Gait & Posture 58 (2017) 409–414

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Texting during stair negotiation and implications for fall risk

Rami Hashish[a,*], Megan E. Toney-Bolger[b], Sarah S. Sharpe[c], Benjamin D. Lester[d], Adam Mulliken[e]

[a] National Biomechanics Institute, Los Angeles, CA, USA
[b] Exponent, Biomechanics Practice, Detroit, MI, USA
[c] Exponent, Biomechanics Practice, Phoenix, AZ, USA
[d] Exponent, Human Factors Practice, Phoenix, AZ, USA
[e] Exponent, Technology Development Practice, Menlo Park, CA, USA

ARTICLE INFO

Keywords:
Gait
Biomechanics
Trip
Fall
Distracted walking

ABSTRACT

Background/Aim: : Walking requires the integration of the sensory and motor systems. Cognitive distractions have been shown to interfere with negotiation of complex walking environments, especially in populations at greater risk for falls (e.g. the elderly). With the pervasiveness of mobile messaging and the recent introduction of augmented reality mobile gaming, it is increasingly important to understand how distraction associated with the simultaneous use of a mobile device impacts navigation of the complex walking environments experienced in daily life. In this study, we investigated how gait kinematics were altered when participants performed a texting task during step negotiation.

Methods: : Twenty participants (13 female, 7 males) performed a series of walking trials involving a step-deck obstacle, consisting of at least 3 texting trials and 3 non-texting trials.

Results: : When texting, participants ascended more slowly and demonstrated reduced dual-step foot toe clearance. Participants similarly descended more slowly when texting and demonstrated reduced single-step foot heel clearance as well as reduced dual-step foot fore-aft heel clearance.

Conclusion: : These data support the conclusion that texting during stair negotiation results in changes to gait kinematics that may increase the potential for gait disruptions, falls, and injury. Further research should examine the effect texting has on performing other common complex locomotor tasks, actual fall risk, and the patterns of resulting injury rate and severity when negotiating complex environments.

1. Introduction

Since their introduction, the use of mobile devices has become increasingly common in modern society. The pervasiveness of this technology has increased rapidly since its inception, with the use of smartphones making up a greater portion of the market space annually. Mobile devices offer the ability to access, send, and receive information at any time, even while performing other motor tasks. With the recent introduction of augmented reality mobile gaming, users are encouraged to use their phones while simultaneously interacting with and navigating their environment, presenting greater potential for mobile device use to interfere with locomotor task performance. In this study, we investigated how gait kinematics are altered when completing a texting task requiring cell phone manipulation and cognitive engagement while simultaneously negotiating steps.

Evidence suggests cell phone use – more specifically, texting – is associated with an increased incidence of injuries in pedestrians. According to emergency department data acquired from the US Consumer Product Safety Commission (CPSC) and the National Electronic Injury Surveillance System (NEISS), the incidence of pedestrian injuries related to cell phone use increased more than 400% from 2000 to 2011 [1,2]. While the increase in injury rates has been attributed to the overall rise in cellular usage in the U.S., the rate of messaging has also increased dramatically in recent years. The Cellular Telecommunications and Internet Association (CTIA) reported that the number of annual text messages in the U.S. increased from approximately 81 billion in 2005 to 1.89 trillion in 2015 [3]. Considering the recent introduction and likely growth of cellular augmented reality games that require the user to manipulate their cell phone while navigating unfamiliar terrain, the prevalence of distracted walking and potential injurious incidents will likely continue to grow. It is therefore imperative to understand how distraction generated by cell phone engagement and manipulation influences pedestrian safety, especially when traversing hazardous environments or performing complex motor tasks that may require increased attention.

Environmental negotiation requires the complex integration

* Corresponding author.
E-mail address: rhashish@nationalbi.com (R. Hashish).

http://dx.doi.org/10.1016/j.gaitpost.2017.09.004
Received 3 March 2017; Received in revised form 16 August 2017; Accepted 4 September 2017

between sensory and motor systems to produce a coordinated and stable pattern of forward progression. Texting challenges cognitive, visual, and sensorimotor domains [24] and has been shown to alter cognitive attention, modify mechanical demands, and reduce the visual field in ways that may negatively affect gait performance [4]. Only recently have studies begun to explore how such changes associated with texting tasks influence gait performance. Previous research has focused on the effect of texting during level ground walking. Some studies have reported gait changes that may indicate adoption of compensatory strategies to increase stability while simultaneously texting and walking. Participants reportedly walk at slower speeds and utilize a wider stance width while texting [4,5]. Further, Marone et al. [6], evaluated how the physical demand of holding a cell phone and texting influenced the frontal plane minimum margin of stability (a measurement incorporating center of mass position, velocity, and distance from the base of support's lateral border) for experienced texters during treadmill walking and found that this measurement increased during cell phone use. The authors hypothesized this modification was a compensatory mechanism used to increase stability should obstacle disturbance be encountered.

