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Research article

Breathing changes accompanying balance improvement during biofeedback

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HIGHLIGHTS

- Impact of breathing on posture decreased while standing on foam with visual feedback.
- Balance improvement during visual feedback was accompanied by breathing changes.
- During visual feedback, chest expansion decreased and breathing frequency increased.

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ABSTRACT

The aim of this study was to determine whether respiration would be altered during visual biofeedback condition while standing on a foam surface. Fifty young, healthy subjects (24 men, 26 women) were divided into a spirometry group, in which additional spirometry analysis was performed, and a control group. All subjects were tested in two conditions: 1) standing on a foam surface and 2) standing on a foam surface with visual biofeedback (VF) based on the centre of pressure (CoP). CoP amplitude and velocity in anterior-posterior (Aap, Vap) and medial-lateral (Aml, Vml) directions were measured by the force platform. Breathing movements were recorded by two pairs of 3D accelerometers attached on the upper chest (upper chest breathing – UCB) and the lower chest (lower chest breathing – LCB). Results showed that significant decreases of CoP amplitude and velocity in both directions were accompanied by a significant decrease of lower chest breathing, and an increase of LCB frequency was seen during VF condition compared to control condition in both groups. Moreover, a significant decrease in tidal volume and increased breathing frequency during VF condition were confirmed by spirometric analysis. Reduced breathing movements and volumes as well as increased breathing frequency are probably part of an involuntary strategy activated to maximize balance improvement during VF condition.

1. Introduction

Maintaining balance during quiet stance is an integrative process. In standing posture, respiratory movements constitute an internal cyclical perturbation to body balance by altering the trunk volume [1–3]. Previous studies have shown that the respiratory rate can be detected by a single tri-axial accelerometer positioned on the abdominal wall, but only in a strictly controlled lying position [4]. In a standing position, two inertial sensors positioned on opposite sides of the chest wall are necessary to reliably sense breathing movements as relative changes in inclination between the two accelerometers [5].

Although it is agreed that respiration disturbs posture, there has been disagreement regarding the degree to which postural disturbances from respiration may be compensated. Hodges et al. [3] found movements associated with breathing at the hip level, but they almost disappeared in centre of pressure (CoP) data in normal subjects. However, some studies have reported evidence of periodic perturbation to equilibrium identified from CoP that was correlated with breathing [2,6,7]. Balance disturbance associated with breathing has been observed in the movement of CoP in the sagittal plane

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in patients with central nervous system pathology [1,8] and lower back pain [9], but it has been reported as insignificant in healthy people [1]. Respiration is a source of highly predictable perturbation, thus postural control foresees its effect and compensates for it in healthy people [1,3,6], using multisegmental compensation through movements of the trunk, pelvis and lower limbs [3]. However, this compensation may not totally cancel the perturbation related to breathing; therefore, the movements associated with respiration still have minimal but not negligible effects on postural sway in healthy people [2,3,6].

It is well known that postural control of healthy people can be challenged when standing on a foam surface. It exaggerates balance deficits by decreasing the reliability of somatosensory information from cutaneous mechanoreceptors on the base of the feet [10]. It has also been proven that reliance on augmented sensory information, i.e., visual biofeedback (VF) for controlling upright posture, increases in conditions with altered somatosensory input from the foot and ankle [11,12]. Real-time VF from CoP during a standing task represents a challenging condition that requires high concentration on the ongoing postural task. It is commonly incorporated in the evaluation and training of postural control. Visual biofeedback consists of supplying individuals with additional visual information about body motion to improve balance. When the magnification of visual feedback is increased, small movements in the CoP are more easily detected, which improves corrective postural adjustments [11–13].

The aim of the present study was to examine respiratory movements during quiet stance on a foam support surface and during a condition that required increased concentration on precise body movements. Visual biofeedback represents such a condition when postural activity may interfere with breathing. It was hypothesized that breathing would be altered to achieve improvements in postural stability during the visual biofeedback balance task.

2. Methods

Fifty healthy subjects (24 men, 26 women) within the range of 22–36 years participated in this study. They reported no history of chronic respiratory, neurological, or orthopaedic diseases or injuries, which might influence balance or respiration. The study was approved by the local ethics committee. Written consent in agreement with the Declaration of Helsinki was obtained from all participants.

