt movement patterns and motor control [2-4].

Significant changes in the body associated with abnormal breathing mechanics also relate to biochemical changes - an increase in blood pH due to a decrease in CO_2 level in the blood, which can lead to respiratory alkalosis, which negatively affects body function [4]. Furthermore, breathing through the upper-costal pattern is shallower; thus, more frequent breaths may be necessary. The second option, which is diaphragmatic breathing, is physiological and does not require the involvement of accessory muscles. This way of breathing not only allows for proper diaphragm activity and correct posture [4] but can also reduce mental stress [5, 6] and the occurrence of migraines and functional constipation [5]. Diaphragmatic breathing can also positively influence heart rhythm, lower blood pressure, as well as increase respiratory muscle endurance, and reduce the rate of breaths taken per minute [4-6].

The poor habits of breathing present at rest also carry over to the area of physical activity. During the beginning of the activity, the minute ventilation of the lungs increases rapidly, and therefore the number of breaths and the tidal volume increases. Starting from a higher breathing frequency at rest, one may encounter difficulties in continuing physical activity or require its discontinuation. Although, physiologically, breathing through the mouth occurs with an increase in minute ventilation of the lungs above 40l/min, assuming that the resting tidal volume averages approximately 0.5l of air [1], the optimal number of breaths at rest is 10-14 per minute [4] (minute ventilation = about 5-6l/min [1]), and the average population reference values are 12-20 breaths/min in adults [7], it seems impossible to reach ventilation this high that would not allow breathing through the nose (in healthy individuals).

Aims

The purpose of the study was to evaluate the relationship between breathing patterns and physical performance in adults under the age of 30. It was examined whether breathing pattern, breathing frequency, and Body Oxygen Level Test (BOLT) were related to gender and correlated with the subjects' age. Furthermore, it was also evaluated whether breathing patterns affect respiratory parameters (BOLT, breathing frequency) and physical performance in healthy young adults.

Materials and methods

Research material

A group of 40 adults that gave written consent to participate in the study was informed of the purpose of this research. These individuals were under the age of 30 and declared that they had no respiratory diseases. An equal number of women and men participated in the study (20). The mean age in the study group was: 22.4 years (SD ± 2.80), the mean height was: 1.75 m (SD ± 0.11), while the mean body weight was: 76.66 kg (SD ± 18.82) (**Table 1**).

Table 1. Statistical analysis of the examined parameters by gender.

Gender	Age [years]	Weight [m]	Height [kg]	BMI [kg/m^2]
Women	22.35 (SD ± 2.23)	1.66 (SD ± 006)	67.73 (SD ± 21.26)	24.12 (SD ± 6.49)
Men	22.45 (SD ± 3.33)	1.84 (SD ± 0.07)	85.80 (SD ± 9.02)	25.28 (SD ± 1.92)

Research Tools

A questionnaire containing questions on: breathing patterns (breathing pattern at rest and during exercise), practiced physical activity, problems encountered during these activities, and smoking habits, was administered. Measurements were also taken of the chest (under the arms) and abdominal (above the navel) circumferences – using a tailor's centimeter on maximum inhalation and exhalation in order to check the dependence of their dimension on breathing pattern. In addition, the number of breaths taken by subjects per minute and BOLT times (taking an exhalation and then holding the breath until the first feeling of needing to take a breath, at which point there should be an unstrained, natural nasal inhalation; the result is expressed in seconds; it indicates the degree of oxygen saturation in the body) was measured, in order to check for differences in these parameters by gender, breathing pattern, and physical activity.

The Margaria-Kalamen power test (MKPT), developed in 1965, was used to measure the subjects' efficiency. It is based on performing two approximately 6-minute exercise tests in the form of stepping onto a 40-centimeter step at a steady rhythm (15 and 25 steps per minute). A 20-minute break between trials allowed the heart rate to normalize and return to resting values. During the test, the subject's heart rate was measured, and the reading was taken in the last 10 seconds of each minute. Values from the last 3 minutes enable the VO2 max to be determined.

Statistical analysis

The analysis was performed in Microsoft Excel (2010) using basic statistical functions to calculate mean values along with standard deviations and minimum and maximum values. These functions were used with data such as age, height, weight, and the studied parameters - BOLT, number of breaths per minute, resting heart rate, and VO2 max (oxygen threshold). In addition, Pearson's linear correlation test was used to examine a relationship between individual data sets and age, and an independent samples t-test was used to investigate the level of significance of differences between measured parameters. The accepted level of statistical significance of the parameters studied was $p < 0.05$.

