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Gait Alterations During Walking Under Smartphone-Based Dual-Task Conditions

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Abstract: Smartphones are widely used, even while walking. This raises concerns regarding their impact on gait and safety during walking. The aim of the present study was to assess the impact of using a smartphone on gait in healthy young adults. 136 subjects aged 18 - 40 years were included in the study. Gait analysis was performed with a G-walk system in three conditions: 1) single-task walking (Control), 2) walking while talking on the smartphone (Talking), 3) walking while tex-ting (Texting). Stride length, normalized stride length, gait cycle duration showed significant differences in Texting compared to Control and Talking. Speed and cadence had significantly lower values in Texting compared to Control and Talking. The DTCs indicated a worse gait per-formance when simultaneously writing a message on the phone compared to talking on the phone while walking. The present study confirms that using a smartphone while walking has an impact on gait parameters. A worse gait performance was reported when simultaneously writ-ing a message on the phone while walking compared to talking on the phone.

Keywords: gait analysis, wearable sensors, texting; talking, dual-task

1. Introduction

Smartphones are widely used, even while walking [1–6]. This raises concerns regarding their impact on gait and safety during walking. Many studies revealed that dual-tasking, such as using a smartphone while walking, significantly alters gait parameters, potentially increasing the risk of accidents [7–11]. Text messaging while walking is quite frequent, especially among younger people. Texting, which requires substantial visual and cognitive attention, has a pronounced effect on gait. Multiple studies have demonstrated that individuals texting while walking exhibit significantly reduced walking speed, increased step width, and decreased step length compared to normal walking. These adaptations likely serve as compensatory mechanisms to enhance stability under increased attentional demands [12–14]. Furthermore, texting while walking was associated with increased gait variability, decreased cadence, and increased double support time, which reflects a more cautious and less efficient gait pattern [7,15]. Individuals engaged in texting during walking tend to prioritize maintaining their texting speed and accuracy, at the expense of gait speed and impaired balance [16]. Some studies also report that texting increases mediolateral trunk sway, indicating decreased postural control [17]. These alterations collectively suggest that texting while walking impairs gait stability and increases the risk of tripping or falls [13].

Conversely, speaking on a smartphone while walking affects gait parameters differently. Although speaking is cognitively demanding, it does not require visual attention to the same extent as texting. Studies showed that talking on a smartphone while walking led to a moderate reduction in walking speed and stride length compared to baseline, but these effects were less pronounced than those observed during texting [7,12]. Speaking on the phone has also been associated with slight increases in gait variability, but not to the same extent as texting [15]. This is because the cognitive load of holding a conversation diverts attention from the motor task of walking. It was suggested that speaking tasks primarily affect cognitive load, leading to increased reaction time and slower responses to external stimuli while walking [18].

The present study aimed to assess the impact of using a smartphone on gait in healthy young adults using a wearable sensor. We hypothesized that using the smartphone while walking would have an impact on gait, writing a text on the smartphone being more challenging than talking, since it requires both cognitive and visual involvement.

2. Materials and Methods

2.1. Participants

Healthy adults, with normal or corrected-to-normal vision, who use a smartphone daily (at least 2 hours per day) for more than 6 months were asked to participate in this study. Those with musculoskeletal, neurological disorders, or other conditions that could affect their gait, dynamic balance, typing, or talking capacity were not included in the study. Participation in the study was voluntary, and all participants signed an informed consent. The study has been carried out in accordance with the Declaration of Helsinki and was approved by the Institutional Ethics Committee (no 2050/26.02.2020).

