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The effect of a short breathing intervention on postural control and heart rate variability

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ORIGINAL ARTICLE

ABSTRACT

Purpose: The objective of this study was to determine the immediate effect of a short breathing intervention on postural control and heart rate variability in healthy individuals. *Materials/Methods:* The study involved 28 participants. Heart rate variability and heart rate were measured using a Polar (H10) sensor, and the sway path during posturography was recorded using the NeuroCom system, with participants standing on a firm then a foam surface in the eyes open and eyes closed conditions. All measurements were performed before and after the breathing intervention to provide baseline and post-intervention data. A short breathing intervention was performed between testing to stimulate the autonomic nervous system. In the Wilcoxon matched pairs comparison using Statistica software, $P < 0.05$ was considered statistically significant. *Results:* The breathing intervention caused a significant decrease in heart rate variability and an increase in heart rate. In the eyes closed condition, on a firm surface, the breathing intervention significantly reduced the sway path. *Conclusions:* The breathing intervention reduced the sway path in conditions without visual information but appeared to have no effect on balance in conditions with visual information, suggesting that the postural function of the diaphragm becomes more prominent in nonvisual conditions. We obtained evidence of the relationship between the autonomic nervous system and postural control. The stimulation of the sympathetic tone by means of the breathing intervention had a significant effect on postural control on firm and foam surfaces without visual information and decreased postural sway.

KEYWORDS

postural control, balance, heart rate variability, breathing

INTRODUCTION

Postural control (PC) is the ability to control the position of the body in space to serve two simultaneous goals: orientation and stability. Orientation is a perceptual goal, while stability is a biomechanical goal [1]. Balance and PC in static positions and during locomotion are the result of a perceptual-motor process: PC involves the sensation of joint position and kinaesthesia derived from the visual, somatosensory and vestibular systems; the processing of sensory information to determine orientation and movement; and the selection of the appropriate motor responses to maintain or restore the balance of the body [2].

Postural sway, which is a reliable indicator of balance and PC, can be measured by force plates during posturography. However, it is not clear from the literature whether increased or decreased postural sway indicates better balance ability. Several studies have shown that decreased postural sway may be an indicator of better PC and balance following participation in balance training [3, 4]. By contrast, there is evidence to suggest that increased postural sway after balance training may also be an indicator of improvement in balance, since we found in our earlier studies with both elderly and young adults that increased postural sway was presented together with improved functional performance after participation in combined balance training [5], as well as with increased balance confidence [2].

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Since human PC is so complex, the whole of the nervous system must be taken into account when assessing balance, not just the sensory, motor and cognitive systems. Postural control includes the regulation of postural tone, the integration of sensory input for posture and balance, and the contribution to anticipatory PC that accompanies voluntary movements. All these are connected with the brainstem nuclei. The ceruleospinal and raphespinal tracts, for example, are both non-specific motor tracts that modulate the activity of spinal lower motor neurons. Both tracts have general motor effects that are unrelated to specific movements and may result in poorer motor performance when anxiety levels are high [6].

Heart rate variability and the autonomic nervous system

The physiological phenomenon of variation in the time interval between heartbeats is known as heart rate variability (HRV). It is calculated by the variation in the beat-to-beat interval and is a non-invasive electrocardiographic marker that determines the activity of the autonomic nervous system (ANS) [7]. It represents the sympathetic and vagal components of ANS activity on the sinus node of the heart. Alterations in ANS afferent and efferent fibre activity, as well as changes in local neural regulation, all contribute to sympatho-vagal imbalance, which is reflected in a reduced HRV. Besides gender, age, circadian rhythm and body position, breathing has been highlighted as a physiological characteristic that can affect HRV [8].

Heart rate variability is therefore an important indicator of ANS state and stress levels in individuals: reduced HRV results from higher sympathetic tone, while increased HRV is a consequence of lower sympathetic tone or increased parasympathetic activity.

The Elite HRV smartphone application is accessible via all smartphone operating systems for assessing autonomic modulation as expressed through a parasympathetic index (HRV score), and its validity has been tested and proved [9].

The diaphragm is an inspiratory muscle that also serves a postural function. Postural muscles with a respiratory function include one of the local stabilisers of the lumbar spine and the deep abdominal muscles. In regular breathing, the synergistic action of the abdominal muscles and the diaphragm is required for postural stability and intra-abdominal pressure [10]. Moreover, inspiratory muscle training seems to be a potential tool for improving posture [11].

