ANALYSIS OF DYNAMIC STABILITY WHILE TEXTING DURING STAIR DESCENT

Huifen Zheng[1,2], Chuanbao Cao[1], Shuo Zhao[1], Wei Sun[1], Dewei Mao[1]

Shandong Sport University, Jinan, China[1]
Heping Hospital Affiliated to Changzhi Medical College, Changzhi, China[2]

The purpose of this study was to explore the modifications in saggital and frontal dynamic stability during stair descent while texting to provide a database for guidelines of fall prevention. Participants (n=26; 13 male, 13 female) performed three stair descent trials under texting and No texting task conditions at self-selected speed, respectively. Synchronous kinematics and kinetics were collected by an eight-camera Vicon infrared motion capture system and two force platforms. A paired sample t-test was used to analyze the differences between two task conditions. With the interference of texting, anterior–posterior margin of stability (MOS_{ap}) increased in the initiation of double-support phase (DSP), while decreased in the initiation of single-support phase (SSP), medial–lateral MOS (MOS_{ml}) decreased in the initiation of SSP. Posterior instability was induced in the initiation of DSP. The initiation of DSP was the most unstable moment and should alert texters, particularly young adults, to potential risk of falling backward during stair descent.

KEYWORDS: texting, frontal plane, saggital plane, dynamic stability, MOS

INTRODUCTION: With the availability of mobile devices anytime and anywhere, texting while walking has become a routine among young adults. Emerging evidence has demonstrated that using smartphones will cause a certain threat to the safety of pedestrians, and even endanger their lives due to reduced awareness and distracted attention. In comparation with No texting task, Lamberg (2012) found evident lateral deviation during level ground walking toward a target of 8 m away while texting. So it requires urgent exploration that how the cognitive distraction ralated to texting compromised the safety during walking.

Texting during walking, a typical multiple integration of vision, cooperation of tapping keyboard with thumbs, and cognition, has been estimated as a dual task paradigm in previous study. Demura (2009) demonstrated a significant decline in stride width during walking a 10 m walk-way while sending an e-mail, which was similar to texting in operation. The reduction in stride width weakened the base of support (BOS) and further impaired the balance. Strubhar (2015) found an increased center of mass (COM) sway movement, and the reactive balance ability was thus impaired by texting. Thus, stability modifications were demonstrated indirectly by gait parameters instead of instantaneous and intuitive indicators in previous study.

Safe ambulation requires not only saggital active control but also frontal active control (Bauby, Kuo & Bauby, 2000). Dynamic stability can be quantified by MOS reflecting the instantaneous difference between center of pressure (COP) and extrapolated COM (CM), determined by the position and velocity of COM (Hof, Gazendam & Sinke, 2005). The requirements of stair descent for body stability (Lee & Chou, 2007) in lower extremities were higher than those of level walking. To date, there is no study focusing on modifications of dynamic stability in saggital and frontal planes during stair descent while texting. Blazewick (2017) revealed that young adults in their 20s dominated a relatively higher percentage in all the stair-related injuries treated in America. Thus, the study aimed to investigate the saggital and frontal modifications in MOS and its components among young adults while texting during stair descent to provide a database for developing fall prevention guidelines.

METHODS: Twenty-six young healthy adults (13 female, 13 male, age: 21.97±2.08 years, BMI: 21.29±2.60) were recruited. Inclusion criteria: 1) own a smartphone with a 5.5–6.0 inches touch screen and text with a QWERTY keyboard with two thumbs for more than 3 months; 2) free from any neuromusculoskeletal and cardiovascular diseases. All participants signed the written informed consent.

Two force platforms (Kistler, 9287BA and 9281CA, Switzerland) were embedded in the second and third steps of the staircase consisting of six steps, and the lower right corner of third step was set as the origin of global coordinate system. 41 markers were affixed on the bone landmarks. Three-dimensional kinematics and kinetics were recorded by an eight-camera Vicon motion capture system (Vicon, Oxford Metrics Ltd., UK) at 100 Hz synchronized with the force platform at 1000 Hz.

Prior to the formal test, each participant did 5 min warm-up. All partcipants were tested to be right foot dominance. Upon hearing a instruction of “go”, individuals began each trial from the start point approximately 15 cm away from the front edge of sixth step at self-selected pace in a step-over-step manner. The trial ended when reaching the terminal point 1m away from the front edge of first step. Each participant performed at least six random trials consisting of three texting trials and three No texting trials with a 1-min break every two trials.

