Everyday multitasking habits: University students seamlessly text and walk on a split-belt treadmill

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Abstract

With increasing numbers of adults owning a cell phone, walking while texting has become common in daily life. Previous research has shown that walking is not entirely automated and when challenged with a secondary task, normal walking patterns are disrupted. This study investigated the effects of texting on the walking patterns of healthy young adults while walking on a split-belt treadmill. Following full adaptation to the split-belt treadmill, thirteen healthy adults (23±3 years) walked on a tied-belt and split-belt treadmill, both with and without a simultaneous texting task. Inertial-based movement monitors recorded spatiotemporal components of gait and stability. Measures of spatial and temporal gait symmetry were calculated to compare gait patterns between treadmill (tied-belt and split-belt) and between texting (absent or present) conditions. Typing speed and accuracy were recorded to monitor texting performance. Similar to previous research, the split-belt treadmill caused an alteration to both spatial and temporal aspects of gait, but not to time spent in dual support or stability. However, all participants successfully maintained balance while walking and were able to perform the texting task with no significant change to accuracy or speed on either treadmill. From this paradigm it is evident that when university students are challenged to text while walking on either a tied-belt or split-belt treadmill, without any other distraction, their gait is minimally affected and they are able to maintain texting performance.

Keywords: Gait, Split-Belt Treadmill, Dual-Task, Texting

1. Introduction

Students walking while texting is a common phenomenon on the University campus. Young adults maintain balance and avoid tripping or falling while simultaneously texting on a cell phone, requiring cognitive input to understand the screen's contents and fine hand control movements to respond. Despite the fact that locomotion is a well-practiced motor task, it involves both executive functions and attention [1, 2]. When challenged with a secondary cognitive task while walking, healthy young adults decrease the level of attention used to maintain gait performance during normal steady-state walking in order to transfer attention to perform the concurrent task [3, 4].

Typical gait can be adapted to the environment where it is performed, such as during walking on a split-belt treadmill (SBT) where both feet are driven by independent belts capable of operating at different speeds. Over the course of gait adaptation to the SBT, initial gait asymmetries are reduced [4-6]. Several mechanisms, facilitated by both peripheral (i.e. proprioceptive) and central (i.e. spinal) feedback signals, are used during asymmetric gait to control muscular coordination of both lower limbs [5, 7]. Once adaptation has occurred, the resulting walking pattern utilizes a decreased step frequency, increased gait cycle time and an increased time spent in double support (DS) as compared to tied-belt treadmill (TBT) walking [5, 7, 8]. Furthermore, asymmetric walking induced by SBT increases the overall attentional requirements of walking as compared to typical walking [9] and could be used to manipulate the attentional requirements of locomotion.

Texting on a cellular phone requires visual attention for reading, cognitive processing for communication and fine motor coordination for typing [10]. Its demands on working memory to maintain communication has an influential role on maintaining attention on surroundings while walking overground [11, 12]. It does appear that texting performance is prioritized while walking: dialing speed on a phone was unaltered from standing [13], calculations performed on a phone did not change in accuracy [14] and texting increased the likelihood of unsafe walking behavior (i.e. improper road crossings, inattentiveness) in young adults [15, 16]. In addition, participants had trouble retaining certain spatial information by inadequately dividing attention between texting and walking [11]. Finally, changes in medio-lateral stability during texting and walking have mainly been attributed to the physical constraints of holding the cellular phone and therefore, no arm swing [13, 14, 17, 18].

The purpose of this study was to examine changes to gait biomechanics due to texting during SBT in an adapted state. Since SBT walking requires more attention, we expected texting performance during SBT walking to decrease in speed and accuracy. We also expected an increase in overall temporal, spatial and step phasing asymmetry with minimal change in medio-lateral stability. Finally, texting on the SBT was expected to further exacerbate gait asymmetries.

2. Methods

2.1 Participants

Thirteen healthy University students (6 males, mean age 23±3 years) with normal or corrected-to-normal vision and no history of vestibular dysfunction or musculoskeletal or neurological disorders participated in the current study. Participants completed a 25-

minute SBT adaptation protocol (Hinton & Paquette, in preparation) immediately before their participation in this study and were therefore adapted to the SBT. Written informed consent was obtained from all participants who were frequent smartphone users, owned a phone with touch screen and were familiar with smartphone text messaging. The experimental protocol was approved by the McGill Institutional Review Board.

