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Effects of different unstable supports on EMG activity and balance

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HIGHLIGHTS

- We analysed balance strategies and EMG activity using different unstable surfaces.
- Centre of pressure displacements and EMG activity were affected by unstable boards.
- Postural equilibrium is mostly oriented around the anteroposterior axis.
- Results highlighted new knowledge about central nervous system organisation.
- Balance is modulated by ecological strategies.

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ABSTRACT

This study analysed the equilibrium strategies and EMG activity during postural equilibrium in four different unstable surfaces. Thirteen team sport males were tested on a FLAT surface and on three different wobble boards (JAKOBS® with easy multidirectional displacements, FREEMAN with strong multidirectional displacements and LATERAL with unidirectional lateral displacements). They had to maintain single-limb stance during 5 s for each condition. The right foot centre of pressure (COP) position and its variability with concomitant EMG activity of soleus (SOL), tibialis anterior (TA), peroneus longus (PL) and extensor digitorum longus (EXD) muscles were recorded. Subjects maintained balance by making seesaw rotations. LATERAL and FREEMAN boards demonstrated significantly greater COP variability than JAKOBS® and FLAT in both anteroposterior and mediolateral directions. Similarly, PL, EXD, and TA muscles EMG activity were significantly greater using the LATERAL board, and in some cases using FREEMAN as compared with JAKOBS® and FLAT. These results highlighted new knowledge about central nervous system organisation while keeping equilibrium with a predominant anteroposterior control.

1. Introduction

Humans, in contrast with other mammals, sustain bipedal stance which requires several systems to maintain equilibrium. Orientation information is derived from three independent sensory sources: somatosensory, vestibular and visual inputs. Proprioception is a component of the somatosensory system which has the ability to give afferent information on segments' position and movement from various receptors located, for example, in joints, muscles and tendons [19]. It plays an important role in the elaboration of postural reference [12,26] and to maintain equilibrium.

In upright stable position, stabilisation mechanisms tend to counteract perturbations by reducing the horizontal distance between the centre of mass (CoM, point within the body where vertical forces may be applied) and the centre of pressure (CoP, point location of the resultant ground reaction force) [34]. In unstable conditions, humans rather maintain equilibrium by mechanisms located within the ankle joint. Indeed, the support instability alters the relation between sensory inputs and motor actions [16]. Balance is therefore maintained by means of displacements of the foot contact point on the unstable support in parallel with a body CoM shift [15]. More particularly, stabilisation mechanisms are achieved through an active intervention of the central nervous system and a modulation of ankle joint angle and muscle stiffness [20,21].

Exercising under unstable conditions is a strategy used to reduce equilibrium loss and falls in elderly peoples [25]. In addition, numerous studies have demonstrated balance exercises benefits in rehabilitation programmes and for reducing injury risk rate [3,11,14], for example, for anterior cruciate ligament injuries [3,27,29] as well as ankle sprains [32]. Because injuries are related to ankle functional instability [6,7], balance exercises may be efficient by improving motor control and strengthening stabilisation

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muscles [14,24]. As a consequence, balance training is now a major component of sport training and is gaining recognition as an important part of the pre-season injury prevention programmes for many athletes [10].

Balance training using unstable surfaces is most commonly performed on wobble boards. They are generally composed of a board with hemi-spherical or hemi-cylindrical bases that allow multi- or uni-planar movements, respectively. However, little data are available concerning their specific effects and detailed description of the different unstable supports are generally lacking. For instance, we know that balance platforms produce greater ankle muscular activity in comparison with flat surfaces or trampolines [1]. But, when considering different unstable supports, the neuromuscular solicitation of lower-limb muscles and the postural control is still unknown. Therefore, the goal of the present study was to investigate the effects of different unstable supports on electromyographic (EMG) activity of ankle muscles. We hypothesised that multi-directional unstable supports cause greater perturbations and consequently higher muscular activation than flat and uni-directional boards. Results should provide knowledge to better understand equilibrium on unstable supports and suggestions for adapting balance training to improve motor performance and reducing injury risk rate.

2. Materials and methods

2.1. Subjects

Thirteen volunteer males (football, rugby and handball regional players) were recruited from a Sport Science Department. Their mean (±SD) age, height and body mass were 22.7 ± 2.6 yrs, 179.8 ± 5.9 cm and 78.9 ± 6.0 kg. Subjects had no history of musculoskeletal pathology, neuro-degenerative or infectious disease, chronic ankle instability, recent ankle sprain, vestibular pathology and visual impairment. To avoid any neuromuscular fatigue, subjects were requested not to perform any intensive training for at least 24 h before the experiment. Before the onset of the study, all signed an informed consent form. The study was conducted according to the Declaration of Helsinki and approval was obtained from the local committee on human research.

