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Processes of anticipatory postural adjustment and step movement of gait initiation

Hiroki Mizusawa [a], Yasutomo Jono [a], Yasuyuki Iwata [a], Atsushi Kinoshita [a], Koichi Hiraoka [b,*]

[a] Graduate School of Comprehensive Rehabilitation, Osaka Prefecture University, Habikino, Osaka, Japan
[b] College of Health and Human Sciences, Osaka Prefecture University, Habikino, Osaka, Japan

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ABSTRACT

The purpose of this study was to elucidate whether the anticipatory postural adjustment (APA) and focal step movement of gait initiation are produced as a single process or different processes and whether the APA receives an inhibitory drive from the ongoing stop process of gait initiation. Healthy humans initiated gait in response to a first visual cue that instructed the initial swing leg. In some trials, a switch or stop cue was also provided after the first cue. When the stop cue was provided, participants withheld gait initiation. When the switch cue was provided, participants immediately switched the initial swing leg. In both the stop and switch tasks, the APA in response to the first cue, represented by the S1 period of the displacement of the center of pressure, appeared in more than half of the trials in which the withholding of gait initiation or switching of the initial swing leg was successfully completed. These findings indicate that the APA and focal step movement of gait initiation are produced as a dual process. In trials in which the APA in response to the first cue appeared, the amplitude and duration of the APA were decreased when the participants switched the initial swing leg or withheld gait initiation. This finding indicates that the ongoing stop process of gait initiation produces an inhibitory drive over the APA. The decreases in the amplitude and duration of the APA during the switching of the initial swing leg were similar to those during the withholding of gait initiation; moreover, the decreases during the switching of the initial swing leg were positively correlated with the decreases during the withholding of gait initiation. Thus, the stop processes during switching the initial swing leg and withholding gait initiation likely share a common inhibitory mechanism over the APA.

1. Introduction

Gait initiation is referred to as the transition between an upright stance and steady-state gait (Caderby et al., 2013; Mickelborough, Van Der Linden, Tallis, & Ennos, 2004). Leg movement of gait initiation is initiated with heel off of the initial swing leg (Caderby, Yiou, Peyrot, Begon, & Dalleau, 2014; Ruget, Blouin, Teasdale, & Mouchnino, 2008). Prior to heel off of the initial swing leg, the displacement of the center of pressure (COP) occurs (Burleigh-Jacobs, Horak, Nutt, & Obeso, 1997; Mann, Hagy, White, & Liddell, 1979; Ruget et al., 2008). The COP initially moves to the initial swing side and backward (S1 period), subsequently moves to the initial stance side in the next moment (S2 period), and ultimately moves forward (S3 period)

* Corresponding author at: College of Health and Human Sciences, Osaka Prefecture University, 3-7-30 Habikino, Habikino City, Osaka 583-8555, Japan.
E-mail address: hiraoka@rehab.osakafu-u.ac.jp (K. Hiraoka).

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before gait initiation as shown in Fig. 1 (Hass, Waddell, Wolf, Juncos, & Gregor, 2008). The COP displacement in the S1 period correlates well with the momentum to the initial stance leg before gait initiation, which indicates that the medio-lateral displacement of the COP in the S1 period contributes to the shift of the center of gravity to the initial stance leg (Polcyn, Lipsitz, Kerrigan, & Collins, 1998). Based on this view, the COP displacement in the S1 period before gait initiation is considered an anticipatory postural adjustment (APA) (Caderby et al., 2014; Mouchnino, Robert, Ruget, Blouin, & Simoneau, 2012; Sun, Guerra, & Shea, 2015).