2.2 Equipment

Spatiotemporal measures of gait and stability (trunk movement) were measured and analyzed using the APDM Mobility Lab System (Opal™, APDM Inc., Portland, OR). Participants wore seven wireless inertial sensors (triaxial accelerometers, gyroscopes and magentometers; weight 22 grams) on the sternum, forehead, sacrum, left and right wrist, and left and right lower shank which continuously streamed data to a computer with Mobility Lab™ software. Participants walked on a treadmill (Forcelink Dual Belted Treadmill on N-Mill Frame) consisting of two independently-operating belts with a 3cm gap and three safety bars while wearing a safety harness. The harness provided no mechanical support nor hindered movements and was only engaged in the case of a fall.

A texting application (TapTyping™), installed on a touchscreen cellular telephone (iPhone5c) produced a three-sentence paragraph of logical, on-screen text. Participants re-typed a series of three consecutive, and different, TapTyping paragraphs for a single texting trial (approximately 90 seconds). Participants were instructed to continue without correcting texting errors (shown in red) and were given no instruction for their gaze while texting.

2.3 Procedure

All participants first completed a seated texting familiarization trial, followed by two texting trials while standing upright, wearing the safety harness beside the running treadmill. Participants were instructed to “type as fast as possible while making minimal mistakes”. Baseline texting performance was deemed the mean typing accuracy and speed of these two trials.

Seven participants started with the TBT condition followed by the SBT condition, with the reverse order for the remaining participants (See Figure 1, groups A and B). This protocol aimed to assess participants’ gait in an *adapted* state while walking on the TBT and SBT. All participants began with a 5-minute familiarization period to generate reproducible gait patterns [19-22] followed by the no-texting condition.

The no-texting condition required participants to maintain gaze on a 10X10cm ‘X’ on the wall 1-meter ahead of the treadmill, and walk without the phone and normal arm swing. The treadmill speed was set to each participants’ self-selected pace (mean=0.72±0.14m/s). To determine walking pace, both treadmill belts’ speeds were increased by 0.08m/s increments until participants reported the speed most closely resembled daily walking. The texting condition required participants to walk at their self-selected pace while holding the phone with both hands and texting. In the SBT condition, the belt underneath the dominant leg was reduced to one-half of the speed of the non-dominant leg (Waterloo Footedness Questionnaire [23]). Gait data was collected for two 1-minute bouts without texting and two bouts while texting (90 seconds). Participants ended with a seated texting trial to determine if any changes in texting performance occurred over the entire walking protocol.

2.4 Data Analysis

Texting speed (words per minute, WPM) and accuracy (percentage letters correct) were automatically calculated by the TapTyping™ application. Spatiotemporal gait outcomes were directly obtained from the Mobility Lab™ algorithms of the iWalk plugin. Evidence from SBT adaptation indicates spatial and temporal aspects of gait are adapted separately [24]. Stride length (SL; distance (meters) between consecutive heel contacts of the same foot) and SL symmetry (SLS;[24]) assessed spatial aspects of gait. SLS was calculated via *Equation 1* using the SL of each leg. Temporal measures of gait included step time (ST; duration (seconds) between consecutive opposite heel contacts), ST symmetry (STS, Equation 1), time spent in dual support (DS) and dual support symmetry (DSS, Equation 1). Dual support was divided based on the leg which was at the end of stance [12] (i.e. left DS was from right foot contact to left foot toe-off). Variability was assessed via coefficient of variation (COV) for SL, ST and DS of each leg (Equation 2). Stability was assessed by frontal plane (i.e. lateral flexion) trunk range of motion (ROM, degrees) and peak frontal plane trunk velocity (degrees/second).

2.5 Statistical Analysis

One-way repeated measures analysis of variance (ANOVA) analyzed the effect of condition (standing baseline, TBT, SBT, seated post-walking) on texting (WPM, accuracy; Figure 2). Pearson's correlations assessed the relationship between baseline texting performance and texting in each condition (WPM, accuracy; Figure 3). All symmetry measures were obtained from the first 5- and last 5-strides of each trial of all conditions

(TBT, TBT+texting, SBT, SBT+texting) to assess for learning effects in texting. Five 3-way repeated measures ANOVA's analyzed the effects of treadmill (tied-belt, split-belt), texting (present, absent) and within trial phase (first 5-strides, last 5-strides) on each gait symmetry parameter (DSS, SLS, STS) and stability measure (trunk ROM, peak velocity) with a Bonferroni post-hoc test to compare main effects (Figure 4 A-E). Three 3-way repeated measures ANOVA's analyzed the effects of treadmill (tied-belt, split-belt), texting (present, absent) and leg (dominant/slow on SBT, non-dominant/fast on SBT) on variability measures (stride length, step time, dual support COV). Pearson's correlations compared each symmetry measure (DSS, SLS, STS) between baseline TBT and SBT performance without texting to TBT+text and SBT+text respectively (Figure 5A-C). A secondary Pearson's correlations compared each symmetry measure (DSS, SLS, STS) in the last 5-strides of each condition with gait speed. Significance level was set at 0.05, correlations were deemed strong at $r>0.6$ and all statistical tests were performed in SPSS Version 22 (IBM Corp., Armonk, NY, USA).