2.2. Experimental procedure

All tests were performed in a standard position: (i) upright standing on the right foot, without shoes and with an extended leg, (ii) the left leg was flexed with a $\sim 90^{\circ}$ knee angle and maintained in contact with the right knee, (iii) hands were kept on the hips and (iv) open eyes fixed at a set point on a wall (170 cm height and 200 cm away). Subjects had to maintain this position on a flat surface and on three different wobble boards. Data collection, lasting 5 s, started when subjects achieved an equilibrium position. Trials shorter than 5 s or invalid (i.e., incorrect position or when boards touched the ground) were excluded from analyses. Each support was tested twice with at least 15 s rest between trials. Results from the two trials were then averaged.

Subjects were firstly tested on a posture platform only (Posture Win, Techno Concept, Cereste, France). It aimed to determine the foot centre of pressure (CoP) position [23] and to measure balance on a flat surface (FLAT). For this condition, the foot was lined up on the platform vis-à-vis to the heel and second toe imaginary axis using a graduate grid.

Then, subjects randomly performed the 5 s tests on three different wobble boards (Fig. 1) placed on the posture platform. The foot CoP, found on FLAT, was vertically lined up with each wobble board's geometric centre and posture platform centre, as shown in Fig. 2. Boards were chosen from commercially available supports. One large plastic (JAKOBS®, 109 cm circumference and 5 cm height) and one small wood (FREEMAN, 31 cm circumference and 8 cm height) hemi-spherical board permitted multidirectional displacements. The third board, called LATERAL, with a hemi-cylindrical wood base, only allowed lateral movements (12.5 cm circumference and 7 cm height).

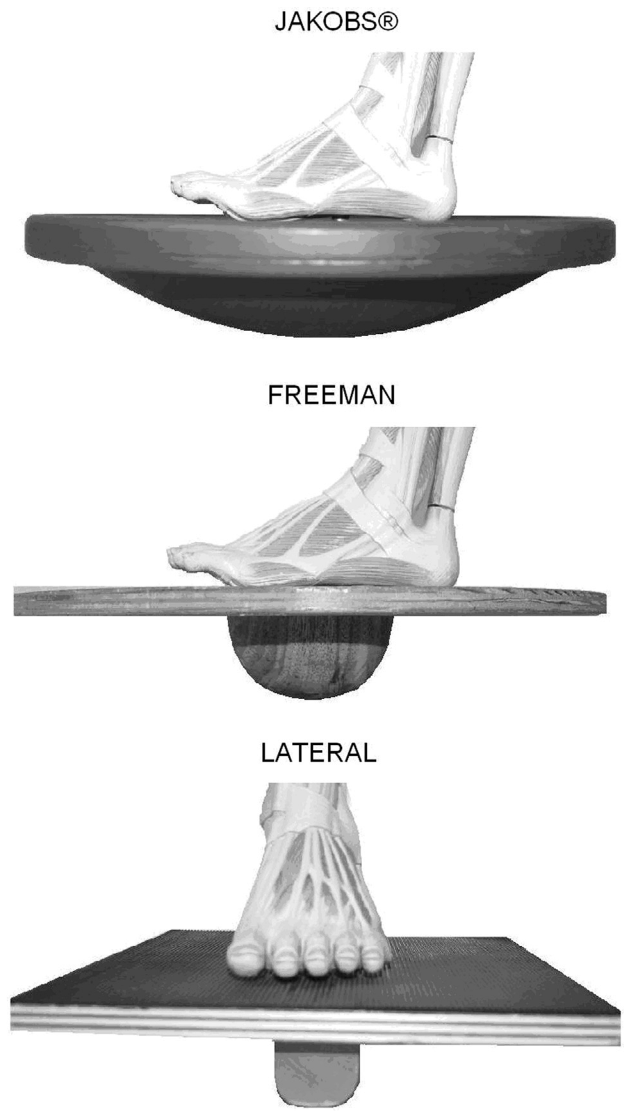

Fig. 1. Wobble boards used during balance tests.

Finally, subjects performed isometric maximal voluntary contractions (~ 5 s) in order to obtain maximal EMG activity and then normalise EMG activity during balance tests. Maximal voluntary contractions consisted in maximal plantarflexion, dorsiflexion and eversion with the foot in a neutral position (tibia perpendicular to the sole of the foot, i.e., same position as during balance) [18].

2.3. Measurements

During all tests, the CoP position was measured using the posture platform in mediolateral and anteroposterior directions. From the stabilograms were retained the mean CoP position (i.e., average position; Fig. 2) and CoP position variation (i.e., CoP variability calculated from standard deviation values) [8,17]. CoP position signals were recorded during 5 s for each trial at a 40 Hz sampling frequency and synchronised with EMG.