Results

Respiratory parameters and gender

Daily, 80% of male respondents and 70% of female participants breathed through the nose. The relationship between breathing patterns and gender was statistically insignificant ($p=0.239$). At rest, the upper-costal breathing pattern prevailed among the female subjects (70%), while 55% of men used the diaphragmatic pattern and 45% the upper-costal breathing pattern. The relationship between gender and resting breathing pattern was almost statistically significant ($p=0.058$). During moderate to high-intensity physical activity, the majority of women (85%) and men (70%) were breathing in the upper-costal pattern - the relationship between breathing pattern during exercise and gender was not statistically significant (p=0.134).

The breathing frequency was, on average higher in women (15.45 SD ± 3.46) than in men (14.00 SD ± 2.70), but the correlation between the number of breaths taken and gender was not statistically significant (p=0.074). The maximum value was 23 in women and 18 in men, and the minimum was the same for both genders - 10 breaths per minute.

The oxygen level test took, on average less time in women (18.75 s SD ± 6.12) than in men (18.95 s SD ± 6.26), and the difference was not statistically significant (p=0.460). The minimum and maximum values were 10 seconds and 32 seconds for women and 10 seconds and 35 seconds for men, respectively.

Physical efficiency varies greatly between the genders - more than half of the women showed very good (40%) or highest (15%) physical efficiency, the remaining 45% were women with good efficiency (20%) and women whose exercise test was stopped (25%). Among men, on the other hand – 50% of the subjects showed average physical efficiency, 20% very good physical efficiency, and the remaining 30% were those with low efficiency (15%) and men whose exercise test was stopped (15%). The level of efficiency in the study group was presented in the chart below.

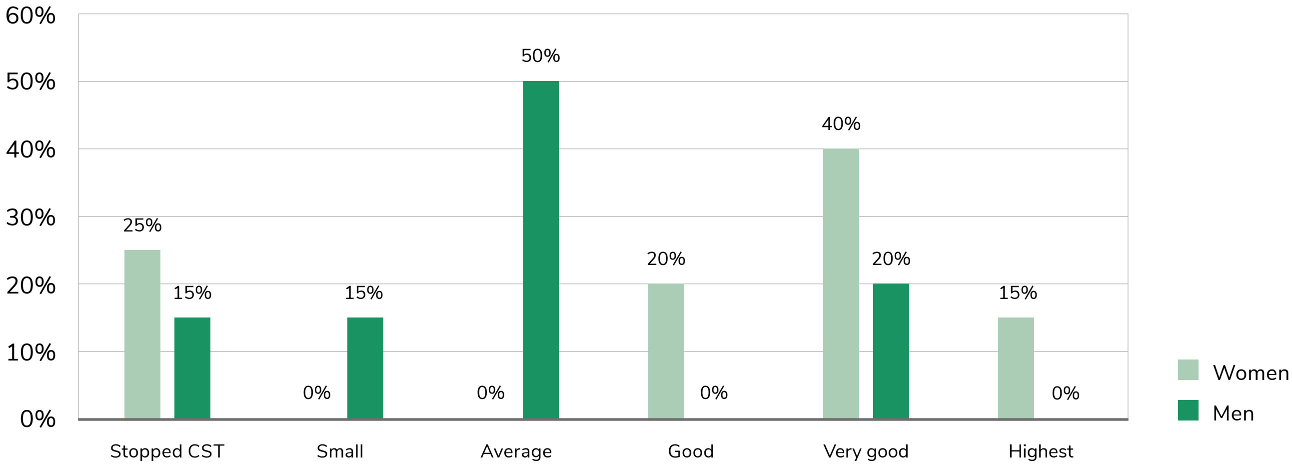

Figure 1. Performance level by gender (CST = cardiac stress test).

Respiratory parameters and breathing pattern, efficiency

Subjects breathing in the diaphragmatic pattern had a lower average number of breaths taken per minute (13.71 SD ± 2.97) than those breathing in the upper-costal pattern (15.48 SD ± 3.38) – a statistically significant correlation (p=0.038). The minimum and maximum number of breaths taken per minute by diaphragmatic breathing subjects were 10 and 19, respectively, and 10 and 23 breaths per minute for upper-costal breathing.

BOLT averaged 20.82 seconds (SD ± 6.23) for the diaphragmatic breathing group and 17.39 (SD ± 5.73) for the upper-costal breathing group - the difference was statistically significant (p=0.041) and was shown in the chart below. The minimum and maximum values were 13 seconds and 35 seconds, respectively, in the first group and 10 seconds and 29 seconds in the second group.