In contrast, researchers have reported gait changes suggesting an increased potential for gait disruption and falls while texting and walking. For example, Schabrun et al. [4] reported participants tended to deviate from walking along a straight path when composing a text relative to the deviation when walking without distraction on flat ground and when walking while reading on a cellular phone. Similarly, Parr, et al. [5] found reductions in swing-toe clearance among participants performing a texting task during level walking. Reduced toe clearance of the swing foot in level walking positions the foot closer to the ground and may increase the propensity for interaction with obstacles, such as in the event of a ground level change that is not perceived or visualized. These findings suggest that the potential for unintended interactions with obstacles and trip initiation may increase while texting. Additionally, Smith et al. [1] found that 78% of reported injuries associated with cell phone use while walking resulted from a fall, suggesting that distraction with cell phone use could lead to changes in walking biomechanics that could then result in greater fall and injury potential. These findings suggest that, despite adopting compensatory strategies to increase gait stability on level ground, the potential for unintended interactions with obstacles and trip initiation may increase while texting.

A recent study by Kao et al., [25] showed that healthy young adults tried to maintain dynamic stability during cell phone use by controlling their foot placement and joint kinematics. Plummer et al. [26] showed that healthy adults are also able to flexibly prioritize attention between texting and walking in both a laboratory and real-world environment, but tend to prioritize texting in a low-distraction setting. Cell phone use paradigms have been examined during normal, level walking using both dual and tri-tasks [26,6] but has yet to be examined during negotiation of complex walking environments frequently encountered in daily life. Stair ascent and descent is inherently complex both in physical execution and motor control, with increased potential for trips, slips and subsequent falls [7]. Stairs by nature are elevated structures, and falls in these environments have a greater potential to be from increased height, resulting in potentially higher impact forces and more severe injuries than falls on level ground [8]. Lee et al. [28] investigated the effect of concurrent cognitive task on lower limb muscle activity during downward stepping in an older fallers and non-faller, and found that when performing a secondary task, individuals exhibited changes in muscle activation timing. However, to our knowledge, no studies have investigated kinematic changes in the gait during step negotiation while performing secondary tasks. The effects of texting that may increase the potential for trips, compounded with the inherent hazards associated with stair negotiation, may lead to greater safety concerns should individuals choose to text while negotiating stairs.

It currently remains unclear how the motor demands, reduced visual field, and increased cognitive distraction associated with texting influence simultaneous execution of complex locomotor tasks, such as stair negotiation. Previous work has shown that performing secondary tasks while walking negatively impacts gaze patterns [9,22] and gait kinematics [4,10–12]. The purpose of this study was to investigate how the cognitive distraction and additional motor demands associated with texting while walking influence execution of the complex locomotor task of step negotiation. We hypothesized that participants would walk more slowly, foot clearance would be reduced, and stance width would increase when participants negotiated a step obstacle while texting compared to navigating the same obstacle without performing a texting task.

2. Materials and methods

2.1. Participants

Twenty participants (13 female, 7 male) were recruited from the Phoenix, Arizona area. Participants met the following criteria for inclusion: 1) 25–55 years old; 2) not currently taking medications that influence balance or walking; 3) no musculoskeletal or cardiovascular pathologies that might compromise balance or walking; 4) daily use of a mobile device for texting. Participants were 39 ± 9 years old, with a height and weight of 64.8 ± 4.4 inches and 174.2 ± 37.2 pounds, respectively. A summary of the participants' ages, weights, heights and number of trials included in the data set is shown in Table S1. The study procedures were approved by Exponent's Institutional Review Board.

2.2. Equipment

Testing was conducted at Exponent's Gait Laboratory in Phoenix, Arizona. Three-dimensional motion analysis data w collected using an 8-camera OptiTrack system (Corvallis, OR, 240 FPS). All participants wore form-fitting full-body motion tracking suits. A series of markers were placed directly on the suits per the standard OptiTrack 41-marker set, which included a toe marker placed near the top of the third distal phalange and a heel marker placed near the calcaneus. Markers were also affixed to the step-desk obstacle, enabling quantification of its position in relation to the participant during each trial. Participants used their personal mobile device during the texting task. Visual gaze data were also collected via a wireless mobile eye-tracker worn as a set of glasses by the participants. These glasses did not interfere with the participant's visual field or their ability to navigate the obstacle.

2.3. Procedures

A step-deck obstacle, mimicking the beginning of stair accent and end of stair decent, was positioned in the middle of a straight (14 feet by 6 feet) walking space (Fig. 1).

Participants began each trial positioned at a start point marked on the floor approximately 5 feet from the front edge of the step-deck obstacle. This starting distance allowed for participants to take approximately two strides before reaching the steps. Participants were instructed to walk at a comfortable pace toward the obstacle and ascend/descend by placing one foot on each step. A trial ended when participants reached a stop point marked on the ground approximately 5 feet from the step-deck obstacle. Participants performed a randomized 8-trial block consisting of at least 4 texting trials and 4 non-texting trials. Trials were excluded and re-run if participants began walking prior to the arrival of the text or marker dropout occurred during data acquisition. Three other conditions (level walking, curb negotiation, and ramp negotiation) were also completed by the participants and were presented in a randomized order This manuscript explores step-deck negotiation only, and the results pertaining to the other tasks is the focus of future work.

Participants were told immediately before beginning each trial