3. Results

3.1 Texting

Typing accuracy did not change across conditions (Figure 2). Participants did however, type significantly faster in the seated post-walking condition compared to the tied-belt condition ($F(3,36)=4.134$, $p=0.027$, $\eta_p^2=0.256$). Baseline texting speed (Figure 3A) and accuracy (Figure 3B) while standing was positively and strongly correlated with texting performance on TBT, SBT and during seated post-walk. This positive correlation indicates participants maintained a similar texting performance relative to the baseline standing condition across all other conditions. Thus, inter-subject variability observed in Figure 2 results from differences in baseline texting performance rather than an effect from the postural/locomotor task.

3.2 Gait

Spatial Measures of Gait: As expected, SBT induced an asymmetry in SLS ($F(1,11)=91.595, p<0.001, \eta_p^2=0.893$; Figure 4A) and significantly increased SL variability ($F(1,12)=35.082, p<0.001, \eta_p^2=0.745$; Figure 5A) as compared to symmetrical TBT walking. Neither texting nor trial phase (First 5-, Last 5-strides) had an effect on SLS (Figure 4A) during TBT or SBT. There was no effect of texting or leg dominance during either TBT or SBT on SL variability (Figure 5A). There was no significant correlation between TBT SLS without texting and SLS on the TBT+texting (Figure 6A). However, a significant and strong positive linear correlation highlights the large between-participant pattern of adaptation (varying levels of asymmetry between participants) in SLS on the SBT ($r=0.806$, $p<0.001$; Figure 6A). The varying levels of SLS asymmetry between participants were not correlated to walking speed for TBT or SBT with or without texting (TBT: $r=0.09$; TBT+text: $r=0.43$; SBT: $r=-0.22$; SBT+text: $r=-0.15$; $p>0.05$). One participant was deemed an outlier (mean SLS during TBT beyond 3 times the interquartile range of the group mean) and was not included in analysis.

Temporal Measures of Gait: STS was significantly more asymmetrical on SBT as compared to the symmetrical TBT walking ($F(1,11)= 97.712, p<0.001, \eta_p^2=0.899$; Figure 4B) and SBT walking significantly increased ST variability from TBT walking

$(F(1,12)=10.263, p=0.008, \eta_p^2=0.461$; Figure 5B). Texting did not have an effect on STS (Figure 4B) nor ST variability (Figure 5B). In addition there was no effect of trial phase on STS (Figure 4B) nor leg dominance on ST variability (Figure 5B) during TBT or SBT. There was no significant correlation between participant means for STS without texting and with texting on either treadmill (Figure 6B). The varying levels of asymmetry for STS between participants were not correlated to walking speed for TBT or SBT with or without texting (TBT: r=0.01; TBT+text: r=-0.02; SBT: r=0.03; SBT+text r=0.06; p>0.05). One participant was deemed an outlier for STS during TB and was not included in analysis.

Both SBT and TBT presented with similar DSS values and DS variability. Neither texting nor trial phase had a significant effect on DSS (Figure 4C) and neither texting nor leg dominance had a significant effect on DS variability during TBT or SBT (Figure 5C). A significant, positive correlation confirmed participant means for DSS remained similar across texting conditions for both TBT and SBT (Figure 6B and 6C). The varying levels of asymmetry between participants for DSS were also not correlated to walking speed for TBT or SBT with or without texting (TBT: r=0.27; TBT+text: r=0.34; SBT: r=0.33; SBT+text: r=-0.06; p>0.05). A summary of absolute population means and SD for SL, ST and DS has been included as a supplementary table.

3.3 Stability

Frontal plane trunk ROM $(F(1,11)=13.863, p<0.01, \eta_p^2=0.558$;Figure 4D) and peak trunk velocity $(F(1,12)=18.229, p<0.01, \eta_p^2=0.603$;Figure 4E) were significantly reduced with addition of texting, when participants held the phone. Neither treadmill nor trial phase had an effect on frontal plane trunk ROM nor peak trunk velocity in the frontal plane during

TBT or SBT (Figure 4D-E). One participant was deemed an outlier for trunk ROM during TBT was not included in analysis.