Participants were divided into two gender-matched groups. The spirometry group (12 men, 13 women, age 27.4 ± 3.6 years, BMI 22.7 ± 2.7 kg m^{-2}) underwent the protocol wearing a spirometric face mask. Tidal volume (Vt) of each breath and breathing frequency were evaluated during balance testing using an Ergostik (Geratherm Respiratory GmbH, Germany) in this group. Participants in the control group (12 men, 13 women, age 28.6 ± 3.8 years, BMI 21.7 ± 2.8 kg m^{-2}) underwent the same protocol without spirometric measurement to eliminate the potential influence of wearing a face mask on postural stability or breathing movements.

The protocol consisted of two conditions: standing on foam with eyes open (control condition – C) and standing on foam with additional visual biofeedback (VF). During control condition, subjects stood on 10 cm thick foam placed on a force plate with feet shoulder-width apart, straight-ahead position, and arms by the sides of the body. Subjects were instructed to stand quietly, move as little as possible, breathe normally and fix their gaze on a black point located in a white scene at the distance of 1 m. During VF condition, the position of the CoP was presented in real time on a

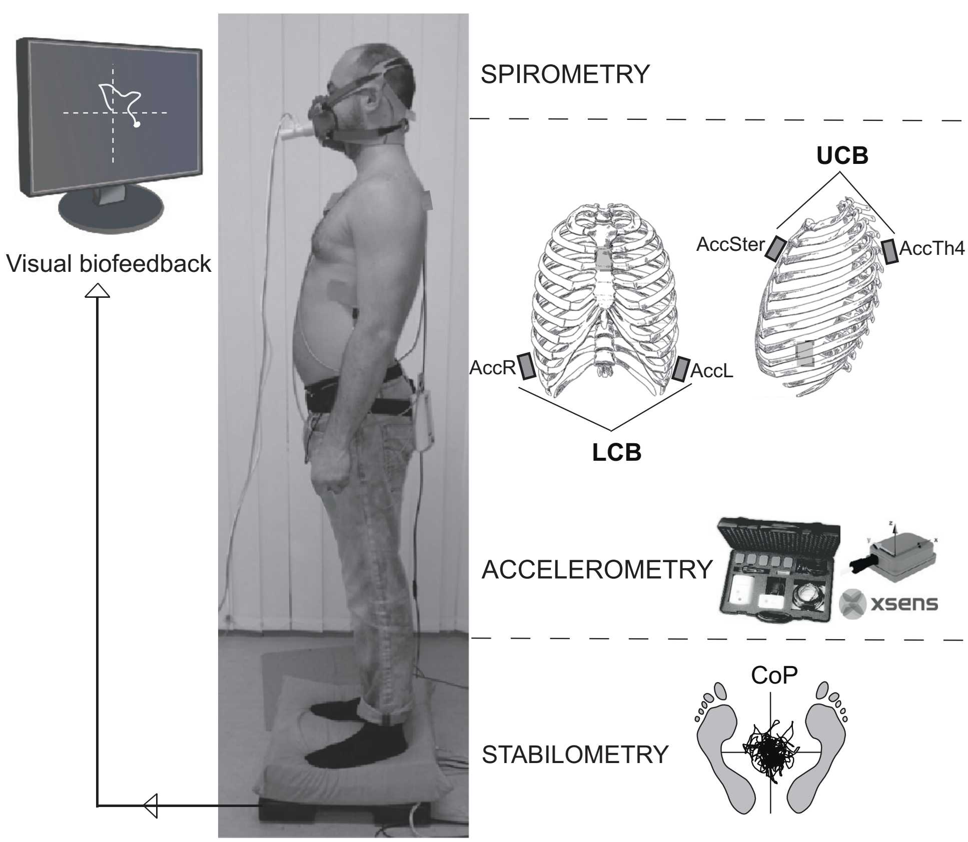

Fig. 1. Schematic illustration of methods used for postural stability measurement (stabilometry – CoP) and for measurement of breathing (accelerometry and spirometry) during visual biofeedback condition. Positions of accelerometers AccSter and AccTh4 for recording of upper chest breathing (UCB) and positions of accelerometers AccR and AccL for recording of lower chest breathing (LCB).