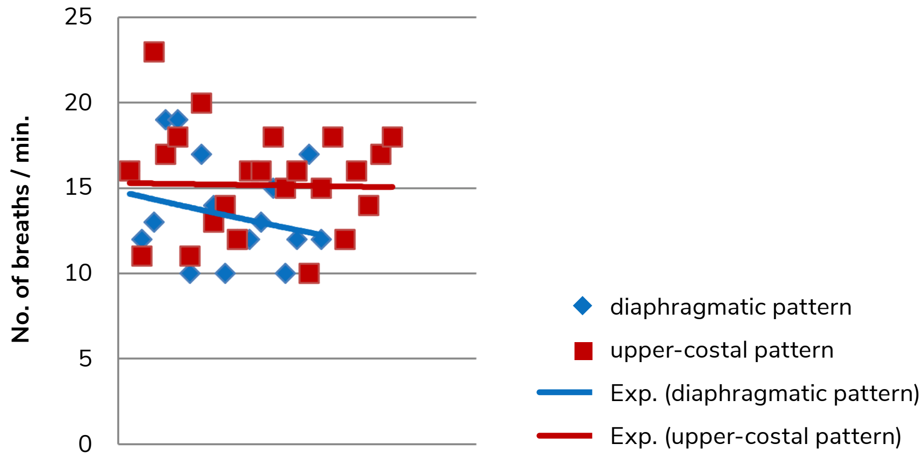

Figure 2. The correlation between the number of breaths taken per minute and the breathing pattern.

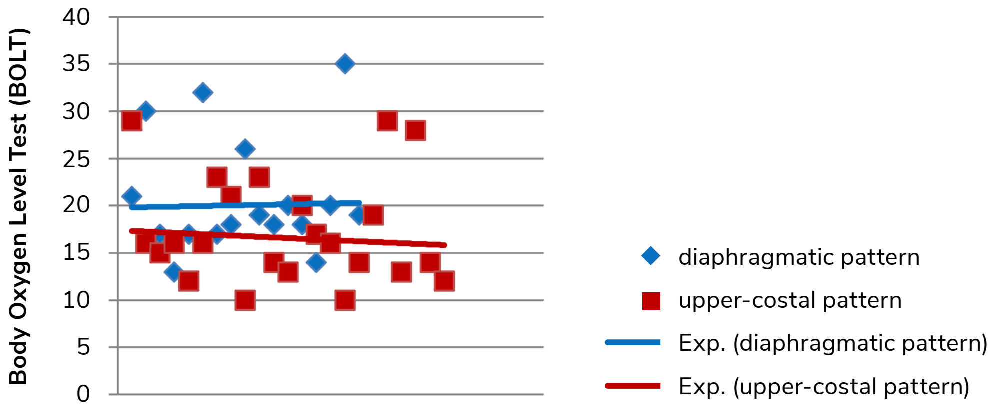

Figure 3. The correlation between BOLT and breathing pattern.

Individuals with shorter BOLT times were breathing significantly more often, and this value was statistically significant (p=0.000). The breathing frequency decreased with a longer duration of the control pause: subjects who held their breath ≤ 15 s breathed an average of 17.50 times per minute (SD ± 2.50), those with a score of 16-25 s breathed an average of 13.82 (SD ± 2.63) times per minute, and those with the most prolonged duration of the control pause (>25 s) had an average of 12.50 breaths per minute (SD ± 2.51). Furthermore, subjects with a BOLT score of ≤15 s were dominated by upper-costal breathing (83.33%) and mouth breathing (58.33%). For the group that held their breath for 16-25 seconds, breathing was done through both the diaphragmatic (54.55%) and upper-costal (45.45%) pathways and mainly through the nose (86.36%). Among those with the highest BOLT scores, the breathing pattern varied (50% each), and all were breathing through the nose.

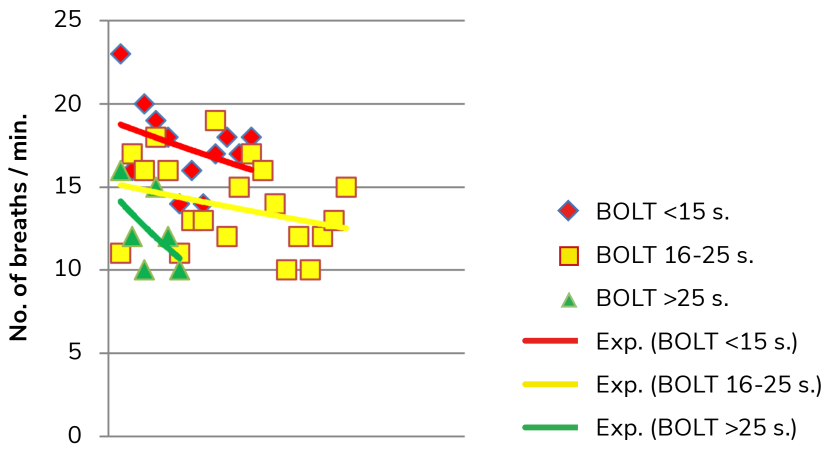

Figure 4. The correlation between BOLT score and the number of breaths taken per minute.