2.2. Assessments

Anthropometric data (age, gender, weight, height) were collected for all participants included in the study. Gait was assessed with the G-walk system (BTS Bioengineering, Italy). The system uses a validated wireless inertial sensor (G-sensor) [19], made up of four inertial platforms, each composed of a triaxial accelerometer, a triaxial gyroscope and a magnetometer [20]. All recorded data were sampled at a 100 Hz frequency and were transmitted to the PC through a Bluetooth connection and processed by the BTS G-studio software (BTS Bioengineering, Italy). The G-sensor (weight 37 g, 70x40x18 mm) was attached with a semi-elastic belt on the lower back of the subjects, at the level of the 5th lumbar vertebrae. The recorded parameters were spatiotemporal gait parameters - gait speed (meter/second), cadence (steps/minute), gait cycle (GC) duration (seconds), stride length (meters), normalized stride length (stride length/height (%)), step length (as % of the stride length), stance, swing, double support and single support duration (as % of the gait cycle), propulsion, differentiated for the right and the left limb. Propulsion represents the difference in anterior/posterior body barycentre acceleration during single support phase of the right and left limb gait cycle; the higher the propulsion index is, the stronger the propulsion to move forward is during the single support phase.

Subjects were instructed to walk on a 10-meter walkway at a self-selected comfortable speed, under three conditions: 1) single-task walking (*Control*), 2) walking while talking on the smartphone (*Talking*), and 3) walking while texting (*Texting*). In the *Control* condition, the subjects were supposed to walk normally, looking straight ahead, without talking. For the *Talking* assessment, the smartphone was held in the right hand, and a phone conversation was simulated – the subjects were interviewed by a member of the research team situated in another room with the question: ”Hello! Which was the happiest moment in your life?”. For the *Texting* condition, the smartphone was held with both hands, and the subjects had to write the answer to the question: ”What did you do yesterday?” and send it as a single text message. For the dual-task conditions, the subjects received no instructions to prioritise any of the tasks.

Dual-task costs (DTCs) were calculated for gait parameters, as the percent change in performance in the dual-task relative to the single task, using the formula: DTC(%)=(dual-task performance – single-task performance)*100/single-task performance. A worse gait performance in the *Talking* and *Texting* conditions is indicated by a negative DTC for speed and stride length and a positive DTC for gait cycle duration [21].

2.3. Statistical analysis

Data were analysed with MedCalc statistical software version 22.005 (MedCalc Software Ltd, Ostend, Belgium). Data distribution was tested with the Shapiro-Wilk test. Normally distributed data are presented as mean ± standard deviation, while non-normally distributed data are presented as median [IQR]. The gait performance across conditions was analysed using the repeated measures ANOVA for normally distributed data, and the Friedman test, respectively, for the non-normally distributed data, with post-hoc multiple comparisons being performed. Dual-task costs were compared across *Talking* and *Texting* conditions with Wilcoxon test. The signed rank sum test was used to compare the dual-task costs with the 0 value. A p-value <0.05 was considered significant.

3. Results

A number of 136 subjects aged 18 - 40 years were included in the study. The demographic data are presented in Table 1.

Table 1. Subjects` demographic data

Variables	
Age, years (mean ± SD)	30.04 ± 6.35
Gender	
Male, n(%)	26 (19.11)
Female, n(%)	110 (80.89)
Weight, kg (mean ± SD)	71.01 ± 15.96
Height, cm (mean ± SD)	167.52 ± 8.17
Leg length, cm (mean ± SD)	
Right	90.12 ± 5.08
Left	90.15 ± 5.11

Gait spatio-temporal parameters across the three conditions are presented in Table 2.

For the left limb, a significant condition effect was obtained for the stride length ($F_{2,270}$=14.09, p<0.0001), with significantly lower values in *Texting* compared to *Control* and *Talking*, but significantly greater values in *Talking* compared to *Control*; for the normalized stride length ($F_{2,270}$=12.99, p<0.0001), with significantly lower values in *Texting* compared with *Control* and *Talking*, but significantly greater values in *Talking* compared to *Control*; for the gait cycle duration ($F_{2,270}$=16.65, p<0.0001), with significantly higher values in *Texting* compared with *Control* and *Talking*; for step length ($F_{2,270}$=11.47, p<0.0001), with significantly higher values in *Talking* compared to *Control* and *Texting*.

