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# The effect of an exercise ball on trunk muscle responses to rapid limb movement

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ABSTRACT

The use of exercise balls as an aid to facilitate improvements in posture in patients with trunk weakness is widely advocated. However, mechanisms underlying any effect on postural mechanisms have received little attention. This study compared the increases in trunk EMG activity in response to limb movement when seated on an exercise ball or on a chair in 16 healthy, moderately active subjects. At the sound of an auditory cue, the subjects carried out either hip flexion or arm flexion (unilateral or bilateral), as fast as possible, whilst sitting on an exercise ball or a standard chair. The amplitude of EMG activity was recorded from selected trunk muscles (erector spinae, external obliques, internal obliques and rectus abdominis) and either an upper limb muscle (deltoid) or a lower limb muscle (rectus femoris).

There were minimal differences in amplitudes of EMG activity in any of the trunk muscles between the conditions (ball or chair) following the upper limb movements. These results suggest that there is no benefit in simple arm flexion movements whilst seated on the exercise ball in comparison to a chair. The onset and amplitude of the rectus abdominis (RA) and external obliques (EO) were significantly different between conditions in the hip flexion protocol. However, they do suggest significant benefit in decreasing RA and EO muscle activity onsets and increasing amplitude in the hip flexion condition. These results may have implications for rehabilitation of those with trunk muscle deficits such as stroke.



## 1. Introduction

The central nervous system (CNS) maintains body equilibrium during rapid limb movements by activating postural muscles in the trunk and lower limbs [1,2]. These activities can be categorised into anticipatory (APAs) and compensatory (CPA) postural adjustments [3]. The anticipatory (feed-forward) responses are initiated in advance of or along with predictable perturbations to the body before feedback is available [4]. The role of the APA is to minimise the excursion of the centre of mass (COM) caused by the rapid arm movement [5,6]. CPA on the other hand serves as a mechanism to restore the position of the COM after perturbation has already occurred [7].

APAs are believed to be pre-programmed to change the background level of activation of postural muscles prior to the movement, within a timeframe too short for it to be classified as a reflex response. CPAs are initiated by sensory feedback signals to deal with the actual postural perturbation and cannot be predicted [8]. The characteristics of APAs have been investigated in several studies in terms of magnitude, timing and spatial distribution of these adjustments [9]. For example, the magnitude of APAs depends on the direction [1,10] and magnitude of the perturbation, in addition to body stability [3]. The timing has been reported to be dependent on the velocity of the perturbing limb movement [11,12], its predictability [11] and the amount of postural support available [2]. The spatial distribution is guided by a directional specificity, such that forward directed movements elicit a primary activation of the dorsal side of the body and vice versa [1,2]. Similar factors have been reported to determine the magnitude of CPAs, along with dimensions of the base of support (BOS), predictability of the perturbation, instructions and involvement of a secondary task [3]. The mechanism of interaction between CPAs and APAs to preserve body equilibrium is not completely understood, however, it has been suggested APAs could scale down the need for large CPAs resulting in better balance control [8].

Postural adjustments are impaired in neurological [13] and musculoskeletal conditions [14]. Taking stroke as an example, studies have found reduced magnitude and delayed anticipatory EMG activity of the superficial postural trunk muscles on the paretic side [11]. This abnormality in APAs was found to be significantly related to deficits in motor and functional abilities [13] and an important predictor of the functional outcome of stroke [13,15]. Training has been suggested as a way of improving APAs in trunk muscles [16], but only one study was found which explored ways of achieving this [17].

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Physiotherapists generally use the exercise ball in rehabilitation and conditioning programmes, in part to improve postural muscle activation. Its use has been justified through increased muscle recruitment and co-ordination required to maintain postural stability; however, the evidence for this is lacking [18]. It has been postulated that training on an unstable surface will provide an increased challenge for the trunk musculature and improve dynamic balance [18]. However, the degree of influence of a stable or labile surface on the abdominal wall is still yet to be fully documented [19]. Research findings have proven to be conflicting, with some studies reporting no difference in trunk muscles [20] and others reporting an increase in lumbar EMG on exercise balls [21].

This study was designed to compare the amplitudes of the trunk muscles EMG activity in healthy subjects whilst performing arm flexion or hip flexion tasks in the seated position on an exercise ball and a chair. We hypothesise that there will be decreased onset of the rise in EMG activity and an increased amplitude of APA muscle activation during tasks performed whilst sitting on the ball.

