



Effects of severity of gross motor disability on anticipatory postural adjustments while standing in individuals with bilateral spastic cerebral palsy



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ABSTRACT

Background: Although individuals with bilateral spastic cerebral palsy (BSCP) exhibit several deficits in anticipatory postural adjustments (APAs) while standing, effects of severity of motor disability on their APAs are unclear.

Aims: To determine whether individuals with BSCP exhibit severity-dependent deficits in APAs.

Methods and procedures: Seven individuals with level II BSCP (BSCP-II group) and seven with level III BSCP (BSCP-III group) according to the Gross Motor Function Classification System and seven healthy controls lifted a load under two different load conditions.

Outcomes and results: Anticipatory activities of the erector spinae (ES), medial hamstring (MH), and gastrocnemius (GCM) were smaller in the two BSCP groups than in the control group. Although the anticipatory GCM activity was similar between the BSCP groups, the ES and MH activities were larger in the BSCP-II group than in the BSCP-III group. In the BSCP-II group, an increase in anticipatory activity with an increase in load was observed in the MH, but not in the GCM. In the BSCP-III group, load-related modulation was not found in the MH or GCM.

Conclusions and implications: The present findings suggest that in individuals with BSCP with severe motor disability, APA deficits extend to more proximal parts of the body.

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What this paper adds?

This study examined APAs associated with lifting a load while standing, revealing the following findings: (1) anticipatory postural muscle activities are smaller in individuals with BSCP; (2) lower leg muscles play minor roles in APAs in individuals with BSCP; and (3) APA deficits extend proximally in individuals with BSCP with severe motor disability.

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1. Introduction

Cerebral palsy (CP) describes a group of disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain (Bax et al., 2005). Bilateral spastic CP (BSCP) is a sub-type of spastic CP, in which limbs on both sides of the body are involved (SCPE, 2000). Although some individuals with BSCP are able to stand and walk independently with or without assistive devices (Badell-Ribera, 1985), these individuals have problems with postural control while standing (De Graaf-Peters et al., 2007). Because postural control is a prerequisite for many daily activities, it is important to examine stance postural control in individuals with BSCP.

When standing humans voluntarily move an arm, the postural muscles of the lower limbs and trunk that control standing posture are activated in advance of the voluntary arm movement (Belen'kiĭ, Gurfinkel', & Pal'tsev, 1967). This type of postural control, known as an anticipatory postural adjustment (APA), is believed to reduce the effects of forthcoming perturbations caused by voluntary movement on posture and equilibrium (Bouisset & Zattara, 1981). Postural perturbations caused by voluntary movement are counteracted by direction-specific postural muscle activity (Aruin & Latash, 1995). For example, the postural muscles on the dorsal side of the body are activated in advance of perturbations inducing a forward body sway. In addition, the direction-specific postural muscle activity is modulated according to task conditions (Yiou, Caderby, & Hussein, 2012). For example, anticipatory postural muscle activity increases with an increasing degree of postural perturbation caused by a voluntary movement. Therefore, the ability to generate adequate APAs is considered to be essential to perform various voluntary movements while standing (Bouisset & Do, 2008; Massion, 1998).

Recent studies have revealed several characteristics of APAs while standing in individuals with BSCP who can stand without support. These findings can be summarized as follows: (1) although individuals with BSCP are able to produce directionally specific APAs, the timing of anticipatory activation is delayed, particularly in lower leg muscles (Tomita et al., 2011), and the activation magnitude is insufficiently small (Girolami, Shiratori, & Aruin, 2011; Tomita, Fukaya et al., 2010; Tomita et al., 2011); (2) anticipatory inhibition of postural muscle activities of the lower limbs is hardly observed (Tomita, Fukaya, Totsuka, & Tsukahara, 2013); (3) individuals with BSCP exhibit a lack of adequate task-specific modulation of anticipatory activation or inhibition of postural muscles (Tomita et al., 2011, 2013); and (4) these deficits in APAs may be related to a larger disturbance of postural equilibrium during voluntary movement (Tomita, Fukaya et al., 2010; Tomita et al., 2011, 2013).

The severity of motor disabilities varies greatly among individuals with BSCP. The Gross Motor Function Classification System (GMFCS) is a five-level classification system that differentiates children with CP based on the child's current gross motor abilities, limitations in gross motor function, and need for assistive technology and wheeled mobility (Palisano, Rosenbaum, Walter, Russell, & Galuppi, 1997). Previous studies examining the relationships between scores of clinical functional balance tests and levels of the GMFCS reported that individuals with CP with severe motor disability exhibit poorer functional balance abilities (Jantakat, Ramrit, Emasithi, & Siritaratiwat, 2014; Pavão, Barbosa, Sato Tde, & Rocha, 2014). Because APAs are a basic mechanism of functional balance abilities, these findings raise the possibility that the characteristics of APA deficits differ among individuals with BSCP with varying levels of motor disabilities.

The present study was designed to determine whether APAs while standing are more impaired in individuals with BSCP with severe motor disabilities. For this purpose, we examined anticipatory postural muscle activities and a resultant disturbance of postural equilibrium associated with lifting a load while standing in individuals with level II and level III BSCP according to the GMFCS–Expanded & Revised version (Palisano, Ronsenbaum, Barlett, & Livingston, 2007) (general headings for each level: walks with limitations and walks using a hand-held mobility device, respectively).

2. Methods

2.1. Participants

Seven individuals with GMFCS level II BSCP (BSCP-II group, 3 females and 4 males, 12–22 years), seven individuals with GMFCS level III BSCP (BSCP-III group, 3 females and 4 males, 13–23 years), and seven individuals without disability (control group, 3 females and 4 males, 12–22 years) participated in this study. The inclusion criteria for the BSCP-II and BSCP-III groups were as follows: no surgical procedures within 2 years prior to participation; and no history of any genetic or neurological disorder other than BSCP. All participants with BSCP could stand with their entire soles in contact with the floor without support for 3 min or more. No participants in the control group had any history of neurological or orthopedic impairment.

Table 1 shows demographic data of each participant group. There were no significant differences with respect to age, height, weight, foot length, or body mass index between the three groups.

After an explanation of the experimental protocols, all participants and their parents provided written informed consent in accordance with the Declaration of Helsinki. This study was approved by the Ethics Committee at Toyohashi SOZO University.

2.2. Apparatus and data recording

All measurements were performed with participants standing barefoot on a force platform (measurement error ≤ 1 mm; G-6100, Anima, Japan) and with their hands strapped to a wooden board (Fig. 1). The force platform was used to measure the positions of the center of pressure (CoP) in the mediolateral and anteroposterior directions (CoPx and CoPy, respectively).

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