Although several studies have revealed a link between breathing interventions – especially inspiratory muscle training – and PC in healthy individuals, there is a gap in the literature when it comes to the effect of short breathing interventions on postural sway and HRV.

The objective of the present pilot study was to investigate the immediate effect of a short breathing intervention on PC. We postulated that there would be a significant link between the short breathing intervention and postural sway and HRV in healthy adults, and that the ANS interacts with PC.

MATERIALS AND METHODS

Participants

Twenty-eight healthy young adults between the ages of 18 and 30 were recruited to participate in the project. All the participants were informed about the entire project process and gave their written informed consent prior to participation. The measurements and training used complied with the current laws of Hungary and were in line with the Helsinki Declaration, and the protocol was approved by the National Public Health Centre (48590-8/2020/EÜIG).

Study design

The study began with baseline assessments of the participants. First, 60 s of HRV and heart rate (HR) measurements were taken through paced breathing, after which sway path measurements were performed using a NeuroCom Basic Balance Master® force plate, with participants standing on a firm (stable) surface and a foam (unstable) surface in the eyes open (EO) and eyes closed (EC) conditions. Each measurement was performed three times, with a duration of 10 s. Following the baseline measurements, a short breathing intervention was performed by the volunteers, including 10 abdominal breaths together with 5–10 s (depending on the individual tolerance threshold) of abdominal movements with closed glottis at the end, aimed at stimulating the ANS. The HRV, HR and sway path measurements were repeated after the breathing intervention, following the same procedure as for the baseline measurements. The study design flowchart is presented in Fig. 1.

Short breathing intervention

The participants were asked to stand upright and perform 10 deep abdominal breaths. They were then asked to perform 5–10 s of rapid abdominal inspiratory movements without actually breathing; this involved the participants mimicking abdominal breathing while holding their breath with a closed glottis. After one trial, each participant was instructed individually and observed by the supervisor during the breathing intervention measurements. The aim of the short breathing intervention was to stimulate the ANS, after which the effects of this stimulation on posture, HRV score and HR were assessed.

Postural stability measurements

We measured static postural stability in a standing position on a single force plate (NeuroCom Basic Balance Master®, Neurocom International Inc., Clackamas, Oregon, USA), recording the centre of pressure (CoP) displacement with a single force plate. The NeuroCom Balance Master® has high test-retest reliability, supporting its use in assessing dynamic postural stability in healthy participants [12], thus the intraclass correlation coefficients (ICCs) of the measurements were not evaluated in the present study. In the case of healthy subjects aged between 24 and 68 years tested one

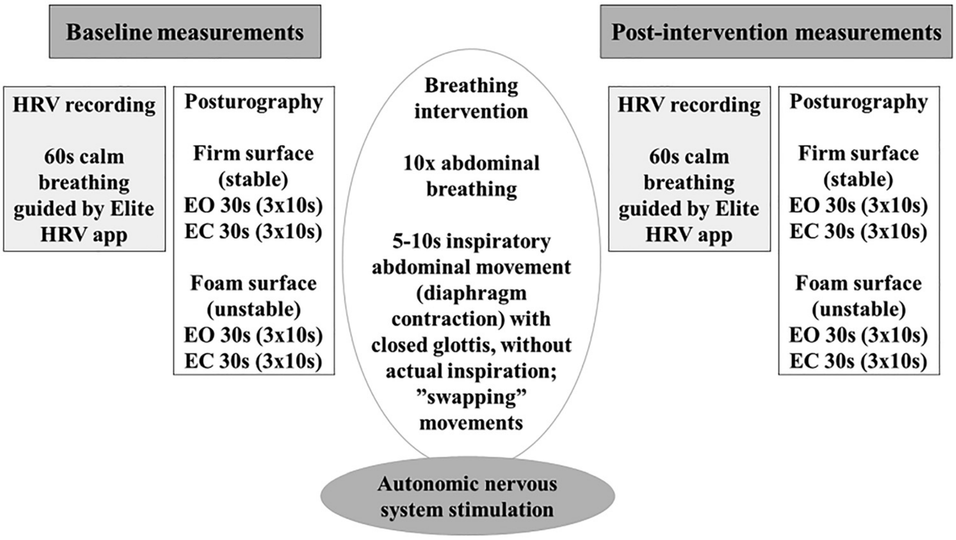

Fig. 1. Study design flowchart
(*Abbreviations:* EO: eyes open; EC: eyes closed; HRV: heart rate variability; s: second)

week apart, the ICC was 0.91 on a firm surface with eyes open and 0.97 on a firm surface with eyes closed [13].

