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Frontal plane margin of stability is increased during texting while walking

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ABSTRACT

Injurious falls associated with cell phone use during ambulation are increasingly common. Studies examining texting while walking suggest this task alters the attentional component of walking to the extent that safety may be compromised. Here, we quantified the extent to which frontal plane dynamic stability while walking was affected by the cognitive and physical demands of texting. Twenty experienced texters performed four, 10-min treadmill walking tasks at a self-selected velocity in random order: (1) normal walk (control), (2) walking while verbally performing mathematical calculations (cognitive demand), (3) walking while bimanually holding and looking directly at a phone (physical demand), and (4) walking while texting continuous mathematical calculations (cognitive and physical). We quantified the frontal plane minimum margin of stability (MOS_{min}), a measure that considers the position and normalized velocity of the center of mass with respect to the lateral border of the base of support was calculated over each 10-min walking period. Compared to the normal walking condition, the texting and phone holding conditions resulted in a small but significant (6%) increase in MOS_{min} ($p = 0.005$ and 0.026, respectively). Compared to normal walking, the effect of performing mathematical calculations on MOS_{min} was not significant ($p = 0.80$). These results suggest that frontal plane stability of experienced texters during controlled treadmill walking conditions can be affected by the physical, but not the cognitive demand of texting. This may represent a compensatory mechanism by the CNS to ensure stability in the event of an unexpected disturbance.

1. Introduction

With the availability of electronic content that can be easily accessed using cell phones, texting while walking has become a commonly observed motor task, one that is performed with a wide range of effectiveness. Reports of accidents attributed to texting include people walking into obstacles, falling into unseen fountains, and falling off treadmills frequently appear in the popular press [1–3]. In 2008, emergency rooms reported 1000 visits due to cell phone usage, including texting, with injuries ranging from lacerations to ankle fractures [3,4]. Comparison of over-ground walking trajectories toward a target with and without texting revealed that during texting, subjects demonstrated a 61% lateral deviation from the most direct pathway, resulting in a 13% increase in distance traveled [5]. These authors concluded that the demands on executive function and working memory during texting while walking in the community may compromise safety due to diminished attentiveness to environmental cues.

Safe community ambulation requires that stability is monitored on a step-by-step basis. Disturbances to stability can occur while walking in a complex and cluttered environment and executive function and attention may be necessary to modify the gait pattern and maintain stability. Even during level walking, gait pattern modifications occur, suggesting the need for some control to maintain dynamic stability on a step-by-step basis [6,7]. Safe ambulation appears to require greater active control of frontal, as compared to sagittal plane dynamics [6,8]. A decline in frontal plane stability has been linked to falls in healthy elderly [9]. Therefore, it is reasonable to assume that during level walking, some attention is allocated toward control over step-to-step frontal plane dynamics. Engaging in dual tasks that compete for this attention may negatively impact frontal plane dynamic stability. Because texting and walking requires attention directed

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to both the physical task of holding and viewing the phone and the cognitive generation of the text, it is possible that texting and walking could negatively impact frontal plane dynamic stability.

Our purpose was to determine the extent to which the cognitive and physical demands of texting during walking affect frontal plane dynamic stability as measured by the "margin of stability" (MOS) [10]. By using a calculated vector quantity defined as the extrapolated center of mass (xCOM), the MOS accounts for both the position and the velocity of the center of mass (COM) relative to an individual's base of support (BOS). The magnitude of MOS is proportional to the impulse required to destabilize an individual, and during locomotion can be controlled by altering medio-lateral foot placement within the frontal plane [10,11]. It has been suggested that the central nervous system uses the information encapsulated by this measure to regulate stability [10].

In healthy populations, frontal plane MOS appears to be invariant when the mechanics of the walking task are altered such as in continuous treadmill vs. overground walking [12,13]. However, in these studies, subjects retain full use of visual and vestibular feedback mechanisms and are able to employ compensatory arm movements to ensure stability on a step-by-step basis. Given the number of reported injuries that occur as a result of texting while walking, it is possible that the combined physical and cognitive demands required for texting and walking could negatively affect compensatory strategies necessary to maintain frontal plane dynamic stability. Therefore, in light of the active control of frontal plane foot placement during gait, we hypothesized that both the physical and cognitive demands of texting would significantly decrease frontal plane dynamic stability during steady-state treadmill walking.

2. Methods

Twenty healthy young subjects (10 male; mean age ± sd: 23.3 ± 2.3; height: 170.2 ± 8.9 cm) volunteered to participate and provided written informed consent. The study was approved by the Institutional Review Board. Subjects were considered experienced texters; all exceeding 200 texts per month minimum.

