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Effect of haptic sensory input through a fluttering cloth on tandem gait performance

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ABSTRACT

This study investigated the effects of haptic sensory input through a fluttering cloth on balance control during locomotion. Twenty-one healthy men performed a tandem gait test for 4 m with their eyes closed under two different conditions: (1) wearing only half or short tights (HT-condition), or (2) wearing a fluttering cloth that was wrapped around the waist and extended to the lower leg (CLOTH-condition). Participants performed two trials with a 3-min rest period. The first trial involved the HT-condition, whereas the second trial involved either the CLOTH-condition (n = 11), or the HT-condition again (n = 10). The gait time and double support phase were significantly lower in the CLOTH-condition than in the HT-condition, and the relationship between the change in these two parameters was significant (r = 0.74, $P < 0.01$). Further, the relationship between the change in gait time and subjective walking sensation (evaluated through a visual-analogue scale) was significant in the CLOTH-condition (r = 0.82, $P < 0.01$). Therefore, if the participant demonstrated improved gait performance while wearing a fluttering cloth, it was accompanied by an improvement in subjective walking sensation. These results suggest that wearing a fluttering cloth can provide a haptic sensory cue to enhance the individuals' perception of their body orientation, which contributes to better balance control during locomotion. Therefore, locomotive ability may improve depending on the shape of the garment.

1. Introduction

Postural stability during standing or locomotion is believed to play an important role in independent mobility, which contributes to quality of life. Many researchers have attempted to increase postural stability using various tools and procedures. Previous studies have reported that providing additional haptic sensory input through a light finger touch decreases postural sway in various physical positions (Jeka, 1998; Jeka & Lackner, 1994, 1995; Nagano, Yoshioka, Hay, & Fukashiro, 2006; Oshita & Yano, 2013; Riley, Stoffregen, Grocki, & Turvey, 1999). Jeka et al. (1994) and Jeka and Lackner (1995) showed that a light touch made with the tip of the index finger on a surface at waist height (producing insufficient force (< 1 N) to have any appreciable mechanical effect on stability) resulted in decreased postural sway during the tandem stance. This "light touch effect" has also been observed and reported during light finger contact with an unstable object. Riley et al. (1999) reported that the application of a light touch to a cloth curtain decreased postural sway. It has also been found that lightly touching a finger to the upper part of one's own thighs significantly decreases postural sway while standing (Nagano et al., 2006; Oshita & Yano, 2013). These findings indicate that lightly touching an object while standing quietly primarily provides information about the relative movement of the body segments. In effect, it helps an

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individual sense the movements of the trunk, arms, and thighs, relative to each other.

Along with postural control during static stance (static balance control), postural control during movement (dynamic balance control) is also important for daily activity. Hageman, Leibowitz, and Blanke (1995) reported that although static balance does not decrease in the elderly until remarkable functional declines occur, dynamic balance decreases much earlier. Riemann, Caggiano, and Lephart (1999) and Sell (2011) suggested the making of a shift away from static balance testing toward dynamic balance testing, as it may be more functional and applicable in healthy, physically active individuals. From the viewpoint of applying light touch effects during daily activities, lightly touching a real cane improves not only static balance (Oshita & Yano, 2016a) but also dynamic balance (Oshita & Yano, 2015). Moreover, both dynamic balance and balance control while walking or performing locomotive activities are also important in preventing falls and fall-related injuries (Campbell, Borrie, & Spears, 1989; Granata & Lockhart, 2008). Therefore, a study should make considerations regarding balance control while walking or performing locomotive activities to develop light touch effects for useful applications during daily activities.

The association between postural stability and light touch is of particular interest to researchers because of its influence on balance control, both in the static and dynamic stances. However, it is unusual for an individual to lightly touch an object while walking or during another locomotive activity. Lightly touching an object is likely to impede the performance of certain types of human movement. For instance, it would be difficult to walk while touching something. However, a previous study found that a passive haptic stimulus applied to the skin of the leg, a small piece of Velcro® (Velcro Companies, Middlewich, UK) attached to a flexible mount applied to three different sites on the leg, also significantly reduces body sway during standing, even in healthy young individuals (Menz, Lord, & Fitzpatrick, 2006). Further, light touch to a cloth decreased postural sway (Riley et al., 1999) and postural tremor (Oshita & Yano, 2016b). If haptic input through clothing can provide a light touch effect, it could be used to improve human movement. Furthermore, this finding would be useful for the development of a garment that could be worn while performing daily activities. Therefore, this study investigated the effects of contact with cloth on balance control during locomotion.

2. Method

2.1. Participants

Data were obtained from 21 healthy men (age, 20–30 years old; height, 1.63–1.83 m; weight, 55.3–72.6 kg) with no current or previous medical history of neural, muscular, or skeletal disorders. The participants were randomly stratified to either a control group (n = 10) or the experimental group (n = 11). Prior to inclusion in the study, the participants were informed of the purpose of the study, and informed consent was obtained from each of them. Further, this study was approved by the Human Ethics Committee of Graduate School of Human Development and Environment, Kobe University.

2.2. Experimental setup Fig. 1

To evaluate locomotive ability, participants were asked to perform a tandem (heel-to-toe) gait. The participants were instructed to remove their footwear, step onto the edge of a walkway board with one foot, and maintain a tandem stance with the other foot on the floor. The walkway board was 75 mm wide, 15 mm high, and 4 m long, and had a firm surface. The experimenter then instructed the participants to close their eyes, and begin walking in a tandem gait (with the heel of one foot continually placed directly in front of the toe of the other foot) along the board. When the participants were close to reaching the end of the board, the experimenter instructed them to finish (i.e., stop) walking. During the board walk, the participants were asked to avoid any contact between the

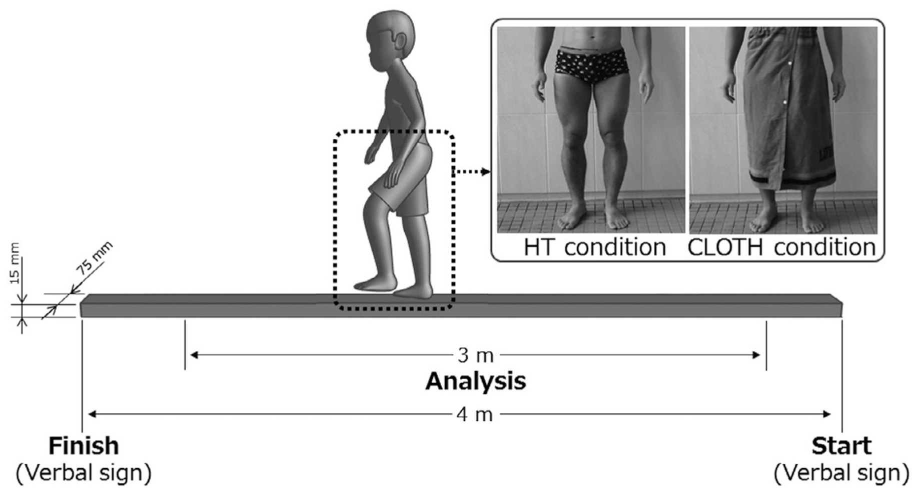

Fig. 1. Schematic of the experimental design.