4. Discussion

Unexpectedly, texting performance did not vary between tied- belt (TBT) and split-belt (SBT) walking. Adding a texting task when walking under symmetrical (TBT) or asymmetrical (SBT) conditions on a treadmill required minimal spatiotemporal gait alterations for young adults. A lack of difference in DSS and dual support variability with texting supported findings of previous dual-task split-belt work using an auditory Stroop Task [9], indicating DS is well controlled in dual-task scenarios and prioritized when stability and balance control are challenged in an asymmetrical environment. We believe a lack spatiotemporal gait changes to walking on a TBT or SBT with the addition of texting can be attributed to a lack of required online-updating or external perturbations typical of a dynamic environment. Finally, the reduction of medio-lateral trunk excursion during the texting task is likely caused by the arm swing restriction from holding the phone and stabilizing it to maintain gaze and minimize retinal slip of the screen [14].

When young adults spontaneously allocate their attention, they tend to prioritize cognitive tasks over typical overground walking, causing altered gait patterns in a dual-task scenario [25]. However, when required to walk in a more challenging conditions, such as uneven pavement, young adults prioritized stable walking over cognitive task performance [10, 25, 26]. Furthermore, texting performances and gait patterns were considerably altered when typing speed or accuracy were prioritized [25]. In order to assess for a global effect of texting on walking, we instructed participants to consider both speed and accuracy components of texting performance. Our results support previous findings which also did not show changes in texting performances from standing, walking, and perturbed stance [27]. Our texting protocol, similar to that used by others, did not involve any memorization, reasoning, or utilization of other communication skills that would be required in a real-life texting scenario [25, 27]. Interestingly previous work found slower typing speed, increased texting errors and riskier overground walking behaviors when texting involved responding to a conversation [10, 28]. While our use of a standardized texting application allowed for control over length and time spent texting, it was not cognitively demanding nor did it elicit an emotional response. Since texting performance changes did not occur across conditions, we believe the difficulty level of treadmill walking (without external risks to typical overground walking) combined with this simultaneous texting task did not require participants to compromise texting or gait performance, especially given it was completed at the same performance level while SBT walking as while seated.

Surprisingly, the more challenging and less practiced asymmetrical walking condition did not see walking pattern changes with the addition of texting. The attentional capacity sharing model states that more than one task can be completed simultaneously if the attentional requirements of each task do not exceed the overall capacity of the individual [29]. Even though both TBT and SBT have been shown to have attentional requirements [9], the lack of external perturbations and decreased sensorimotor integration requirements of the laboratory setting such as curbs, traffic or navigation may have removed a large attentional focus of both typical and asymmetrical walking. As such, the attentional requirements to perform both texting and either symmetrical or asymmetrical walking did not exceed the overall capacity of our young adult population and they were able to complete both tasks simultaneously. In addition, it has been suggested that the safety harness may give participant's more confidence in dynamic balance, thus requiring less attention to be focused on walking and providing more attention for the secondary task [9]. As the harness was required for safety reasons and in order to maintain a similar setup for all tasks, participants wore the harness during all texting trials including standing baseline and seated post-walking to allow for comparison across trials.

Texting while treadmill walking has been shown to reduce trunk lateral flexion to provide a greater distance between whole-body centre of mass movement and the edge of the base of support in single stance [14]. However, Marone and colleagues [14] also saw this same cautious balance control strategy when participants were just asked to hold a phone while walking, without the secondary cognitive-motor dual task. Results of the current protocol align well with their hypothesis that bringing the arms towards the centreline of the body in order to hold the telephone reduces trunk motion in the lateral plane, rather than a dual-task effect on trunk movement. This hypothesis also explains why there were no differences in trunk movements in the frontal plane between tied-belt and split-belt conditions.

Finally, it is important to note that these findings are from participants where texting while walking is extremely common, and where the walking speed was relatively slow (<1.0 m/s). All participants tested use a cellphone with a touch screen on a daily basis and were asked to walk at a speed they felt mimicked everyday walking. The average treadmill walking speeds (0.72m/s) of the participants in our study were slower than expected of typical overground walking, especially for younger adults. This could be attributed to their perception of a comfortable walking speed on the treadmill where optic flow is reduced [30].

