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Concurrent phone texting alters crossing behavior and induces gait imbalance during obstacle crossing

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Abstract

Texting during walking has become a very common daily activity and could alter gait performance, especially during locomotion when additional visual attention is demanded, such as obstacle crossing. The purpose of this study was to examine biomechanical changes in obstructed gait characteristics while engaging in a phone texting activity. Gait analyses were performed on ten young healthy adults under the following two tasks: 1) walking and crossing an obstacle set at a 10% of the subject's height and 2) walking and crossing an obstacle while responding to a text message. Whole body motion data were collected with a 10-camera motion capture system. Our data demonstrated that a conservative gait pattern was adopted while performing texting when approaching and crossing over the obstacle, which was indicated by slower walking speeds and greater toe-obstacle clearances. This gait pattern was, however, accompanied by a greater body sway in the frontal plane during crossing, which could be an indication of perturbed gait balance control. Increased visual-attentional demand from a concurrent phone texting could negatively impact young pedestrians' safety during obstacle crossing.

Keywords

Texting; Obstacle-crossing; Foot placement; Toe-obstacle clearance; Center of mass

1. Introduction

Concurrently performing a cognitive task, such as talking or texting on the phone, during walking has been reported as one of causes for accidental injuries in pedestrians, as a result of falls or collisions [1]. Compared to a non-visual demanding task (i.e. talking or listening to music), phone texting during walking has been reported to slow down gait speeds [2,3], increase lateral deviations from the targeted path [2], and require greater demands on dynamic postural control [4]. As phone texting has become the mainstream of

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Conflict of interest

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communication currently [5], it is important to examine how phone texting while walking influence gait performance and to identify biomechanical changes that could be related to accidental injury.

Previous studies have reported several conservative adjustments on gait spatiotemporal variables while texting during level walking, including a slower walking speed and deteriorated lateral balance [2,6–8]. There is still a lack of knowledge on how phone texting affects the performance of a gait task that also requires a significant visual attention, such as obstacle crossing [9,10]. Successful obstacle avoidance relies on sufficient visuospatial attentional resources to plan for appropriate foot trajectories [11]. Visuospatial attention is engaged when an individual is approximately two steps prior to reaching the obstacle [11,12]. In addition, a gaze fixation on the obstacle is required to gather enough information about obstacle characteristics and plan for a safe crossing [12]. However, phone texting would demand constantly orienting and re-orienting the pedestrian's vision and attention among phone, travel path, and the obstacle [13,14]. Such interference is expected to impose changes to an individual's crossing behavior and perturb balance control. To bridge this knowledge gap, it is important to examine how phone texting alters dynamic balance control, as determined by the whole body center of mass (CoM) motion, while crossing an obstacle during walking.

Young adults are most likely to own a smart phone and use it for texting during daily activities [15], as well as to report cellular phone use related injuries [1]. The purposes of this study were to examine changes in obstacle crossing characteristics and gait balance control while engaging in a phone texting activity in young adults and the association between texting-induced changes in crossing characteristics and gait balance control. We hypothesized that individuals adopt a more conservative crossing strategy to compensate for increased demand of dynamic balance control during phone texting.

2. Material and methods

A priori power analysis, with a 2-tails alpha error of 0.05 and 80% power, was conducted using the lateral deviation from a straight walking path previously reported in the literature [7]. It indicated that a minimum of 9 participants were required for the study. Ten healthy young adults (5 males and 5 females, age mean $\pm$ SD: 21.5 $\pm$ 2.1 years) were recruited for the study. Prior to testing, participants were surveyed with questions related to their cellular phone usages and health histories for participation eligibility. All participants reported no histories of neurological disease, musculoskeletal impairments, uncorrectable vision problems, symptoms of dizziness or light-headedness, or any other medical conditions that may affect the ability to walk and cross over an obstacle. In addition, they all reported to have had more than one year experience using a touch-screen smart phone and texted more than five messages per day on average. All participants were informed of the experimental protocol, which was approved by the Institutional Review Board of the university, and signed the informed consent form.

