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# EFFECTS OF ACCELERATED BREATHING ON POSTURAL STABILITY

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ABSTRACT
**Purpose.** The aim of the paper was to determine the effect of respiration on body balance in quiet standing. **Basic procedures.** Postural performance during quiet standing was compared in 37 young healthy subjects in two trials on a force plate: first with natural breathing, and then with accelerated high-volume breathing at the rate of 1 Hz. Each trial included 20 s quiet standing with eyes open, and the center of pressure (COP) was recorded with the sampling rate of 20 Hz in both anterior-posterior (AP) and medial-lateral (ML) planes. Based on the recorded signals the COP dispersion measures and postural frequency were calculated. **Main findings.** The forced respiration contributed significantly to the increase in all COP stability measures in the AP plane: dispersion ($p < 0.01$), range ($p < 0.001$) and mean velocity and frequency ($p < 0.00001$). In the ML plane only mean velocity ($p < 0.001$) and frequency ($p < 0.01$) were affected. **Conclusions.** In view of the evidence provided by other authors that stress tests increase the amplitude- and frequency-based stability measures, our results indicate that the contribution of natural accelerated breathing after strenuous physical exercise will bias the results of stabilographic studies, rendering them worthless in understanding the role of neuromuscular fatigue in stability deterioration. Such studies must use data collected after the respiration returns to normal rate. However, if the study aims at overall assessment of postural stability post-fatigue, the postural testing may be performed immediately after the stress test.

**Key words:** postural sway, body balance, respiration, fatigue

## Introduction

One of the most common experimental paradigms used in body balance studies is assessment of the effects of physical exercise on selected parameters of postural stability [1, 2]. For individuals, especially elderly people, who are characterized by deficits of postural control, the insufficient resistance to fatigue of their system of equilibrium can be the cause of falls [3]. In the case of athletes resistance to fatigue can be decisive for their final training results [4]. The most common method of evaluation of postural stability is stabilography, which permits the recording of oscillations of the center of pressure (COP) on two planes [5].

In order to assess correctly changes of body balance due to physical fatigue it is necessary to know the effects of natural mechanical processes accompanying the impact of physical exercise on the stabilographic parameters. This concerns in particular the impact of accelerated breathing on the positioning of the center of mass (COM) of the whole body, causing rhythmic changes of the chest volume and generating extra force [6]. Apart from the studies by Hunter and Kearney [7] and Jeong [6], who showed an increase of the COP mean velocity with breathing frequency, the correlation between increased pulmonary ventilation and postural stability has been largely neglected. Only Hodges et al. [8] and Hamaoui et al. [9] studied these relationships in the context of postural compensation for respiration with simultaneous anticipatory movements of hip and knee joints. On the other hand, Caron et al. [10] compared COP measures in trials during natural breathing and apnoea.

The lack of professional literature on the effects of breathing rate, inconsistencies in reports on the impact of fatigue on postural stability [1, 2] and development of methodology of measurement of postural control in the last decade [5, 11, 12] point to the need of further research on the effects of accelerated high-volume breathing on the parameters of postural stability in subjects at rest. Considering different anatomical and physiological

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factors, it can be assumed that the measures of COP dispersion and frequency should increase in the anterior-posterior plane (AP) and remain unchanged in the medial-lateral plane (ML).

## Material and methods

The study sample included 18 male students and 19 female students ($n = 37$) of the Technical University of Opole, aged 22–23 years, with no health conditions affecting their body balance. The subjects' mean body weight was 66.4 ± 14.0 kg, and their mean body height 173.3 ± 7.7 cm. The subjects were to perform two trials during quiet standing on a force plate with their eyes open: first with natural breathing, second with accelerated high-volume breathing. The respiration in the second trial was forced with the use of a metronome. The entire breathing cycle (inhaling followed by immediate exhaling) was performed at the rate of 1 Hz. Both trials lasted 20 s each, with a 30 s break in between, without stepping off the plate. During the trials COP signals were recorded in the medial-lateral plane (ML) and the anterior-posterior plane (AP) with the sampling rate of 20 Hz.

On the basis of the recorded signals the traditional COP stability measures were calculated: dispersion, range, mean velocity and frequency of the corrected signal [13]. The corrected signal was calculated by subtracting an approximate COM signal from the COP signal using exponential smoothing [13]. To analyse the differences between the calculated measures in both trials a t-test for repeated measures was used (Statistica 7.0) at $p < 0.05$.

## Results

The results of both trials are presented in Table 1. The metronome-forced respiration contributed to a 23% increase of COP dispersion and range and 141% increase of mean velocity in the AP plane. Also a 39% increase in the frequency of the corrected signal was recorded. The respective changes in the ML plane were observed in the mean velocity (31% increase), due to forced respiration, and frequency (12% increase).

