Gait & Posture 62 (2018) 415–421

Contents lists available at ScienceDirect

Gait & Posture

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

Full length article

Specific smartphone usage and cognitive performance affect gait characteristics during free-living and treadmill walking

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ARTICLE INFO

Keywords:
Cell phone
Mobile phone
Cellular phone
Walking
Attention
Dual-task
Gait variability

ABSTRACT

Background: Mobile phone tasks like texting, typing, and dialling during walking are known to impact gait characteristics. Beyond that, the effects of performing smartphone-typical actions like researching and taking self-portraits (selfie) on gait have not been investigated yet.

Research question: We aimed to investigate the effects of smartphone usage on relevant gait characteristics and to reveal potential association of basic cognitive and walking plus smartphone dual-task abilities.

Methods: Our cross-sectional, cross-over study on physically active, healthy participants was performed on two days, interrupted by a 24-h washout in between. Assessments were: 1) Cognitive testing battery consisting of the trail making test (TMT A and B) and the Stroop test 2) Treadmill walking under five smartphone usage conditions: no use (control condition), reading, dialling, internet searching and taking a selfie in randomized order. Kinematic and kinetic gait characteristics were assessed to estimate conditions influence.

Results: In our sample of 36 adults (24.6 ± 1 years, 23 female, 13 male), ANCOVAs followed by post-hoc *t*-tests revealed that smartphone usage impaired all tested gait characteristics: gait speed (decrease, all conditions): $F = 54.7$, $p < 0.001$; cadence (increase, all): $F = 38.3$, $p < 0.001$; double stride length (decrease, all): $F = 33.8$, $p < 0.001$; foot external rotation (increase during dialling, researching, selfie): $F = 16.7$, $p < 0.001$; stride length variability (increase): $F = 11.7$, $p < 0.001$; step width variability (increase): $F = 5.3$, $p < 0.001$; step width (Friedmann test and Wilcoxon Bonferroni-Holm-corrected post-hoc analyses, increase): $Z = -2.3$ to -2.9; $p < 0.05$); plantar pressure proportion (increase during reading and researching) ($Z = -2.9$; $p < 0.01$). The ability to keep usual gait quality during smartphone usage was systematically associated with the TMT B time regarding cadence and double stride length for reading ($r = -0.37$), dialling ($r = -0.35$) and taking a selfie ($r = -0.34$).

Significance: Smartphone usage substantially impacts walking characteristics in most situations. Changes of gait patterns indicate higher cognitive loads and lower awareness.

1. Introduction

With over two billion worldwide users [1], smartphones and their impact on our everyday live are of increasing cultural relevance [2]. A recently published survey revealed that over 20% of the young adults use their smartphone during walking [3]. As both, smartphone usage and walking, require cognitive attention, dual-task interference caused by mobile phone handling is associated with cognitive loads and reduced situational awareness [4]. As a result, texting messages and dialling are known to impact gait characteristics [2,5] due to cognitive distraction, visual field alterations and changes in mechanical demands [4]. All these impairments may result in falls or other safety issues, such as accidents of pedestrians avoiding obstacles or crossing the road.

As stated above, most studies on this topic focused on texting and dialling situations only. Texting and dialling are suggested to increase absolute lateral foot position from one stride to another and to decrease gait speed [4], found in overground walking. Further, stride length and step cadence are different during texting and dialling than during standard walking. As reading a message, internet researching and taking a picture of oneself (selfie) may differ from the classical mobile phone tasks texting and dialling, in physical (position of the smartphone and the head), visual (eye position and/or movements), and cognitive demands, their impact on gait characteristics are of relevance but unknown yet.

Beyond standard spatiotemporal characteristics, first hints indicate that gait variability may increase when dialling on a smartphone [6].

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https://doi.org/10.1016/j.gaitpost.2018.04.007
Received 4 August 2017; Received in revised form 4 April 2018; Accepted 5 April 2018
0966-6362/

Table 1
Participants' anthropometrics and demographics as well as relevant co-variates (parts A and B) and neuropsychological tests (part C). n = number; MA = Master degree; BA = Bachelor degree; FoF = fear of falling; TMT = trail making test.