Each participant performed two different gait task conditions: obstacle-crossing only (OC) and texting while obstacle crossing (OC + texting). In the OC condition, participants were

instructed to walk toward to an obstacle placed in the middle of a 15 m walkway, cross over it and continue walking towards the end of the walkway at their self-selected speeds and manners. In the OC + texting condition, they were asked to perform the same obstructed gait task as in the OC condition, but were required to concurrently respond to a text message. The condition sequence was determined randomly, and five walking trials were performed for each condition. The obstacle was made of a plastic pipe with a diameter of 1.3 cm and a length of 1.3 m, which was placed on two adjustable metal stands at 10% of each participant's height. The obstacle was placed at a location approximately 8 m away from the starting line and visible to the participant. The distance would be able to allow the participant reaching a steady-state gait before encountering the obstacle.

The text messages used in OC + texting condition were all short questions with specific answers (for example: What is the third month of the year?). The message was sent to an iPod Touch held by the participant during the gait cycle prior to crossing the obstacle, as previous studies indicated that the visuospatial attention was engaged when an individual was approximately two steps prior to reaching the obstacle [11,12]. Participants were asked to respond to the message by texting back their answers.

A ten-camera motion capture system (Motion Analysis Corp., Santa Rosa, CA) was used to collect kinematic data of the whole body at a sampling frequency of 60 Hz. A set of 29 retro-reflective markers was placed on bony landmarks of the participant [16], and two additional markers were affixed at the both ends of obstacle. Marker trajectory data were filtered with a low-pass, fourth order Butterworth filter with a cutoff frequency of 8 Hz and processed using the Cortex software (Motion Analysis Corp., Santa Rosa, CA).

Dependent variables for obstacle crossing characteristics included the toe-obstacle clearance and foot placements of the leading and trailing feet. Toe-obstacle clearance was calculated as the vertical distance between the obstacle and toe marker placed between 2nd and 3rd metatarsal when the toe marker is directly above the obstacle. Foot placement of trailing foot was determined by the horizontal distance between the obstacle and toe marker of the trailing foot prior to crossing, while the foot placement of the leading foot was determined by the horizontal distance between the obstacle and heel marker of the leading foot immediately after crossing the obstacle. Gait balance control was examined using the peak forward velocity of the center-of-mass (vCoM) and the total medial-lateral CoM displacement (M-L CoM) during approaching and crossing strides, respectively. The whole-body center of mass (CoM) was calculated as the weighted sum of 13 body segments [10]. Anthropometric reference data were adopted from the initial work of Dempster [17]. Gait speeds were calculated as the average forward CoM velocity during a gait cycle. The crossing stride was defined as the gait cycle during stepping over the obstacle between heel strikes of the trailing foot immediately before and after crossing the obstacle, whereas the approaching stride was defined as the gait cycle immediately prior to the crossing stride.

Paired-sample t-tests were applied to detect differences between two gait conditions in all dependent variables with α level set at 0.05. The effect size was also reported with Hedges's g_{rm} or Hedges's g_{av} using the spreadsheet provided by Lakens [18]. In addition, Pearson correlation analyses were used to examine the association between phone texting-induced

changes (value from OC + texting condition – value from OC only condition) in gait balance control (M-L CoM) and obstacle crossing characteristics variables. All statistical analyses were conducted using SPSS version 23.0 (IBM Corp., Armonk, NY).

3. Results

Participants reported sending an average of 127 text messages daily on their cellular phones. Eight participants had the experience of texting while crossing a street, and two participants reported feeling unsafe with distracted walking.

When texting concurrently, participants demonstrated a significantly slower gait speed in both approaching and crossing strides than they did during the OC only condition (approaching: $t(9) = 3.76$, $p = .004$, 95% CI [0.04, 0.17], Hedges's $g_{av} = 1.40$; crossing: $t(9) = 4.22$, $p < .002$, 95% CI [0.07, 0.24], Hedges's $g_{rm} = 1.52$; Table 1). When compared to the OC condition, significant increases in toe-obstacle clearances were detected for both trailing and leading feet in the OC + texting condition (leading: $t(9) = -4.76$, $p = .001$, 95% CI [-4.91, -1.75], Hedges's $g_{av} = 0.81$; trailing: $t(9) = -3.03$, $p = 0.014$, 95% CI [-10.77, -1.57], Hedges's $g_{av} = 1.06$; Table 1). Immediately after crossing, the leading foot was placed at a significantly closer position ($t(9) = 2.47$, $p = .036$, 95% CI [0.34, 7.92], Hedges's $g_{av} = 0.84$) to the obstacle in the OC + texting condition as compared to the OC condition. However, no significant differences were detected for the trailing foot placement between gait conditions.