## Discussion

The aim of the study was to evaluate the effects of mechanics of chest movements of healthy rested subjects, force-breathing at the rate of 1 Hz, on selected measures of postural stability during quiet standing. As previously assumed forced respiration caused a significant increase of the COP dispersion, and increase of the frequency of the COP-COM signal in anterior-posterior plane (AP). The COP mean velocity in the AP plane was two times higher. In the ML plane the only significant difference between the trials was observed in the increase of mean velocity. The results obtained confirm the hypothesis assumed and correspond to the results of other authors. However, a more detailed analysis reveals that Jeong [6] noted a mere 23% increase of mean velocity in subjects breathing at an accelerated rate of 0.4 Hz as opposed to subjects breathing naturally. Whereas data obtained by Hodges et al. [8] point to a three-times increase of COP amplitude due to the high-volume respiration at the natural rate in comparison with natural breathing. This unusually great increase of dispersion of COP data in Hodges et al. [8] might be partially explained by the longer stress test duration (2 min) in their study. Another reason for the observed discrepancy between our results and those of Hodges et al. [8] could be possible hyperventilation effects on postural sway mechanisms due to reduction of the $CO_2$ blood level [14]. Taking into account the above observations and differences between individual tests it can be postulated that in the most common case, short (20–30 s) post-ex-

Table 1. Comparison of the mean values (± SD) of COP parameters examined during quiet standing tests with natural breathing (Nat) and accelerated high-volume breathing at the rate of 1 Hz

| | Medial-lateral plane | | Anterior-posterior plane | |
|---|---|---|---|---|
| | Nat | 1 Hz | Nat | 1 Hz |
| D (mm) | 3.9 ± 1.5 | 4.8 ± 2.5* | 2.8 ± 1.0 | 2.9 ± 1.0 |
| R (mm) | 19.3 ± 8.5 | 23.7 ± 11.0** | 14.3 ± 5.1 | 14.6 ± 2.9 |
| MV (mm/s) | 8.2 ± 2.5 | 19.8 ± 11.3*** | 7.1 ± 2.4 | 9.3 ± 3.8** |
| F (Hz) | 0.54 ± 0.14 | 0.75 ± 0.19*** | 0.69 ± 0.15 | 0.77 ± 0.15* |

D – dispersion, R – range, MV – mean velocity, F – frequency of the corrected signal, *$p < 0.01$, **$p < 0.001$, ***$p < 0.00001$

ercise tests of postural stability, COM oscillations induced by more intensive breathing should significantly increase the mean velocity of the COP and moderately increase the parameters of variability of this signal. However, the distinction between the mechanical and physiological effects on the changes observed seems highly unlikely, or not possible at all. The observed disproportionately high increase of COP mean velocity in comparison with the COP dispersion can be explained by the periodical component value in the signal induced by forced respiration at a high rate.

Another problem is the influence of fatigue on the frequency of the corrected signal. The results of this study point to an increase in the frequency; however, the question of the precise cause of it arises. It remains an open question whether the noted increase in the frequency was caused by fatigue itself, or by mechanical results of fatigue due to cyclic changes generated by the respiratory system. Hodges et al. [8] carried out a spectroanalysis of the COP and noted distinct peaks in the power spectrum of the signal consistent with peaks of chest movements. The amplitude of these peaks was slightly lower than the mean power of the COP signal for natural breathing, and dominant for high-volume breathing at the natural rate. Considering these observations and results of our study it seems plausible that the noted increase of the corrected signal could have largely resulted from dynamic breathing rather than from fatigue itself.

## Conclusions

The obtained results can be applied in research practice. An important question arises whether postural stability should be evaluated immediately after exercise without waiting for return to the normal breathing rate, or should all the factors be treated together as a collective disturbance of the body balance immediately after exercise. It seems that the latter is the only justified approach facing the need of total, functional evaluation of postural stability after exercise, which is the case in sport. On the other hand, if we want to understand the processes of muscle fatigue and their effects on the system of equilibrium, the former approach is proper as it eliminates a few interfering variables and makes the interpretation of results easier.

It should be noted, however, that the above problems refer to the traditional measures of postural stability, which depend on chest movements and compensatory body movements. The results should be interpreted with utmost caution. A good methodological indication is application of new measures of postural stability, which, at least in theory, should be highly resistant to the COP-related interference. They include chaotic measures [11, 15] and time-to-boundary measures [12]. The experimental verification of these suggestions will constitute an enormous development in research on postural stability during quiet standing.

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