The protocol consisted of four, 10-min walking trials on a treadmill at a self-selected velocity. Prior to data collection, subjects were familiarized with the treadmill and the self-selected walking velocity determined by increasing the treadmill velocity until the subject indicated that the pace was "purposeful". To ensure that this velocity was not too slow, velocity was increased until it became uncomfortable, and then decreased until the subject again indicated the velocity was purposeful. This velocity was maintained for each trial. The mean ± s.d. self-selected velocity for all subjects was 1.19 m/s ± 0.19.

The four walking trials, performed in random order, included a control trial of normal walking while looking forward at a picture on the wall. A second trial required subjects to perform continuous mathematical calculations for 10 min while walking. The investigator assigned a starting number (#) between 7 and 30 at the beginning of the trial. Subjects performed the following calculation variation of serial 7's: {[(# − 7) +4] * 2}, verbalizing the answer to each sequential operation, which was recorded by the investigator. When the answers approached 1000, the subject was immediately given a new starting number and calculations continued. This specific calculation was used to minimize the ability of the subject to determine a mathematical pattern, and to provide an uninterrupted intellectual task throughout the 10 min walking period. A visual guide for the mathematical operation to be executed was placed on the wall in front of the subjects. A third trial involved bimanually holding and looking at a cell phone while walking. A fourth trial involved bimanually holding a cell phone and texting sequential mathematical calculations in the same manner described above, but with different starting numbers; subjects verbally notified the investigator for a new starting number when the sum approached 1000. Texts were emailed to one investigator immediately after completion of that trial. All mathematical calculations were assessed for rate and accuracy. During all trials, subjects were instructed to perform the overall task to the best of their abilities; the instruction set deliberately avoided emphasis on performance of either gait or condition.

Subjects wore their own comfortable shoes and a safety harness attached by a dynamic rope affixed to a ceiling mounted rolling trolley. The motions of 22 passively reflective markers placed over bony landmarks [14] were tracked using an eight camera motion capture system operating at 60 Hz (Motion Analysis, Santa Rosa, CA). A 12-segment rigid body model was constructed from which the whole body center of mass (COM) location and kinematic measures were derived (Matlab, Mathworks, Natick, MA).

To test for baseline calculation accuracy and determine if effort was invested in cognitive task, subjects performed additional calculations using the same method during a 5 min standing trial. Three of the twenty subjects were unable to complete this task due to personal time constraints.

Dynamic stability was quantified as the MOS [10], which considers the position and normalized velocity of the COM (vCOM) with respect to the lateral border of the base of support (BOS). The calculation of the lateral border of the BOS has been previously described [12] in detail. Briefly, the lateral edge of the base of support was estimated with respect to the heel and second metatarsophalangeal marker as well as anthropometric estimations of the foot width. The vCOM was calculated from the COM time-displacement data using a first-central difference algorithm and normalized by the eigenfrequency, i.e., the natural frequency of a non-inverted pendulum 1.34 times leg length [15]. The position of the COM and normalized vCOM were combined to quantify the xCOM expressed in mm [12]:

$$\text{xCOM} = \text{COM} + \text{vCOM}/\surd(g/(1.34 * \text{leglength})$$

Dynamic stability was quantified as the MOS, which was calculated as the distance between the xCOM and the lateral border of the BOS, expressed in mm [12]:

$$\text{MOS} = \text{BOS}_{\text{lat}} - \text{xCOM}$$

We calculated the MOS from heel strike to contralateral toe off and selected the minimum value (MOS_{min}) [12]. Repeated measure ANOVA was used to test the effect of each condition on MOS_{min}. Post hoc analyses were performed using Bonferroni adjusted *t*-tests. Paired *t*-tests were used to determine if calculation frequency and accuracy differed between texting and calculation conditions. All analysis was done using IBM SPSS 19.0 (Armonk, NY), with statistical significance set at $p < 0.05$.

3. Results

Frontal plane dynamic stability remained unchanged or increased as individuals attended to cognitive and physical dual tasks of texting and walking, respectively (Fig. 1). Compared to baseline standing, calculation accuracy was unchanged during both the texting and calculation conditions; however calculation rate slowed upon the addition of each physical task (Table 1).

4. Discussion

The purpose of this study was to determine the extent to which cognitive and physical demands of texting during walking affect frontal plane dynamic stability as measured by the MOS_{min}. We hypothesized that both the physical and cognitive demands of