A	mean	standard deviation	minimum	maximum
age [years]	24.7	1.97	21.0	30.0
BMI [kg/m^2]	22.5	2.43	18.8	29.7
smartphone usage [h/day]	3.4	1.5	1.0	7
alertness day 1 [cm]	6.0	1.9	2.5	10
alertness day 2 [cm]	5.8	2.0	2.1	10
coffee consumption [cups]	2	1	0	6

B	number			
		yes	partially	no
sex	female = 23; male = 13			
drug/medication consumption [n]		0		36
educational degree	MA = 5; BA = 29; A-level = 2			
contact/collision sports		26		10
injury history lower extremity		23		13
		often	sometimes	never
phone texting/reading during walking [n]		14	21	1
phone calling during walking [n]		16	19	1
internet research during walking [n]		16	8	12
selfie during walking [n]		4	0	32
FoF during walking [n]	none = 35, some = 1, quite = 0, a lot = 0			
FoF during texting/reading [n]	none = 33, some = 3, quite = 0, a lot = 0			
FoF during calling [n]	none = 52, some = 1, quite = 0, a lot = 0			
FoF during selfie [n]	none = 30, some = 4, quite = 2, a lot = 0			
FoF during researching [n]	none = 28, some = 7, quite = 1, a lot = 0			

C	mean	standard deviation	minimum	maximum
TMT A [sec]	21.0	5.6	14	39
TMT B [sec]	44.4	11.6	21	73
Stroop colour [sec]	42.7	6.4	32	61
Stroop word [sec]	27.4	3.3	20	35
Stroop interference [sec]	66.5	11.8	46	104

Variability during repetitive movements reflects an inherent functional feature of the neuromuscular system [7]. It has recently been delineated to be of relevance for new motion patterns' learning processes [8, 9] and thus it is of relevance when rating gait characteristics under smartphone dual-task conditions.

The ability to simultaneously walk and use a smartphone might further be mediated by cognitive functions such as attention, working memory, secondarily task-switching abilities, parallel processing of the irrelevant and the relevant information and executive control. First hints indicate an association of cognitive performance and dual-task walking conditions in healthy [10]. Participants with poorer performance in working memory, secondarily task-switching abilities showed higher dual-task costs during walking. Currently no study has investigated, if such classic cognitive abilities are related to the ability of maintaining adequate walking patterns during smartphone usage as the second task.

We aimed to 1. Investigate the effects of smartphone usage (no use, calling, reading a message, internet searching and taking a selfie) on relevant gait characteristics and 2. Reveal potential association of basic cognitive and walking plus smartphone dual-task abilities. We hypothesized that smartphone usage will lead to impairments in spatio-temporal kinetic and kinematic outcomes and that these impairments are negatively associated with basic cognitive abilities.

2. Methods

2.1. Design, ethical standards and participants flow

The study adopted a cross-sectional crossover design in young, healthy and physically active individuals.

Ethical approval was obtained from the local institutional review board and the trial was conducted in accordance to the ethical standards set by the declaration of Helsinki (WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects) with its recent modification of 2013 (Fortalezza).

Participants were considered eligible if they fulfilled the following inclusion criteria: male or female aged 18–30, physically active (self-reported, > 150 min/week of physical activity), possession and regular use of a web-enabled smartphone (in everyday situations).

Exclusion criteria consisted of delayed onset muscle soreness, surgery in the previous 12 months, pregnancy or nursing period, intake of analgesics and/or perception changing substances, severe cardiovascular/pulmonary/renal dysfunction, confirmed neurologic/psychological diseases, degenerative musculoskeletal, incompletely cured injuries and alcohol consumption 12 h prior to study inclusion.

Participants were recruited by personal request of one of the authors. Interested persons were scheduled for a visit and then screened for eligibility. All participants subscribed informed consent prior to study enrolment.

2.2. Study flow

The cross-sectional, crossover study was performed on two consecutive days, interrupted by a 24-h washout period in-between. At day one, sociodemographic characteristics as well as all potential known and suggested confounders (including potential circadian rhythm confounders) and co-variates were assessed using structured interviews, followed by the cognitive testing battery, consisting of the trail making test part A and B (TMT A, TMT B) and the Stroop test. Subsequently, preferred walking speed – to be reproduced in the actual experiment