When compared to the OC only condition, a significant increase in total medial-lateral CoM displacement during the crossing stride was detected in OC + texting condition ($t(9) = -3.08$, $p = .013$, 95% CI [-2.97, -0.45], Hedges's $g_{rm} = 1.34$) but not during the approaching stride. In addition, participants demonstrated significantly slower peak CoM forward velocity during OC + texting condition ($t(9) = 3.56$, $p = .006$, 95% CI [0.04, 0.17], Hedges's $g_{av} = 1.11$).

Pearson correlation analyses revealed that the texting-induced changes in M-L CoM were significantly associated with changes in the toe-obstacle clearance of trailing limb ($r = .683$, $p = .029$, Fig. 1a) and foot placement of the leading limb ($r = .796$, $p = .006$, Fig. 1b).

4. Discussion

The current study investigated how concurrent phone texting alters gait characteristics and balance control during obstacle crossing in healthy young adults. Our findings were two-fold. First, a conservative gait pattern was adopted, as participants were able to accommodate a concurrent texting task with a more cautious crossing behavior, i.e., walking slower with a greater toe-obstacle clearance. Secondly, such behavioral changes are accompanied with a closer leading foot placement to the obstacle and greater body sway in the frontal plane during crossing, which could be an indication of perturbed gait balance control.

Most studies on cellular phone texting are limited to unobstructed level walking [2,6–8], only few studies have examined its effects on more complex walking conditions, such as

stair ascending/descending [19,20] or obstacle avoidance [21]. Although reductions in the toe-step clearances were reported during stair ascending with concurrent texting [19], staircase dimension and limited space for foot placement could restrict the foot elevation. Dual-task effects on attentional demands and crossing behaviors have been examined using different visual [9] or physical [10] tasks, but not with phone texting, which imposes cognitive, visual and motor demands. Our results showed that the toe-obstacle clearances of both limbs were increased while texting concurrently. This finding was consistent with those of previous studies [20,21] and suggests that participants recognized the impending distraction from the texting task and intentionally planned a conservative crossing strategy by walking slower and lifting their feet higher to avoid tripping. Moreover, these gait modifications are similar to those reported in a previous study in which the participant's visual field was blocked using goggles while approaching an obstacle [22], indicating a significant demand on visual attention while texting during obstacle crossing.

Reductions in gait speeds while texting and crossing obstacle concurrently from this current study were approximately 9% and 15% during the approaching and crossing strides, respectively. Previous studies have reported a similar range of gait speed reduction, 16 to 33%, on cellular phone use while walking [2,6,7,23]. Unlike typing test [6,8] or responding to math questions [19,24] or questions with lengthy answers [2,7] as were in previous studies, the text questions utilized in this study were short questions with specific answers. These differences in texting questions and answers may account for the smaller reduction in gait speeds found in the current study. All participants were able to reply to text messages without errors. Although no measurement pertaining texting speed was calculated, it may imply that young adults tend to prioritize texting over gait task to maintain texting accuracy at the expense of walking speed. However, the result of prioritization on texting may only be found in laboratory settings as young adults were shown to allocate attention equally between tasks in the real world settings [23].

In addition to walking slower with greater toe-obstacle clearances, the leading foot was placed at a closer location to the obstacle when concurrently texting. The increased leading foot toe-obstacle clearance would lengthen the swing foot trajectory and single-foot support duration. Such prolonged single-foot stance could induce a greater medial-lateral body sway and imbalance. Thus, a faster placement of the leading foot on the ground after crossing the obstacle would establish a larger base of support for a better stabilization, which would result a closer leading foot placement to the obstacle. Additionally, we found the step lengths during the approaching and crossing strides in the OC + texting condition were all significantly smaller when compared to those in the OC condition, which indicates the overall reduction in gait speed also contributes to this closer leading foot placement. This closer foot placement of leading foot to the obstacle may impose the risk of stepping onto the obstacle.

