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Research article

Anticipatory and compensatory postural adjustments in individuals with multiple sclerosis in response to external perturbations

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HIGHLIGHTS

- Anticipatory and compensatory postural control was studied in individuals with multiple sclerosis (MS).
- External perturbations were used to perturb standing balance.
- Anticipatory postural adjustments (APAs) were delayed in individuals with MS.
- Enhancement of APAs may add to balance rehabilitation of individuals with MS.

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ABSTRACT

Deficit in balance control is a common and often an initial disabling symptom of multiple sclerosis (MS). The aim of the study was to investigate the organization of anticipatory and compensatory postural adjustments in individuals with MS dealing with external perturbations. Ten individuals with MS and ten age-and-gender matched healthy controls were exposed to external perturbations applied at the shoulder level. The perturbations were either predictable or unpredictable as subjects stood with eyes open or closed. Electrical activity of six leg and trunk muscles as well as displacements of the center of pressure (COP) were recorded and quantified within the time intervals typical of anticipatory (APAs) and compensatory (CPAs) postural adjustments. Individuals with MS demonstrated delayed anticipatory onsets of muscle activity and smaller anticipatory COP displacements as compared to healthy control subjects. The deficiency of the APAs was associated with increased displacements of the COP during the balance restoration phase. The results demonstrate the underlying impairment in anticipatory postural control of individuals with MS. The study outcome provides a background for development of rehabilitation strategies focused on balance restoration in people with MS.

1. Introduction

Multiple sclerosis (MS) is a chronic autoimmune demyelinating disease affecting the central nervous system (CNS) [6]. Postural imbalance is often described as one of the initial symptoms of MS [7,10,22] and one of the most disabling MS symptoms that affects about 75% of patients during the course of the disease [24,25]. Poor balance control is a significant contributing factor to the increased risk of falling in individuals with MS [7,8,11,36] and is also linked to lower engagement in physical activity [26]. Moreover, poor balance control in individuals with MS is associated with impaired anticipatory postural adjustments [15]. It was also shown that inefficient anticipatory postural adjustments could result in accidental falls [37]. Likewise, fear of falling is also associated with an increased risk of falls in MS [11,29] and over 80% of people with fear also report activity restrictions [29]. Additionally, people with MS identify fatigue as one of the primary reasons for falling [28].

The stability of human vertical posture is affected by the high location of the center of mass, small support area, and multiple joints between the feet and the center of mass. Moreover, when a standing person performs a quick movement or interacts with external objects, the mechanical coupling of body segments leads to postural perturbations that may be detrimental for the fragile balance. While maintaining vertical posture, the CNS uses two main types of adjustments in the activity of the trunk and leg muscles when dealing with body perturbations. Anticipatory postural adjustments (APAs) control the position of the center of mass (COM) of the body by activating the trunk and leg muscles prior

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to a forthcoming body perturbation, thus minimizing the danger of losing equilibrium [reviewed in [23]]. Compensatory postural adjustments (CPAs) are initiated by the sensory feedback signals and serve as a mechanism of restoration of the position of the COM after a perturbation has already occurred [1].

APAs are an essential mechanism of balance control that ensures adequate postural preparation prior to task performance or in dealing with the external environment. Impairments of APAs have been reported in the elderly [16] and various neurological populations such as in individuals with stroke [35], cerebral palsy [12], Parkinson's disease [20], individuals with Down syndrome [2], as well as in individuals with MS [17,18]. However, the majority of APA studies in these populations utilized voluntary movement of an upper limb or load release from extended arms. However, in the arm lifting or load releasing paradigms most commonly used to study APAs, motor action and perturbation are interrelated as slow movements do not induce APAs [13]. Therefore, the diminished APAs seen in patients could be either a consequence of the disease or the result of slowness of performance of the arm movements seen for example in patients with Parkinson's disease or elderly individuals.

In order to have a clear understanding of how MS affects the organization of APAs, it is important to distinguish the influence of voluntary movement performance and postural preparation. In the recent past, external perturbations were used to investigate anticipatory postural control. The studies involving external perturbations such as load catching [3,34] and pendulum impact paradigms [32,33] revealed that APAs could be seen in preparation to perturbations that were externally induced with no voluntary movement being performed by the subjects themselves. Thus as long as the perturbation is predictable (either external or internal in origin), APAs are observed with patterns that are adequate for counteracting the expected impact. Moreover, external predictable perturbations provide a definite advantage of delivering consistent postural disturbances that are independent of the variability intrinsic to the voluntary movement performance. In addition, using an external perturbation paradigm eliminates the influence occurring from the interaction between voluntary movement and postural control. Therefore, to avoid the possible interaction with a focal voluntary movement (such as during arm raising tasks) and to investigate the direct effect of MS on the anticipatory postural control by itself, using an external predictable perturbation (with its magnitude consistent across the subjects), will allow minimizing the confounding effects of the voluntary movement itself. This study was thus focused on investigating the differences in anticipatory and compensatory postural adjustments between individuals with MS and control subjects exposed to external perturbations. We hypothesized that in individuals with MS: (1) the latency of the APAs will be delayed, (2) the anticipatory displacement of the center of pressure (COP) will be smaller and (3) compensatory COP displacement will be larger when compared to healthy controls.