5.0 Conclusion

Texting while walking on the SBT minimally affected University students' gait patterns or texting performance. To the best of our knowledge, this is the first study which examines how young adults manipulate gait patterns and stability when challenged to execute simultaneous texting and asymmetric walking, which can be seen in the case of limping, turning or walking on uneven pavement. Although none of the participants received formal training in texting while walking, it has become habitual practice among university students who can now carry out both tasks without strenuous efforts. It was made apparent in this investigation that when external stimuli and risk is removed, participants did not have any adverse effects of texting on their typical walking patterns.

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Conflict of Interest Statement

None to declare.

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Equations:

Equation 1:

$$Symmetry = \frac{Fast\ Leg - Slow\ Leg}{Fast\ Leg\ +\ Slow\ Leg}$$

Stride Length (SL), Step Time (ST) and time spent in Dual Support (DS) were substituted into Equation 1 to calculate Stride Length Symmetry, Step Time Symmetry and Dual Support Symmetry values. A symmetry value of 0 represents symmetrical gait with no difference between each leg's spatiotemporal parameter (ie, SL, ST or DS). A positive value indicates a longer spatiotemporal parameters of the leg driven by the fast belt and a negative value indicates the opposite.

Equation 2:

$$Coefficient\ of\ Variation = \frac{Standard\ Deviation}{Mean}$$

Stride Length (SL), Step Time (ST) and time spent in Dual Support (DS) were substituted into Equation 2 to calculate the Coefficient of Variation (COV) of each leg (Dominant and Non Dominant) during the first 5 strides of each condition. COV represents a percentage change from the mean and its magnitude can be compared between measures.

Figure Captions

Figure 1: Protocol timeline illustrating periods of texting practice, baseline and post-walking assessments. Grey shaded area shows treadmill walking conditions alternating between tied-belts and split-belts with and without texting. All participants completed a 25-minute split-belt adaptation protocol prior to testing.

Figure 2: Texting performance for speed and accuracy across all testing conditions. Group means ± SD are shown. *= $p<0.05$.

Figure 3A-B: Pearson correlations of participant means between Standing Baseline texting speed (A) and accuracy (B) and each testing condition.

Figure 4A-E: Group means (±SD) for the First 5 and Last 5 Strides for Stride Length Symmetry (A), Step Time Symmetry (B), Dual-Support Phase Symmetry (C), Frontal Plane Trunk Range of Motion (D) and Peak Trunk Velocity in the Frontal Plane (E) of the non-texting and texting walking trials.

Figure 5A-C: Group means (±SD) for the First 5 Strides for Stride Length Coefficient of Variation (COV) (A), Step Time COV (B) and Dual-Support Phase (COV) of the non-texting and texting walking trials for the dominant (slow) and non-dominant (fast) legs.

Figure 6A-C: Pearson correlations of participant means between baseline without texting stride length symmetry (A), step time symmetry (B) and dual support symmetry (C) and performances while texting for both tied-belt and split-belt walking.

Highlights

- Minimal changes to gait and trunk control while texting and walking on split-belt treadmill.
- No alteration to texting performance from standing baseline to walking.
- Young adults capable of incorporating texting into asymmetric treadmill walking.

Supplementary Table 1: Spatiotemporal measures. Absolute group means (±SD) used to calculated symmetry measures.

Measure	Leg	Tied-Belt	Tied-Belt with Texting	Split-Belt	Split-Belt with Texting
Stride Length	Dominant	74.2 (±5.5)	73.6 (±4.7)	57.0 (±5.7)	55.8 (±5.5)
(% Height)	Non-Dom.	74.3 (±5.8)	73.6 (±4.8)	61.6 (±5.8)	59.6 (±6.0)
Step Time	Dominant	0.49 (±0.06)	0.48 (±0.04)	0.48 (±0.07)	0.46 (±0.05)
(Seconds)	Non-Dom.	0.48 (±0.05)	0.47 (±0.05)	0.60 (±0.11)	0.57 (±0.08)
Dual Support Phase	Dominant	0.15 (±0.02)	0.14 (±0.03)	0.16 (±0.03)	0.16 (±0.03)
(% Gait Cycle)	Non-Dom.	0.15 (±0.02)	0.15 (±0.03)	0.15 (±0.02)	0.15 (±0.03)