One issue to be elucidated regarding the APA that precedes gait initiation is whether the APA and focal step movement of gait initiation are produced as a single process or different processes. There are two potential models of this issue (Massion, 1992; Massion, Alexandrov, & Frolov, 2004; Stuart, 2005). One model includes a single process model in which the APA and focal step movement are produced as a single process, and the other model includes a dual process model in which the APA and focal step movement are produced as different processes (Caderby et al., 2014; Corbeil & Anaka, 2011; Hass et al., 2008; Huntley & Zettel, 2015; Leonard, Brown, & Stapley, 2009; Robert, Blouin, Ruget, & Mouchnino, 2007; Schepens & Drew, 2003; Slijper, Latash, & Mordkoff, 2002; Stamenkovic & Stapley, 2016). Several previous findings support the dual process model. There was a decoupling of the onset of the APA and that of the reaching movement in cats (Schepens & Drew, 2003). The path and kinematics of hand movement during reaching to a target was not changed by the modulation of the initial APA setting in standing (Robert et al., 2007). Moreover, the reaction time of arm movement in standing was negatively correlated with the onset of the APA (Slijper et al., 2002).

However, other findings support the single process model. Both the onset of the focal muscle activity and the onset of the postural muscle activity were similarly changed with temporal and spatial foreknowledge (Huntley & Zettel, 2015). The postural activity of the leg muscles that preceded reaching was dependent on the direction of the reaching (Leonard et al., 2009). Similarly, the trunk muscle activity during stance was dependent on the direction of reaching (Stamenkovic & Stapley, 2016). These previous findings support a view that focal movement and postural activity are produced as a single process. Moreover, there are several findings that indicate the APA and focal step movement of gait initiation are produced as a single process. Limb movement of gait initiation is delayed when the APA is mechanically perturbed, which indicates that the APA process interacts with the process of the focal step movement of gait initiation (Mille, Simoneau, & Rogers, 2014). The APA amplitude increases as the velocity of gait initiation increases (Caderby et al., 2014). The APA amplitude before stepping depends on the direction of the initial step (Corbeil & Anaka, 2011; Hass et al., 2008).

The present study was conducted to obtain further insights into the coordination between the APA and focal step movement of gait initiation by investigating the COPs in three tasks. In one task, the participants initiated gait with the leg instructed by a first cue. In the second task, the initial swing leg of gait initiation in response to a first cue was switched

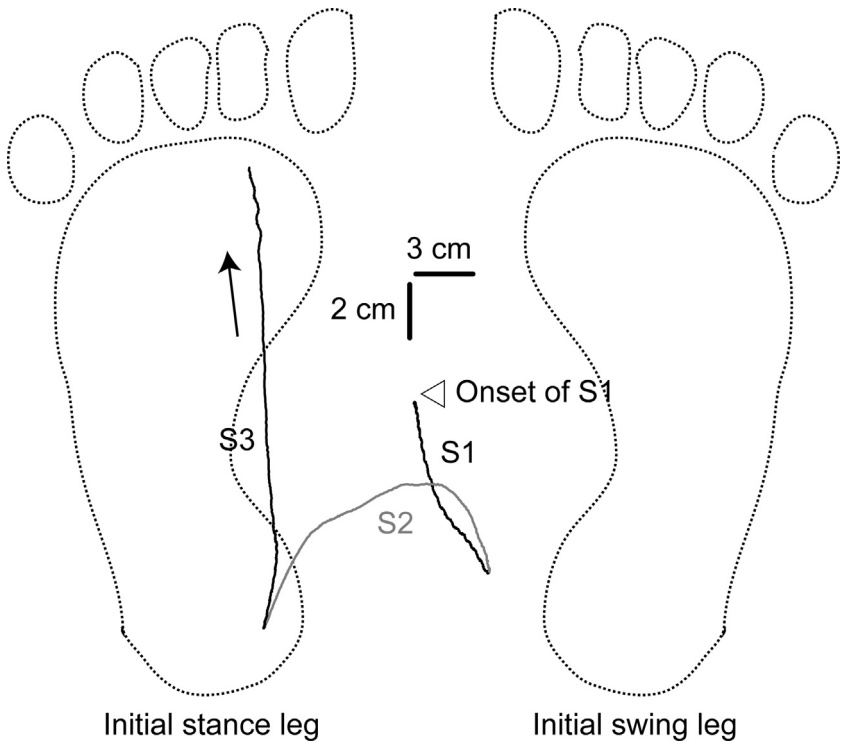

Fig. 1. Three periods of the COP displacement in response to the first cue before gait initiation in the go task of the right leg condition. An arrow indicates the direction of the COP displacement.