2. Material and methods

2.1. Participants

Ten individuals (8 females and 2 males) with remitting-relapsed MS (MS group, mean age 52 ± 13 years, height 169.8 ± 10.3 cm, mean weight 68 ± 12 kg, mean EDSS score 2.3 ± 0.9) and ten age and gender matched healthy subjects (HC group, mean age 51 ± 14 years, mean height 167.8 ± 10.0 cm, mean weight 73 ± 12 kg) participated in the study. The inclusion criteria for the individuals with MS were: normal or corrected to normal vision, an EDSS [19] score of 5 or less, and the ability to stand independently without any aid or orthosis for at least 3 min. Patients with a history of shoulder subluxation or dislocation, any kind of pain, or unable to perform the experimental tasks were excluded. The experiments were approved by the UIC Institutional Review Board.

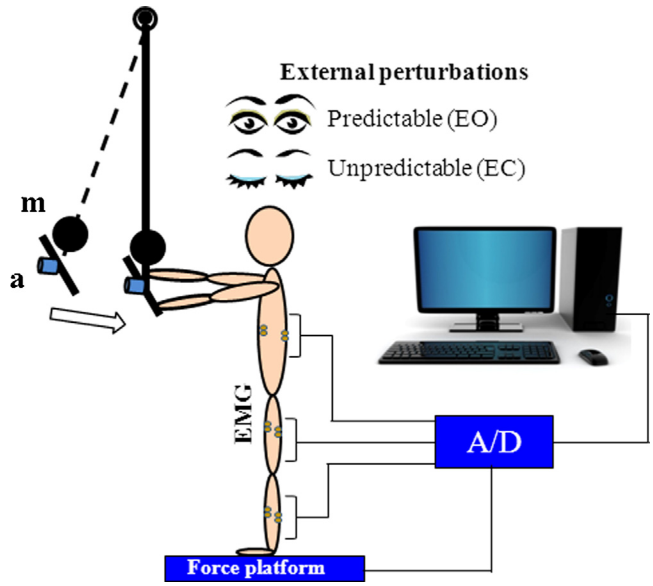

Fig. 1. Schematic representation of the experimental set up. Subjects were exposed to a predictable (eyes open) and unpredictable (eyes closed) perturbation. EMG activity and ground reaction forces were recorded. *m* – mass of the pendulum, a – accelerometer, A/D – analog-to-digital converter.

2.2. Experimental set-up and procedure

The subjects were instructed to maintain upright stance while standing barefoot on the force platform with their feet shoulder width apart. The pendulum impact paradigm was used to perturb the subjects. A load (mass, m = 3% of the subjects' body weight) was attached to the pendulum next to its distal end. The subjects were required to receive each pendulum impact with their hands, while their arms, wrists, and fingers were extended at the shoulder level (Fig. 1), and to maintain their balance after the perturbation. Both the groups received a series of perturbations while their eyes were open (EO) and with eyes closed (EC). When vision was available the perturbations were thus predictable and hence elicited both, APAs and CPAs. When vision was not available, the perturbations were unpredictable and only CPAs were generated. Two to three practice trials were given to both the groups in each experimental condition. For safety purposes, the subjects wore a harness (NeuroCom, USA) with two straps attached to the ceiling. Ten trials were performed, each five seconds in duration. All participants were allowed to have rest periods as needed.

2.3. Instrumentation

Disposable self-adhesive electrodes (Red Dot 3M) were used to record the electrical activity (EMG) of the following right muscles: tibialis anterior (TA), gastrocnemius lateralis (GASL), vastus lateralis (VL), biceps femoris (BF), rectus abdominis (RA), and erector spinae (ES). Based upon recommendations reported in previous literature [4], electrodes were attached to the muscle belly of each of the above muscles after cleaning the skin area with alcohol wipes. A ground electrode was attached to the anterior aspect of the leg over the tibial bone. EMG signals were collected, filtered, and amplified (10–500 Hz, gain 2000) with the EMG system (Myopac, RUN Technologies, USA). A force platform (model OR-5, AMTI, USA) was used to record the ground reaction forces and moments of forces.