Under texting task condition, individuals held the smartphone and texted with two thumbs. A random computer-generated double-digit number ranging from 50 to 99 was sent to WeChat (a widely used communicating app in China) just before the instruction. Participants iteratively subtrcted 7 from the random double-digit number during each trial concurrently. Each arithmetic result should send back to the experimentor untill they reached terminal point. For example, if the participants received a number “67”, then they would perform the calculation “67−7=60, 60−7=53, 53−7=46” and text “60, 53, 46” back to the experimentor before completing the trial. A successful descent trial was defined as follows: the right foot had a complete contact with the third step, and a stair descent trial was continuous, uninterrupted. Starting the trial before receiving a double-digit number or striking the third step with left foot would be considered a failure.

Dynamic stability was quantified by MOS using an inverted pendulum model during stair descent. The equations (Hof, Gazendam & Sinke, 2005) were as follows:

$$MOS = BOS_m - CM$$

$$CM = dCOM + \frac{\nu COM}{\sqrt{g/l}}$$

where BOS_m denotes the maximum boundary of BOS, and it is represented by center of pressure (COP) in our study. CM denotes the dynamic position of COM under the influence of velocity. dCOM denotes anterior–posterior or medial–lateral component of the vertical projection of COM to the ground. νCOM denotes anterior–posterior or medial–lateral velocity component of COM. g denotes the gravitational acceleration, with a value of 9.8 m/s^2. l denotes the distance between COM and the center of ankle joint.

Positive value means a posterior or right νCOM and COP was in the posterior or on the right of CM. Minus value means anterior or left νCOM and COP was in the anterior or on the left of CM. A small value of MOS indicates short distance between COP and CM, and high stability of the participants. MOS was analyzed during the supporting phase of right leg.

A paired sample t-test was used to analyze the differences between No texting and texting task conditions for MOS and its component at right foot landing (RL) and left foot taking off (LT), significance was set as $p<0.05$.

RESULTS: Variation of dynamic stability was showed in Figure 1. At RL (the initiation of DSP for right leg), the anterior–posterior νCOM (νCOM_{ap}) decreased significantly, and anterior–posterior CM (CM_{ap}) was in a more posterior position, while the anterior–posterior dCOM ($dCOM_{ap}$) and MOS_{ap} increased signifcantly while texting compared with No texting. By contrast, medial–lateral νCOM (νCOM_{ml}) increased significantly and move rightward, and medial–lateral CM (CM_{ml}) was further to the right with the interference of texting, while no

significant difference in medial–lateral dCOM ($dCOM_{ml}$) and MOS_{ml} between the two different task conditions (Table 1).
At LT (the initiation of SSP for right leg), young adults showed significantly lower $vCOM_{ap}$, larger $dCOM_{ap}$, smaller MOS_{ap}, and CM_{ap} was in a more posterior position and even behind of the origin while texting compared with No texting. Regarding frontal stability, significantly increased νCOM_{ml}, further right position of CM_{ml}, and smaller MOS_{ml} were observed while texting, while no significant difference was found in $dCOM_{ml}$ between the two conditions (Table 1).

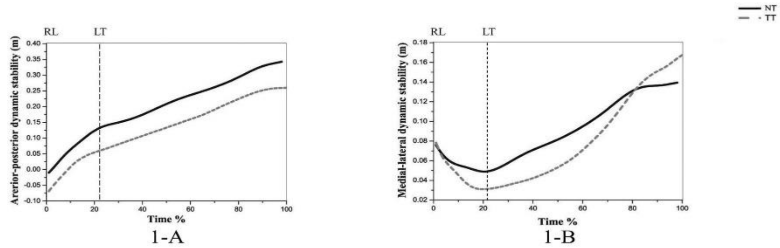

Figure 1: Mean anterior–posterior (Figure 1-A) and medial–lateral dynamic stability (Figure 1-B) in support phase of right leg under two different conditions during stair descent. NT=No texting task; TT=texting task; RL=right foot landing; LT=left foot taking off.

Table 1: Anterior–posterior and medial–lateral dynamic stability at the moment of the right foot landing and left foot taking-off under texing and No texting conditions while descending stairs.