The posturography was performed before and after the short breathing intervention, with participants standing quietly, their arms hanging loosely at their sides. Participants stood barefoot on the plate with their feet side by side, as indicated on the force plate, under two visual conditions (EO and EC) and two surface conditions (firm and foam). The EC condition was supervised by the examiner, and opening the eyes during the measurement was an exclusion criterion. We preferred the participants to close their eyes rather than be blindfolded during the measurements and training, bearing in mind the different psychological effects of these two conditions. Using a blindfold is a type of constraint, which may induce a feeling of uncertainty during balance assessment. This may result in a negative compensatory balance strategy, such as fixing or stiffening, which we wanted to avoid during the testing and training periods [14]. Centre of pressure displacements were recorded for 30 s (3 × 10 s) in each condition.

HRV and HR recording

The HRV score and heart rate were measured and recorded during 60 s via the Polar H10 chest strap heart monitor. The Elite HRV smartphone application gave us a score from 1 to 100, and the application guided the pace of inspiration and expiration to ensure standard measurements. Lower HRV scores mean less variability and higher sympathetic tone, while higher HRV scores mean greater variability in R–R intervals and higher parasympathetic activity in the ANS.

Data analysis

The raw data were further processed using the Microsoft Excel program, according to our earlier method [14]. The sway path was calculated from the raw data in both the anteroposterior (AP) and mediolateral (ML) directions, according to the following formulas:

$$S_x = \sum_{i=1}^{n-1} \sqrt{(x_{i+1} - x_i)^2}$$

$$S_y = \sum_{i=1}^{n-1} \sqrt{(y_{i+1} - y_i)^2},$$

where n is the total number of samples, i is the numbering, s_x is the ML displacement of the CoP, and s_y is the AP sway.

Data derived from the HRV measurements and posturography were processed using Statistica 13.3 through the Wilcoxon matched pairs test to compare the effects of the breathing intervention on HRV, HR and sway path. We adopted $P < 0.05$ as the level of significance for all statistical analyses of the data.

RESULTS

Breathing intervention and heart regulation

After the short breathing intervention, HR increased significantly ($P < 0.001$) (Fig. 2, Panel A). In parallel with the increased HR, there was a significant reduction in the HRV score ($P < 0.001$) (Fig. 2, Panel B). The effect of the breathing intervention on the HRV score and HR reflected a shift toward greater sympathetic innervation of the heart.

Breathing intervention and postural control

In the EO condition, during which visual information was available for controlling posture, there were no significant changes in the sway path immediately after the short breathing intervention when standing on either the firm or the foam surface. However, a statistically discernible ($P = 0.0013$) decrease in the sway path was observed immediately after the breathing intervention on the firm