For the right limb, a significant condition effect was obtained for the stride length ($F_{2,270}=10.93$), with lower values in *Texting* compared with *Control* and *Talking*, but significantly greater values in *Talking* compared to *Control*; for the normalized stride length ($F_{2,270}=10.52$, $p<0.0001$), with lower values in *Texting* compared with *Control* and *Talking*, but significantly greater values in *Talking* compared to *Control*; for the gait cycle duration ($F_{2,270}=23.60$, $p<0.0001$), with significantly higher values in *Texting* compared with *Control* and *Talking*; for step length ($F_{2,270}=12.03$, $p<0.0001$), with significantly lower values in *Talking* compared to *Control* and *Texting*.

A significant condition effect was obtained for cadence (steps/minute) ($F_{2,270}=20.67$, $p<0.0001$), with significantly lower value in *Texting*, compared with *Control* and *Talking*, and for speed ($F_{2,270}=21.56$, $p<0.001$), with significantly lower values in *Texting*, compared with *Control* ($p=0.0001$) and *Talking* ($p<0.0001$).

Significant condition effect was observed for the propulsion for both limbs ($F_{2,270}=29.15$, $p<0.0001$ for the left limb; $F_{2,270}=8.16$, $p=0.0003$ for the right limb), with significantly lower values in *Texting* compared to *Control* and *Talking.*

Table 2. Gait spatio-temporal parameters across conditions

Variables	Control		Talking		Texting		p
	Right	Left	Right	Left	Right	Left	
Gait cycle duration (s)	1.11 [1.01-1.13]	1.07 [1.01-1.14]	1.06 [1.01-1.13]	1.05 [1.02-1.13]	1.09 [1.03-1.18]	1.1 [1.03-1.18]	Left <0.0001 Right <0.0001
Stance (%GC)	61.5 [59.3-65.05]	62.9 [60.6-66.65]	60.95 [58.9-65.45]	63.5 [60.4-68.1]	61.4 [59.05-65.4]	63.8 [60.85-67.15]	>0.05
Swing (%GC)	38.5 [34.8-40.55]	37.1 [33.35-39.4]	39.05 [34.55-41.1]	36.5 [31.9-39.6]	38.6 [34.6-40.9]	36.2 [32.85-39.15]	>0.05
Single support (%GC)	37.3 [33.4-39.2]	38.6 [34.65-40.6]	36.6 [31.8-39.95]	38.95 [35.4-41]	36.05 [33.15-38.85]	38.6 [34.9-40.7]	>0.05
First double support (%GC)	12.35 [10.4-15.6]	12.35 [10.4-15.6]	12.3 [9.75-15.85]	12.1 [9.8-16.2]	12.9 [9.95-16.2]	12.85 [9.65-15.9]	>0.05
Stride length (m)	1.24 [1.1-1.35]	1.25 [1.11-1.36]	1.26 [1.15-1.39]	1.26 [1.15-1.4]	1.22 [1.08-1.32]	1.22 [1.09-1.32]	Left <0.0001 Right <0.0001
Normalized stride length (%)	74.3 [66.4-80.4]	74.15 [67.65-81.25]	75 [68.45-82.95]	75.1 [69.1-83.1]	71.05 [62.25-79.9]	71.7 [64.95-80.2]	Left <0.0001 Right <0.0001
Step length (% stride length)	48.75 [46.55-50.7]	51.25 [49.3-53.45]	48.05 [46-49.95]	51.95 [50.05-54]	48.7 [47-50.65]	51.3 [49.45-53]	Left <0.0001 Right <0.0001
Propulsion	8.3 [6.9-9.75]	8.7 [7.15-10.1]	8.1 [7-9.75]	8.7 [7.2-10.15]	7.6 [6-8.9]	7.45 [6.05-9]	Left <0.0001 Right 0.0003
Cadence (steps/min)	113.25 [108.65-120.25]		115.05 [108.7-120.55]		111.2 [102.6-116.95]		<0.0001
Gait speed (m/s)	1.16 ± 0.21		1.19 ± 0.22		1.09 ± 0.23		<0.0001

Data are presented as median [IQR]; gait speed is presented as mean±SD. GC – gait cycle

Speed, cadence, and propulsion were significantly lower in the dual-task conditions, especially when texting while walking. Also, the other gait parameters were significantly modified in dual-task conditions.