Figure 1

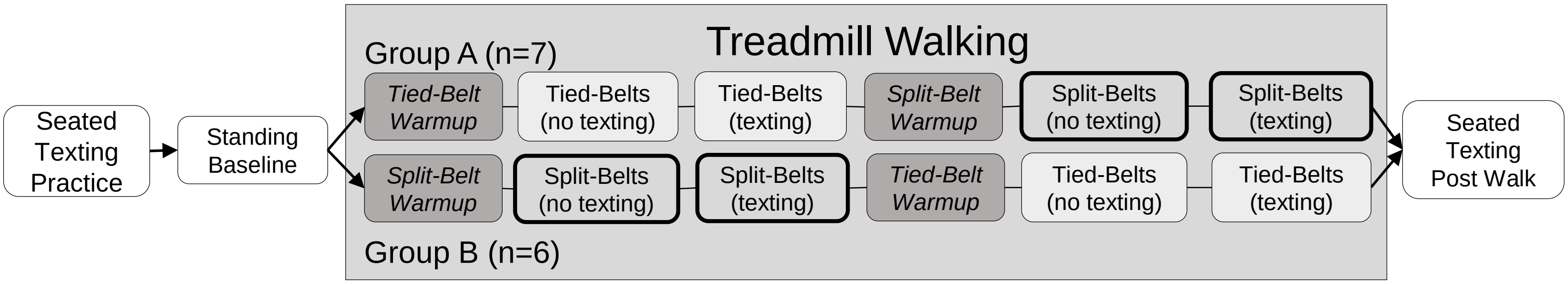


Figure 2

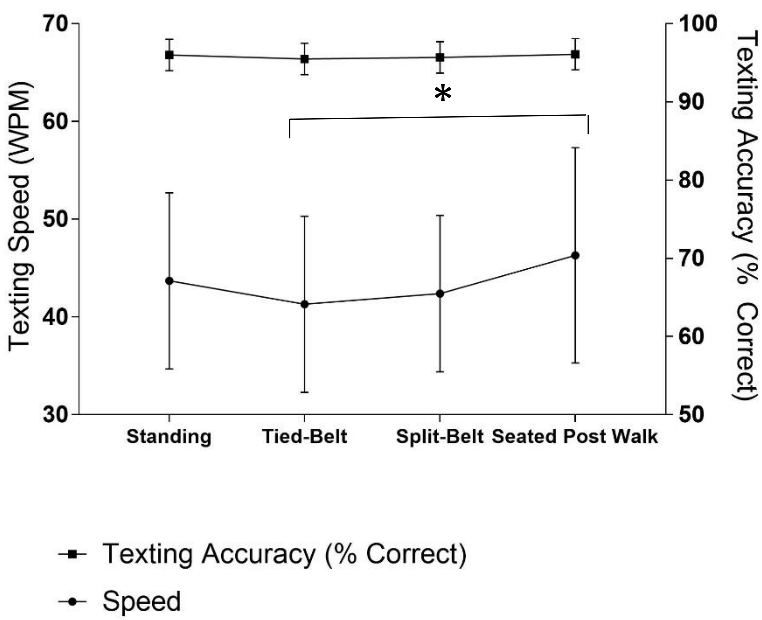


Figure 3

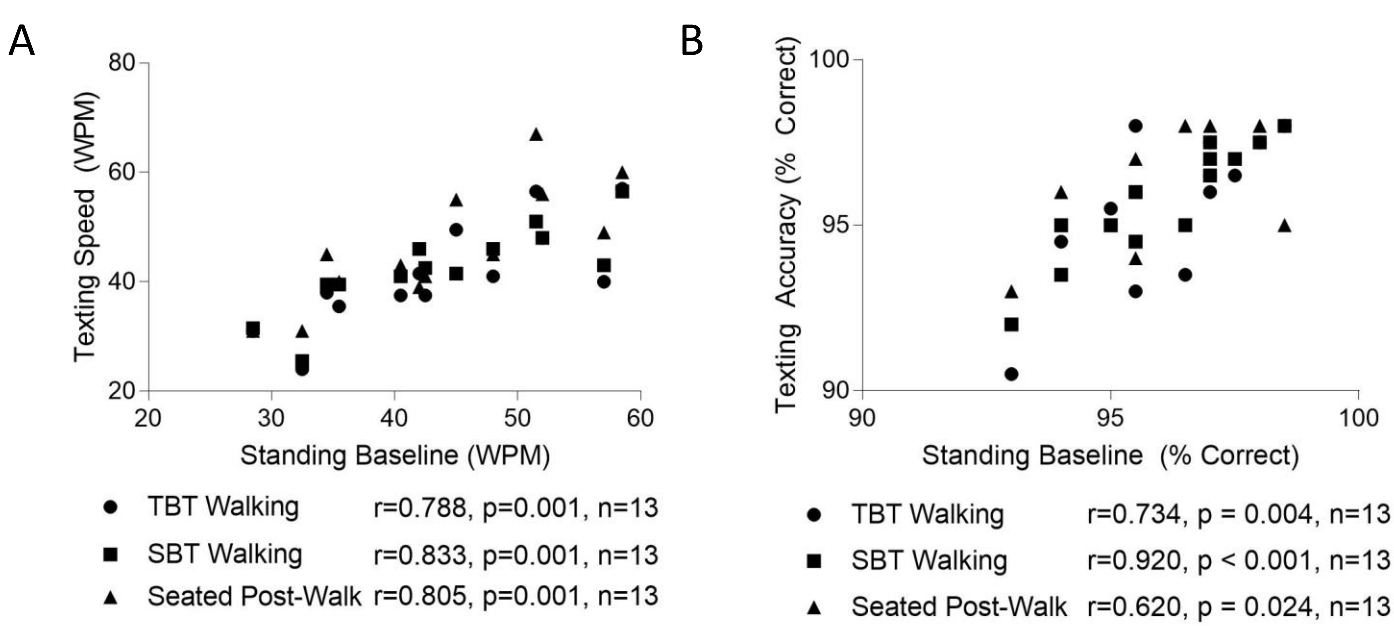


Figure 4

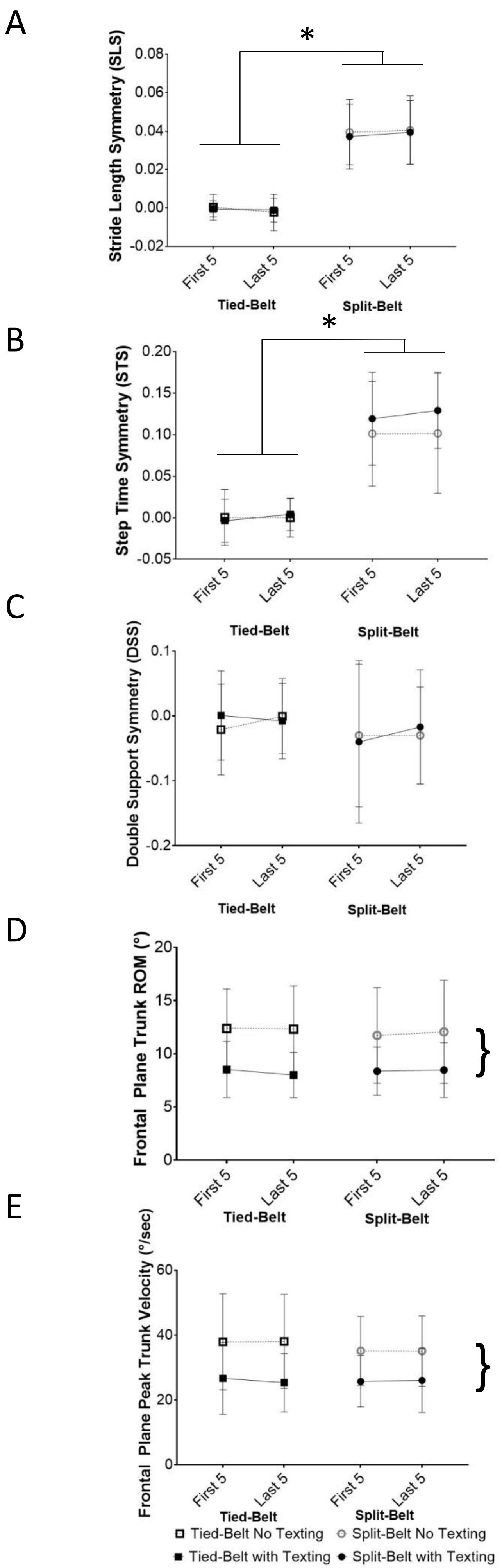