	No texting task	Texting task	P–value
The moment of right foot landing			
MOS_{ap} (m)*	-0.02±0.03	-0.07±0.03	< 0.001
MOS_{ml} (m)	0.08±0.02	0.08±0.02	0.945
CM_{ap} (m)*	0.03±0.03	0.10±0.03	< 0.001
CM_{ml} (m)*	0.34±0.03	0.37±0.04	0.008
νCOM_{ap} (m/s)*	-0.61±0.04	-0.46±0.06	< 0.001
νCOM_{ml} (m/s)*	0.11±0.05	0.18±0.07	< 0.001
$dCOM_{ap}$ (m)*	0.22±0.02	0.25±0.02	< 0.001
$dCOM_{ml}$ (m)	0.31±0.03	0.31±0.04	0.967
The moment of left foot taking off			
MOS_{ap} (m)*	0.12±0.03	0.02±0.02	< 0.001
MOS_{ml} (m)*	0.05±0.01	0.04±0.02	0.029
CM_{ap} (m)*	-0.04±0.03	0.06±0.04	< 0.001
CM_{ml} (m)*	0.35±0.03	0.38±0.04	0.001
νCOM_{ap} (m/s)*	-0.62±0.07	-0.44±0.09	< 0.001
νCOM_{ml} (m/s)*	0.08±0.04	0.17±0.06	< 0.001
$dCOM_{ap}$ (m)*	0.15±0.02	0.20±0.02	< 0.001
$dCOM_{ml}$ (m)	0.32±0.03	0.33±0.04	0.416

MOS_{ap}: anterior–posterior dynamic stability; MOS_{ml}: medial–lateral dynamic stability;
CM_{ap}: anterior–posterior extrapolated COM; CM_{ml}: medial–lateral extrapolated COM;
νCOM_{ap}: anterior–posteriorvelocity of COM; νCOM_{ml}: medial–lateral velocity of COM;
$dCOM_{ap}$: anterior–posterior displacements of COM; $dCOM_{ml}$: medial–lateral displacements of COM;
*Statistically significant differences between two different task conditions ($p<0.05$).

DISCUSSION: Walking stability can be described as an individual's ability to cope with external and internal disturbances without falling. Saggital stability (i.e., anterior–posterior stability) while texting compromised in the initiation of DSP. An increased MOS_{ap} and a minus value of MOSap while texting indicated that CM_{ap} was in the posterior of COP. At this moment, an increased νCOM_{ap} might narrow the distance between CM_{ap} and COP to retain saggital stability. In fact, with the interference of texting, young participants slowed νCOM_{ap}

which was adverse to keep COM moving forward, and thus adopted a conservative strategy of shifting COM backward. Therefore, an increased risk of falling backward was observed under texting task condition at this moment. No difference were detected in MOS_{ml} between the two conditions, althoug νCOM_{ml} increased while texting. Specifically, MOS_{ml} was invulnerable to texting and participants had a relatively good frontal stability (i.e., medial–lateral stability) in the initiation of DSP. Kao (2015) found younger subjects walked on the treadmill with a significantly greater frontal stability while dialing, but the difference in MOS_{ap} was not found. The reason for the contradictory findings was that treadmill walking had an inherent distinction from stair descent, and dialing task did not involve the calculation which required different cognitive resources (Maylor & Wing, 1996). With the interference of texting, young adults adopted a conservative strategy of shifting COM backward, reducing walking velocity, posterior instability was induced in the initiation of DSP. Consequently, the current study suggested that young adults showed an increased risk of falling backward, and the transition from SSP to DSP was most unstable and vulnerable to fall.

In the initiation of SSP, participants walked with reduced MOS_{ap} and MOS_{ml}, which indicated that saggital and frontal dynamic stability could be maintained and even increased with the interference of texting. However, we could not just assume that texting was a safe dual task activity. A safe locomotion requires sufficient attentional resources to retain dynamic stability. Texting in this study employed cognitive, visual and motor domains. Thus, the attentional resource associated with locomotive task reduced dramatically. CM_{ap} was in a more anterior position and ahead of the origin while texting, young individuals thus slowed νCOM_{ap} to narrow the distance between CM_{ap} and COP. Accordingly, saggital stability was warranted. Bauby (2000) found that greater frontal stability was more desirable during safe level locomotion compared with sagittal stability. However, MOS_{ml} was warranted while texting in this study. A significantly increased νCOM_{ml} could keep COM moving rightward to narrow the distance between CM_{ml} and COP, because CM_{ml} was on the left of COP.

Above all, texting significantly induced the modifications in dynamic stability in both saggital and frontal planes. The initiation of DSP should alert texters, particularly young adults, to potential risk of falling backward during stair descent.

CONCLUSION: With the interference of texting, posterior instability was induced in the initiation of DSP despite adopting a conservative strategy of shifting COM backwards, decreasing gait velocity. Therefore the initiation of DSP should be noticed during stair descent, especially while performing a concurrent texting task.

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