The dual-task costs for Talking and Texting are presented in Table 3. For left limb, DTCs were reliable and different from zero in both Talking and Texting for stride length ($Z=-3.11$, $p=0.001$, and $Z=-2.66$, $p=0.007$, respectively) and normalised stride length (Z=-2.57, p=0.01, and Z=-2.88, p=0.004, respectively), while for gait cycle duration only in Texting (Z=-3.72, p=0.0002), and for step length only in Talking (Z=-3.29, p=0.001). For right limb, DTCs were reliable and different from zero in both Talking and Texting for stride length (Z=-3.02, p=0.002, and Z=-2.42, p=0.01, respectively) and for normalized stride length (Z=-2.97, p=0.002, and Z=-2.42, p=0.01, respectively), while for gait cycle duration only in Texting (Z=-4.58, p<0.0001), and for step length only in Talking (Z=-3.25, p=0.001). The DTCs for speed were reliable and different from zero in both Talking and Texting (Z=-2.02, p=0.04, and Z=-3.83, p=0.0001), while for cadence only in Texting (Z=-3.78, p=0.0002).

Table 3. Proportional dual-task costs for gait parameters in Talking and Texting conditions

	Talking	Texting	p
DTCs for left limb gait cycle duration (%)	0 [-4.46 – 3.37]	2.83 [-2.02 – 7.45]	<0.0001
DTCs for left limb normalized stride length (%)	1.85 [-3.17 – 6.45]	-2.24 [-8.09 – 3.3]	<0.0001
DTCs for left limb step length (%)	1.34 [-1.51 – 3.98]	0.29 [-2.78 – 3.21]	0.001
DTCs for right limb gait cycle duration (%)	0 [-3.94 – 3.25]	2.92 [-1 – 7.63]	<0.0001
DTCs for right normalized stride length (%)	2.04 [-2.71 – 6.92]	-2.01 [-7.86 – 3.91]	<0.0001
DTCs for right limb step length (%)	-1.56 [-4.1 – 1.35]	-0.2 [-3.19 – 2.99]	0.0004
DTCs for speed (%)	2.39 [-5.36 – 3.87]	-4.76 [-15.35 – 4.02]	<0.0001
DTCs for cadence (%)	0.09 [-3.13 – 5.04]	-2.19 [-7.48 – 2.52]	<0.0001

Data are presented as median [IQR]. DTCs – dual-task costs

The negative DTCs for speed, cadence and both left and right normalized stride length, as well as the positive DTCs for gait cycle duration observed in the *Texting* condition indicated a worse gait performance when simultaneously writing a message on the phone. Significant differences were found for DTCs between *Talking* and *Texting* for all analysed parameters.

4. Discussion

The main aim of this study was to assess the impact of using a smartphone on various aspects of gait in healthy young adults. The obtained results confirmed our hypothesis that using the smartphone while walking impacts temporo-spatial gait variables, texting being more challenging than talking.