Figure 5

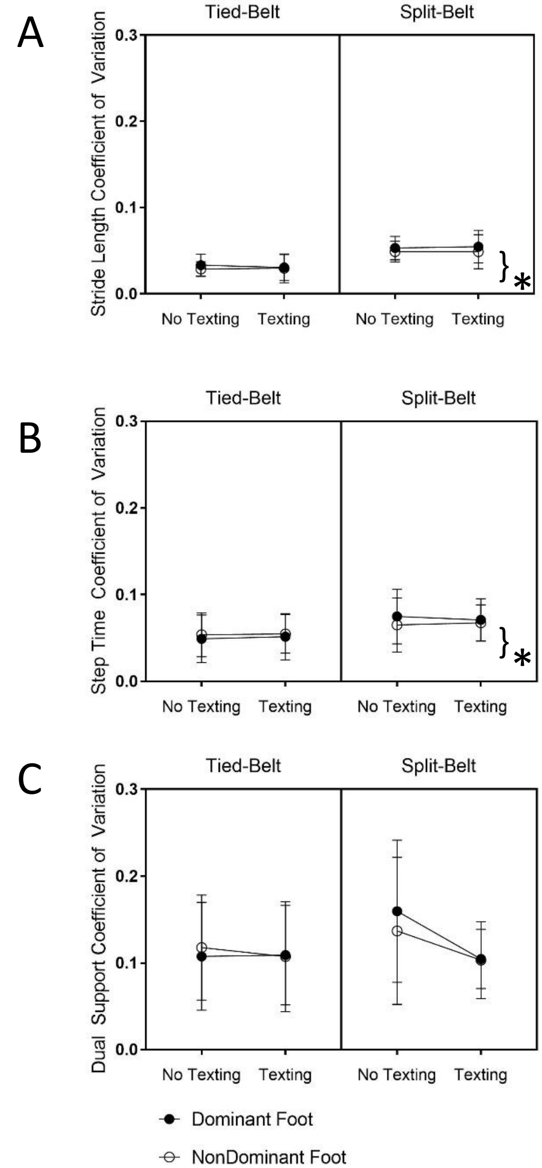
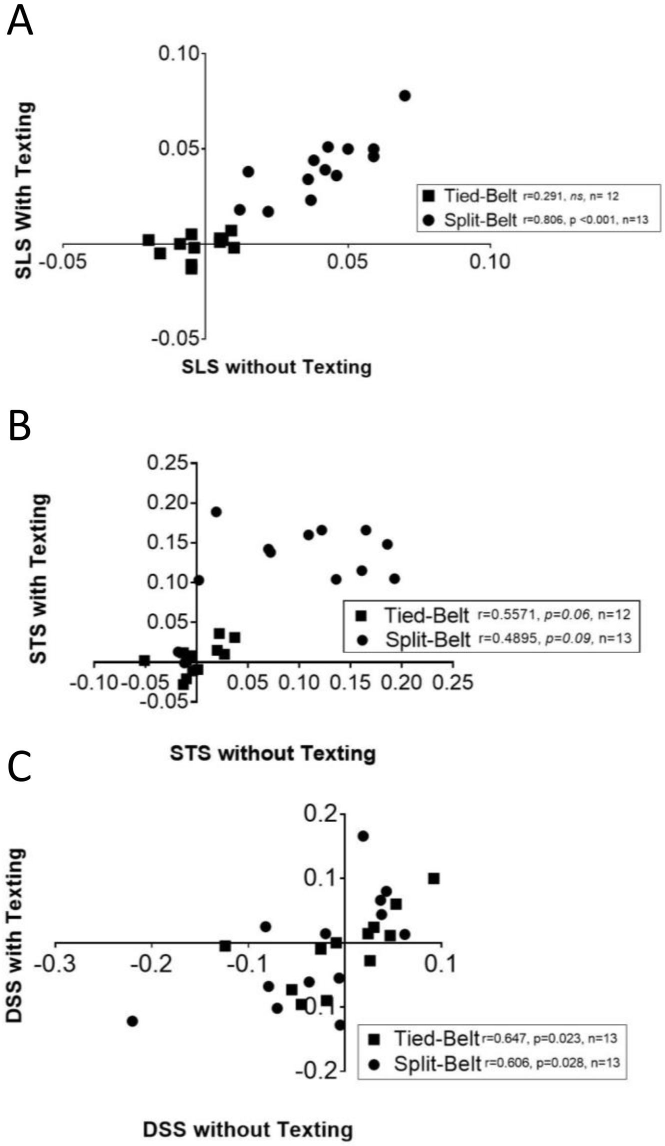


Figure 6


A
SLS With Texting
SLS without Texting
Tied-Belt r=0.291, ns, n= 12
Split-Belt r=0.806, p <0.001, n=13
B
STS with Texting
STS without Texting
Tied-Belt r=0.5571, p=0.06, n=12
Split-Belt r=0.4895, p=0.09, n=13
C
DSS with Texting
DSS without Texting
Tied-Belt r=0.647, p=0.023, n=13
Split-Belt r=0.606, p=0.028, n=13