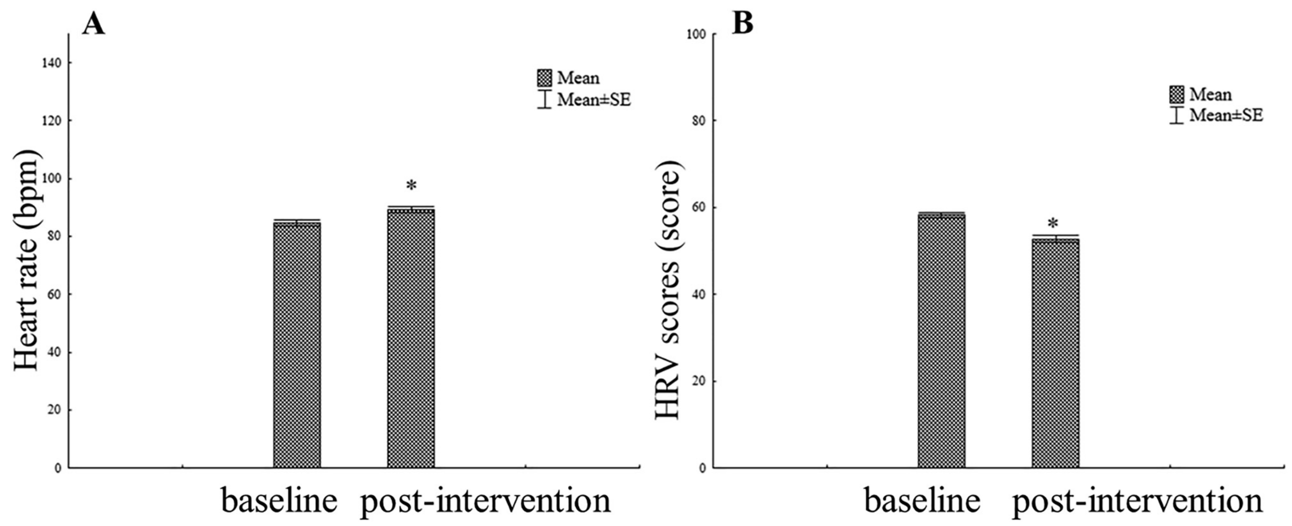

Fig. 2. Panel A: The effect of the breathing intervention on heart rate. Panel B: The effect of the breathing intervention on HRV score. Asterisks indicate significant differences ($P < 0.05$)
Abbreviations: HRV – heart rate variability; SE – standard error.

surface in the EC condition. This change is shown in Fig. 3, Panel A. Moreover, the sway path also decreased when standing on foam in the EC condition, although this was not a significant change ($P = 0.071$) (see Fig. 3, Panel B).

DISCUSSION

The main finding of the present study is that by means of a short breathing intervention we managed to modulate the activity of the ANS and increase sympathetic tone, expressed by a reduction in the HRV score and an increase in HR. In a study conducted by Li et al. [15], the impact of a slow breathing rate on the power spectral component of HRV was investigated in the case of healthy individuals and patients with essential hypertonia. According to their results, slow breathing increased vagal activities and shifted the sympatho-vagal balance toward vagal (parasympathetic) activities. Our results add further evidence to these findings, demonstrating that breathing is a powerful tool in the modulation of ANS activity.

Another important finding is that our short breathing intervention was able to influence PC immediately, since it also had a significant effect on the sway path in the condition without visual input. The decrease in the sway path, presented together with a decrease in HRV (that is, a higher sympathetic tone indicator), may generally be a sign of increased postural tone in the antigravity musculature, which can be mediated by non-specific motor pathways (coerulospinal tract). Increased postural tone in turn causes decreased postural sway.

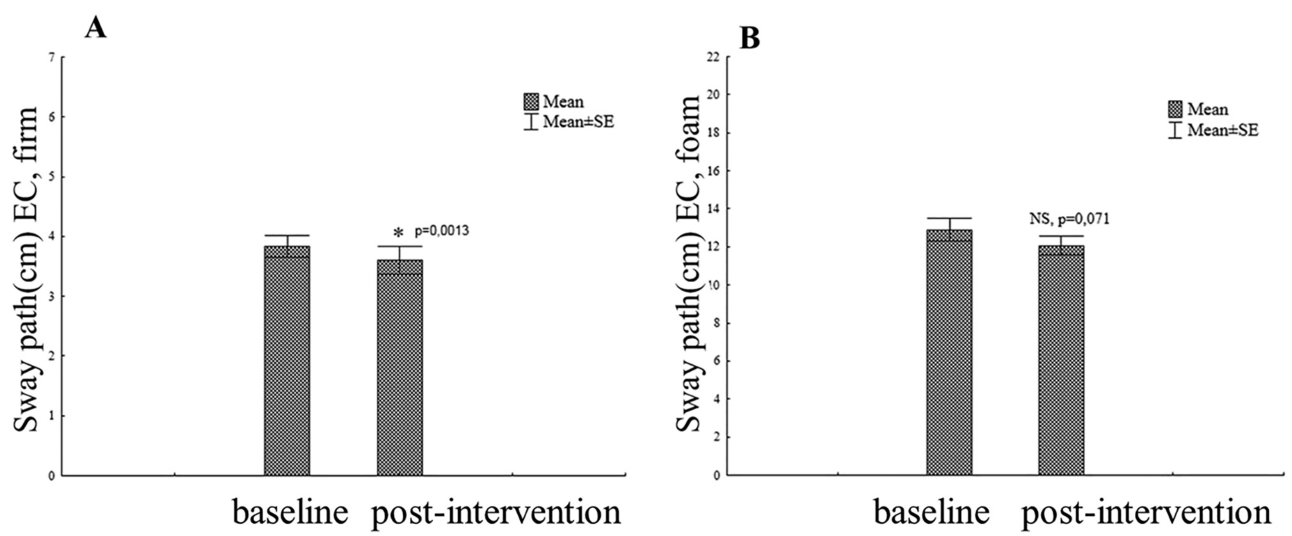

Fig. 3. Panel A: The effect of the breathing intervention on sway path when standing on a firm surface with eyes closed. Panel B: The effect of the breathing intervention on sway path when standing on a foam surface with eyes closed. The asterisk indicates a significant difference ($P < 0.05$)
Abbreviations: EC – eyes closed; SE – standard error; NS – non-significant.