To our knowledge, this is the first study directly examining the whole-body CoM motion when texting while crossing an obstacle. The CoM displacement in the frontal plane was significantly increased during the crossing stride in the OC + texting condition. It has been reported that the medial-lateral CoM displacement is maintained consistently during unobstructed walking and crossing over obstacles of different heights in young adults [25]

and could be a sensitive indicator of gait imbalance in older adults [26] and to distinguish individuals with Parkinson's disease [27] or concussion [28] from healthy controls. The increased CoM medial-lateral sway in the OC + texting condition is similar to the amount of sway been observed from individuals with gait imbalance [26,28]. In addition, cognitive or visual distraction of cellular texting have been reported to induce a greater frontal plane pelvis excursion [8], deviation from walking along the straight line [2,6], greater lateral foot position from stride to stride [6], mediolateral drift of C7 marker [29]. Taking together, this could be an indication that the concurrent phone texting during obstacle crossing perturbs gait balance control.

It is likely that increased medial-lateral CoM displacement is related to reductions in walking speeds [30]. Pearson correlation analysis revealed no significant association between changes in the medial-lateral CoM displacement during crossing stride and changes in gait speeds between conditions. However, individuals who placed leading foot closer to the obstacle after crossing were found to demonstrate less increased frontal plane sway during crossing while concurrently texting, as a significant positive correlation was identified between changes in the leading foot placement and medial-lateral CoM displacement during crossing stride. Placing the leading foot closer to the obstacle may be used as a compensatory strategy to reduce the medial-lateral body sway induced by cellular phone texting and ensure a safe crossing. In addition, the positive association between texting-induced changes in the toe-obstacle clearance and frontal plane CoM sway could be another cause of balance perturbation that is originated from the concurrent texting.

There were limitations to this study. The form or posture used by each participant to hold the phone was not controlled, nor were its effects on the dependent variables examined. Texting and phone holding conditions have been shown to affect frontal plane dynamic stability during walking [24]. Studies may need to include an additional condition in which the participant holds the phone without responding to texting messages. Also, the effect of phone texting experience was not examined even though participants in this study used phone texting frequently. Furthermore, different types of texting questions that could better mimic real-world scenarios should be considered. Lastly, the task prioritization between phone texting and obstacle crossing was not specified in this study. However, all participants were asked to walk and respond to the texting task with their own manners.

In conclusion, findings from this study indicate that obstacle-crossing behavior and balance control were affected by concurrent cellular phone texting. A conservative gait pattern with slower walking speed and greater toe-obstacle clearances was observed. This gait pattern was, however, accompanied by a greater body sway in the frontal plane during crossing, which could be an indication of perturbed gait balance control. Increased visual-attentional demand from a concurrent phone texting could negatively impact young pedestrians' safety during obstacle crossing.

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Fig. 1. Scatterplots describing the relationship between texting-induced changes in (a) toe-obstacle clearances of trailing foot and (b) leading foot placement distances and M-L CoM displacements.

Table 1.

Descriptive Statistics for Obstacle-Crossing (OC) and Obstacle-Crossing While Texting (OC + texting) Conditions.

	OC only	OC + texting
	Mean (SD)	Mean (SD)
Toe-Obstacle clearance (cm)		
- Leading foot *	15.73 (3.52)	19.06 (4.36)
- Trailing foot *	18.69 (4.54)	24.85 (6.63)
Foot placement (cm)		
- Leading foot *	25.37 (5.79)	21.24 (3.67)
- Trailing foot	24.56 (5.93)	23.39 (5.12)
Gait speeds (m/s)		
- Approaching *	1.22 (0.06)	1.11 (0.09)
- Crossing *	1.10 (0.09)	0.94 (0.11)
Peak forward vCoM (m/s) *	1.41 (0.09)	1.30 (0.10)
M-L CoM (cm)		
- Approaching	4.54 (0.87)	4.31 (1.35)
- Crossing *	4.51 (0.75)	6.23 (1.57)

* *Note:* indicates the significant difference between OC + texting and OC only conditions.