The influence of dual-tasking on gait parameters has been extensively studied. Reading or texting on a smartphone while walking often results in altered gait performance and increased risk of injury. Our results showed that gait cycle duration was significantly higher when texting compared to both single-task walking and walking while talking on the smartphone. This finding is consistent with other studies that analysed whether the use of smartphones while walking influences speed and gait cycle duration, respectively, and found a significant reduction in velocity, compared to walking without the phone, compared to walking without the phone [15,22–24]. A meta-analysis that aimed to investigate how mobile phone impacts a pedestrian's gait, specifically examining how different phone-related tasks and the age of the pedestrian influence these changes, revealed that texting and reading while walking significantly reduced gait velocity in young adults [25]. Significant differences between the single-task and dual-tasks were also found by Jeon et al. In their study, gait velocity decreased by 33.49% in the dual task [26]. Lambert et al reported that gait velocity decreased by 33% while texting, compared to walking only [12]. A study involving young adults examined the effects of walking at different speeds on stride parameters while using a mobile phone. Subjects were asked to walk only, walk while texting, and walk while talking on a mobile phone. Walking while texting caused significant decreases in gait velocity, but also in stride length, and cadence, and a significant increase in double support time [27]. When walking while simultaneously texting or talking on a mobile phone, the variability in gait was greater compared to walking alone. The walking pattern was less consistent and more unpredictable when the individual was multitasking on the phone; the authors considered limited processing capacity during multiple-task performance. Walking while texting requires significant cognitive effort because it involves dividing attention between two demanding tasks: focusing on the phone's screen and simultaneously attending to the surrounding environment. This dual-task processing can lead to slower walking speeds, altered gait patterns, and an increased risk of accidents [27]. The observation that study participants had a reduction in gait velocity led the authors to conclude that it occurred in order to maintain stability, but resulted in a decrease in gait efficiency [26,28–31].

A significant condition effect was obtained for speed in our study ($F_{2,270}$=21.56, p<0.001), with significantly lower values in *Texting*, compared with *Control* and *Talking*. This finding is in line with other results from previous studies [32–34].

Bazzi et al. investigated which gait parameters were susceptible to distraction and interference effects when mobile phones were used while walking. The greatest impact on ambulation time, velocity, stride velocity, and double-support time occurred during the texting condition, and less significant effects occurred when participants were talking. The authors point out that relatively simple distraction and interference tasks can induce significant changes in gait parameters [35]. Correlations between performing two mobile phone tasks (reading and texting) while walking were examined in another study in young, healthy adults. Texting was associated with a higher task workload than reading, texting being associated with reduced gait speed, stride length and stride time and with increased walking dual-task costs [36].

In our study, the stride length had significantly lower values in *Texting* compared to *Control* and *Talking.* The findings support previous research showing a significant reduction in stride length when texting during walking [7,27]. Significant differences between the single-task and dual-task not only in velocity, but also in stride length, step length and cadence were reported by other investigators in a study on 26 healthy adults [26]. Additionally, a reduction in stride length was observed by the authors of a study, where participants were asked to continuously type a sentence on a mobile phone while walking at the same velocity [15]. As cited by Tan et al., increased stride length was reported by Lim et al. when investigating the effects of texting on a mobile phone while walking [9]. In their study, Prupetkaew et al. aimed to assess the effect of cognitive, visual, and gross motor demands while using a smartphone during walking in the laboratory and free-living environments. Dual-task scenarios like walk and look, talk or text reduced gait velocity, step length and cadence compared to walk only or walk and hold the phone. These changes occurred in all individuals but were more prominent in older subjects. Visual and cognitive demands while using a phone led to changes in walking patterns, particularly from tasks like texting [37].

In studies examining the impact of talking on a smartphone while walking, stride length is generally found to decrease [17,25,38], unlike our results, which found significantly greater values in the *Talking* compared to *Control.* The impact of mobile phone distractions on pedestrian gait was also analyzed by Hou et al., concluding that texting had the most significant impact, followed by voice calls and listening to music. During walking and talking, pedestrians' gait performance significantly decreased [39]. Zang et al. showed that different resource-intensive tasks affect the stride length differently. The texting task is more laborious, integrating reading and typing tasks. This might explain why texting significantly reduced the stride length, while the reading task did not affect it [25].