Considering the role of the diaphragm specifically in postural stabilisation [10], its muscle tone may have increased following the intervention, since our breathing intervention involved repeated contractions of the diaphragm. However, this was not measured in the present study. Following our breathing intervention, the sway path decreased in the EC condition. However, the fact that we found no significant changes in the sway path in the EO condition demonstrates that the hypothetical increase in diaphragmatic tone is not in itself sufficient to explain the sway path reduction in the EC condition.

When an individual stands on a firm surface in the EC condition, the central nervous system relies to a greater extent on proprioceptive information. However, when an individual stands on a foam surface in the EC condition, the central nervous system relies more on vestibular input as a result of sensory reweighing [6]. From a perceptual point of view, the EC condition, especially when standing on an unstable surface, is considered as the more challenging balance situation. This greater challenge thus places a constraint on the central nervous system, which reweighs the importance of the sensory inputs available for PC and is perhaps forced to change its PC strategy [2], which may be reflected in the decreased postural sway recorded in the EC condition.

It has been clearly demonstrated that behavioural correlates of fear of falling include a conservative "stiffening" or fixing strategy, which is a negative PC strategy. When this stiffening strategy is adopted, the range of motion of a person's centre of mass is reduced by the reflexive co-contraction of the tibialis anterior, soleus and gastrocnemius muscles, resulting in lower amplitude and higher frequency postural sway [16, 17].

We postulate that in our investigation, the increased sympathetic tone in the ANS induced by the breathing intervention may have immediately prompted similar changes in PC, since fear of falling may also be associated with increased sympathetic tone. Although our participants did not express any fear of falling, the sympathetic shift in sympatho-vagal balance caused by the breathing intervention, as monitored and recorded though the HRV, may have influenced both postural tone and the extent of postural sway. We therefore suggest that this breathing intervention may be a useful tool in physiotherapy to influence postural tone immediately and to change the extent of postural sway.

Investigations into the impact of diaphragm training of different durations on balance and PC are well documented, and several studies have yielded evidence of the beneficial effect of diaphragm training in terms of balance and PC in various patient populations, resulting in reduced pain levels in patients with non-specific lower back pain [18–20]. We draw attention to the fact that, as far as we know, there are no other findings in the literature based on analyses of the associations between PC and a short-term breathing intervention of this kind aimed at stimulating the ANS. Our study is therefore unique in assessing the immediate effects of the sympathetic shift in the ANS exerted though our breathing intervention. Our breathing intervention proved to be a useful tool for immediately influencing the postural activation pattern, thus modulating PC and balance in the EC condition by increasing the sympathetic tone.

Limitations

One of the limitations of the present study is the absence of a control group, thus further investigations are needed to clarify the modulatory effect of the breathing intervention on the ANS and its role in PC. Another limitation is that the breathing intervention applied in the study was not standardized and there is no previous evidence in the scientific literature for this special type of intervention.

CONCLUSIONS

We have provided some evidence for the relationship between the state of the ANS and PC. The stimulation of the sympathetic nervous system through a rapid breathing intervention resulted in lower HRV scores and higher HR, which had a significant effect on PC on a foam surface without visual information and immediately decreased postural sway, similar to the Fear of Falling. However, after our breathing intervention the sway path decreased in the EC condition, although we found no significant changes in the EO condition.

These results suggest that further investigations would be valuable, since postural balance is an important part of human functioning in every age group and effective treatment strategies need to be developed to prevent falls and their consequences.

Authors' contributions: EN: Conception and design of the study; Processing of data; Drafting and revision of the manuscript.

NS: Provision of instruction for the breathing intervention; Acquisition of data; Drafting of the manuscript.

Ethical approval: The study is in compliance with the principles of the Declaration of Helsinki and was approved by the National Public Health Centre (48590-8/2020/EÜIG).

Conflict of interest/Funding: The authors declare no conflict of interest. No financial support was received for this study.

LIST OF ABBREVIATIONS

PC	postural control
HR	heart rate
HRV	heart rate variability
ANS	autonomic nervous system
CoP	centre of pressure
AP	anteroposterior
ML	mediolateral
EO	eyes open
EC	eyes closed

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