The average efficiency of diaphragmatic (41.04 SD ± 4.63) and upper-costal (40.34 SD ± 4.58) breathing subjects was similar and not statistically significant (p=0.103). The maximum VO2 max value was 51 ml/kg/min. for the diaphragmatic breathing individuals and 49.5 ml/kg/min. for the upper-costal breathing group. The minimum value, on the other hand, was 36.5 and 35.5 ml/kg/min, respectively.

Respiratory parameters and age

There are no significant correlations between age and any of the examined parameters - number of breaths (r=0.030), BOLT (r=-0.068), VO2 max (r=-0.160).

Discussion

Due to anatomical and functional structure - the breathing pattern and respiratory parameters differ between genders. Women are characterized by a smaller depth and cross-sectional area of the chest, an inclined position of the ribs, as well as smaller lungs and narrower nasal cavities [8], which may be associated with a higher breathing frequency, reduced tidal volume and vital lung capacity, and a higher incidence of upper-costal breathing. Achieved VO2 max values were also lower in women [1]. The results of the current study were consistent with existing findings - most of the examined women were breathing in the upper-costal pattern, and the thorax depth was significantly lower than in men. In contrast, resting breathing frequency by gender did not show statistical significance, similar to other findings [9, 10]. However, it has been investigated that this changes with physical activity, where differences may occur between breathing frequency - women breathe more frequently than men [10] and are more susceptible to the phenomenon of hyperventilation and mechanical ventilation limitations, which may be the result of the compulsion to overcome greater resistance in the airways during inhalation, due to their smaller size [11].

The results obtained in the oxygen level test were similar for men and women. However, no research was found that compared this relationship, and that could confirm the lack of gender dependence on BOLT, although it has been proven that in individuals with upper-costal breathing patterns and abnormal spirometry results, breath holding time may be shorter [12]. Furthermore, low BOLT scores are often associated with chronic hyperventilation or stress. The short duration of the control pause usually occurs in individuals who breathe irregularly and shallowly, in upper-costal breathing, often through the mouth, and the estimated number of breaths per minute is 15-30 [13], which is consistent with the results of the current study. On the other hand, individuals with a BOLT time closer to 30 seconds were breathing noticeably less frequently, more slowly, with pauses between breaths, through the nose, and reported no problems with physical activity, which is consistent with the assumptions made when interpreting the test results. The breathing frequency in this group should be 10-15 [13], which is similar to the results reported in this paper.

There is no doubt that the way of breathing plays an important role in terms of overall well-being, quality of life, and health. However, mouth breathing can negatively affect various spheres of human life. As outlined in other research, mouth breathing has an impact on sleep problems [14], the formation of postural defects [15], and the occurrence of oral dysfunctions [16,17]. Furthermore, mouth breathing may increase the risk of bronchial asthma [18], allergies and atopic dermatitis [19], upper respiratory infections [20], and sleep apnea [21]. Breathing through the mouth often co-occurs with upper-costal breathing, as it engages the upper part of the chest to a greater extent so that the amplitude of diaphragm movement is reduced [22]. An abnormal breathing pattern not only leads to increased breathing frequency but can also reduce the control pause time, limit lower chest movements during inhalation, cause lower back pain, lift the shoulders, and engage accessory respiratory muscles to work, and cause anxiety, stress, and fear. The introduction of correct breathing, using the diaphragmatic pattern, makes it possible to reduce the breathing frequency and reduce the intensity or eliminate the aforementioned ailments, due to the restoration of the correct work of the diaphragm [3, 6].

Conclusions

It can be concluded that at rest, the breathing pattern is related to gender – women are more likely than men to breathe in an upper-costal pattern, although this may change during physical activity. Breathing frequency and BOLT are not gender-specific; however, women are more prone to hyperventilation, which may be related to a higher frequency of upper-costal breathing or increased inspiratory resistance in women.

Based on the obtained results, it can also be concluded that in the studied parameters related to the respiratory system, there are significant differences that can affect the ability to perform physical activity and the objective and subjective feeling of fatigue. The average number of breaths taken per minute is significantly lower for diaphragmatic breathing subjects ($p=0.038$), while the duration of the control pause is significantly shorter for upper-costal breathing subjects ($p=0.041$). The relationship between the duration of BOLT and the number of breaths taken per minute is also statistically significant ($p=0.000$) – the longer the breath can be held for, the lower the breathing frequency/min, which is also supported by the literature.

It was also found that breathing pattern is not directly related to physical performance in adults under the age of 30 - the mean VO_2 max achieved is at similar levels for both upper-costal and diaphragmatic breathing patterns. Furthermore, no correlation between age and the investigated breathing parameters (breathing pattern, BOLT, breathing frequency) was found.

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