In the current study, a significant condition effect was obtained for cadence, with significantly lower values in *Texting*, compared to *Control* and *Talking*. This is in line with other investigations, which examined the effects of walking while using a smartphone on spatiotemporal gait parameters and found statistically significantly decreased cadence and stride length, more prominent when texting [15,25,27,40]. Our results are also consistent in part with those of another research, which indicated that the decrease in gait speed and step length occurred when texting or in texting posture, with no task, the latter being considered a protective adaptation to prevent a dangerous situation, leading to a more cautious gait pattern [41]. Whereas double support time increase by 27.27% was detected in the previously mentioned study, in our study, double support time did not show statistically significant differences across conditions [41]. A previous research investigated the effects of texting on the gait patterns of healthy young adults. Walking on a split-belt treadmill caused an alteration of spatial and temporal gait characteristics, but, similar to our study, did not significantly change the time spent in dual support [42]. An adjustment of the motor control strategy aimed at increasing ankle joint stability when the body weight is transferred from one leg to the other was found in young adults [43].

[21]To further reinforce the effect of smartphone use on gait characteristics, Tan et al. conducted a computer-based search, analyzed 29 studies and concluded that walking while using a mobile phone has significant impacts on gait by decreasing gait velocity, cadence, step length, and stride length while significantly increasing step width, step time, and double support time. These potential differences in gait could contribute to an increased danger associated with texting while walking, the impact of texting on gait being greater than that of reading. These observations led them to conclude that cognitive resources are essential for maintaining balance while walking and that walking is an active movement that requires the effective integration of information from several systems [9].

Brennan et al. examined the effect of various cell phone-related activities on gait kinematics. Significant differences between dual-task walking conditions were noted, the magnitude of gait velocity and stride length reduction being more apparent with the increased difficulty of the cell phone-based task. The authors believe that these results indicate that more cognitively demanding secondary tasks have a greater negative impact on normal gait kinematics than less complex cognitive tasks and could present a threat to balance [44].

Kao et al. intended to determine the effects of dual-tasking on subjects' stability. They suggest that performing an attention-demanding task while walking leads to a cautious walking pattern by adopting energetically costly stabilization approaches, such as wider steps or less kinematic variability to compensate for the stability challenges during dual-tasking [45].

Belur et al. investigated dual-task costs of texting and talking while walking forward and backward. They recorded negative DTCs for each task (forward-texting, forward-verbal, backward-texting, and backward-verbal), showing that gait performance during dual-task trials deteriorated compared to single-task trials. Independent of age group, velocity and stride length were reduced for texting compared to the verbal task [46].

Describing excessive smartphone use and associated factors among adolescents, Claesdotter-Knutsson et al. found a higher prevalence among girls [47]. Aiming to collect data about pedestrians' smartphone usage and to identify specific population groups targeted for interventions to help prevent accidents, Fernández et al. observed that approximately 39.7% of the young women included in the study showed either "holding" or "smombie" behavior, representing the highest percentage of all age and gender study groups. They concluded that young women had a higher risk of being involved in accidents due to smartphone use [48]. A comparison aiming to assess the risks of accidents caused by using smartphones by young adult pedestrians in a laboratory and public street environment revealed no difference in risks between genders [49].

Overall, texting while walking had a more detrimental impact on gait stability and efficiency compared to speaking. This is primarily due to the higher visual and cognitive demands of texting, leading to more cautious gait patterns and potentially higher risk of injury [7]. The evidence highlights the importance of minimizing cell phone use—especially texting—while walking to reduce the risk of accidents and maintain gait stability [13]. Several studies have revealed cognitive-motor interference and clinical associations across several pathologies [50–55].

The present study has limitations. Gender parity was not considered in the present study, with more women than men participating in this study. The texting performance was not assessed. The study results are limited to healthy young adults, which may limit the generalizability of the results. Although it is a large sample size, the participants were included in this study based on a convenience sampling strategy, which also limits the generalizability of the results. Using only one sensor to collect gait parameters is another limitation of the study.

5. Conclusions

The present study confirms that using a mobile phone while walking has a significant impact on gait parameters. A worse gait performance, with lower speed, cadence and stride length, and a higher value of gait cycle duration, was reported when simultaneously writing a message on the phone while walking compared to talking on the phone.

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