## 2. Methods

### 2.1. Subjects

Sixteen healthy, right hand dominant participants were recruited, comprising 7 males and 9 females; mean age (SD) was 25.8 (6.4) years. Those with previous history of lower back problems, postural abnormality, neurological or respiratory conditions or involved in high intensity training and parous women were excluded. Ethical approval was obtained from Imperial College Research Ethics Committee and participants gave their written informed consent.

The Edinburgh handedness inventory [22] was used to determine the subjects' hand dominance and the preferred leg to kick a football was used to identify leg dominance. The dominant hand and non-dominant leg were chosen for the arm flexion and hip flexion protocols, respectively. The International Physical Activity Questionnaire (IPAQ) was used to determine the level of activity of the subjects [23]. This questionnaire categorises subjects by their levels of daily physical activity into one of three categories: low, moderate or high.

### 2.2. Electromyographic recordings

Bilateral surface EMG recordings were made using pairs of Ag/AgCl recording electrodes (self-adhesive, ARBO blue, 2 cm diameter, Henleys Medical Supplies Ltd., Welwyn Garden City, UK), positioned over rectus abdominus (RA), erector spinae at L4 vertebrae level (ES), external obliques (EO), internal obliques (IO) and over anterior deltoid (D) on the dominant arm and over rectus femoris (RF) of the non-dominant leg. A ground electrode was placed on the patella of the dominant leg. Electrodes were placed in the direction of the muscle fibres with 2 cm inter electrode distance.

EMG signals were filtered (10 Hz to 1 kHz) and amplified (1000×, ISO-DAM bioamplifiers, World Precision Instruments, Stevenage, UK) before being sampled (2 kHz) by a data acquisition interface (1401 plus and Signal software, Cambridge Electronic Design Limited, Cambridge, UK) connected to an IBM compatible PC for subsequent offline analysis.

### 2.3. Additional measurements

A biaxial accelerometer (Charge Amplifier Type 2635, Bruel&Kjaer UK Ltd., Stevenage, UK) was attached to the subjects' wrist or thigh during leg or arm movement, respectively, to determine the onset and offset of the movement. A biaxial accelerometer was also attached to the manubriosternal angle to monitor antero-posterior sway during the tasks.

### 2.4. Procedure

The subjects were randomly assigned to their initial seating condition of ball or chair. A regular chair (Fig. 1) and a 90 cm exercise ball were used for all subjects; they were instructed to keep an upright position and not lean against the back of the chair. We ensured that the knee angle was 90° in each subject by using platforms under the feet when sitting on a chair and controlling ball inflation when sitting on the ball. Prior to EMG recording, subjects were allowed three practice trials of sitting on the ball and chair whilst they focused their eyes on a point on the wall away from the experimenter. After this familiarisation, trunk EMG was recorded for 20 s in quiet sitting on the chair and exercise ball to establish a baseline.

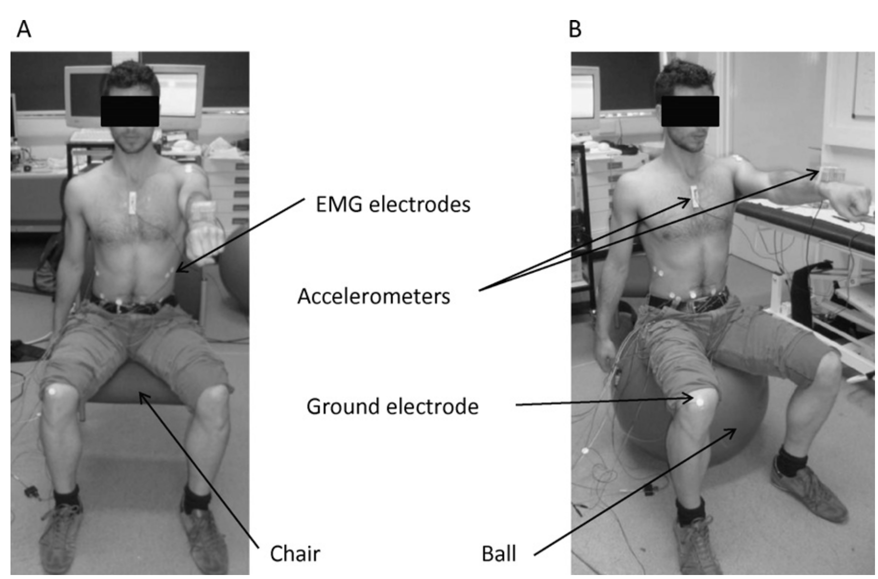


**Fig. 1.** Experimental setup.