Gait & Posture 49 (2016) 97–101

Contents lists available at ScienceDirect

Gait & Posture

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

Full length article

Are there differences in the dual-task walking variability of minimum toe clearance in chronic low back pain patients and healthy controls?

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ARTICLE INFO

Article history:
Received 23 November 2015
Received in revised form 20 June 2016
Accepted 21 June 2016

Keywords:
Gait
Divided attention
Motor-cognition

ABSTRACT

The control of minimum toe clearance (MTC, as quantified with its stride-to-stride variability during walking) is a promising marker to evaluate motor control. The control of MTC, compared to other gait parameters, was reported to have higher priority. The relationship between the control of MTC and other gait parameters should be examined to elucidate tripping mechanisms. This study aimed at investigating the variability of MTC, stride time and stride length in normal walking and in dual-task walking in back pain sufferers. Twelve patients with chronic low back pain and twelve healthy controls walked with inertial sensors attached on their feet with and without a cognitive dual task. Standard deviations of stride time, stride length and MTC were calculated. Regarding the comparison of dual-task walking in pain patients vs. controls, we found higher variability in stride time in the back-pain group. Higher dual-task walking variability was observed in stride length and stride time only in back pain sufferers. Regarding MTC, however, neither a difference between groups nor between walking conditions were found. We observed that individuals with pain, who generally show higher gait variability, are able to control MTC in a dual-task condition indicating that their central nervous system might prioritize control of MTC over other gait parameters. Cases in which also MTC variability increase because of a dual task might characterize alarming fall risk. Dual-task MTC variability should, therefore, be estimated in individuals with severe fall risk as in old individuals with pain, frail people or neurological patients.

1. Introduction

Exploring variability in human movement is critical for understanding the functioning of the human sensorimotor system and motor control [1]. Pathology and aging goes along with altered movement variability [2] with extreme levels of variability indicating non-physiological motor behaviour [1,3]. Especially the variability of minimum toe clearance (MTC) seems to be a promising marker to evaluate motor control during walking in older adults as it depicts a precise-end-point control task [4,5]. The control of MTC reflects the ability to negotiate external surface-related perturbations (control of boundary constraints) which is required to avoid tripping [6]. Thus, whereas other sensitive measures provide information about an individual's ability to adequately respond to a trip or other unexpected perturbations in order to prevent falling (e.g. local dynamic stability [7–9]), the variability of MTC might provide information about the likelihood to experience a trip.

Gait control/automatism is frequently assessed with a motor-cognitive walking dual-task paradigm [10]. Many theories exist regarding why dual-task interferences arise [11–13] but these theories have not been definitively proven. In most established theories, attentional limitations are responsible for the resulting dual-task costs [13]. Stable gait relies on attentional resources and brain activity during walking, which again is sensitive to task complexity, age and pathologies. This phenomenon underpins the significance of cortical and sub-cortical gait control mechanisms [14]. But the human brain's capacity is limited [15]. The neural structures that process information in the motor systems and sensory systems show competitive behaviour [16] which might presumably be because of the brain's limited resources coupled with the inability to sustain activation simultaneously in all neural structures in challenging dual-task situations [17]. Therefore, gait

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[1] All authors were fully involved in the study and preparation of the manuscript. Each of the authors has read and concurs with the content in the final manuscript. The material within has not been and will not be submitted for publication elsewhere except as an abstract.

http://dx.doi.org/10.1016/j.gaitpost.2016.06.026
0966-6362/

variability increases significantly (becomes worse) when walking while performing a cognitive task [18]. However, it was reported that in healthy older people, MTC variability does not change in a dual-task walking condition as compared to normal walking whereas the variability of stride time and stride length did significantly increase. It has been speculated that MTC control might be of higher importance than the control of other gait parameters in challenging situations [19] and, thus, is controlled more precisely even in dual-task situations. In a test-retest reliability study, it further was found that after a period of one week, older individuals were more able to reproduce their MTC variability as compared to the variability of other gait parameters (e.g. stride time and stride length) [20]. These data also indicate that MTC could be a more controlled gait parameter where big changes are avoided by the central nervous system in healthy individuals.

MTC height central tendency has been reported not to be affected by ageing [4]. Its variability, however, has been shown to be greater in older adults [5], and in groups with pathological gait [21]. In addition, we previously observed that in older people, MTC variability of dual-task walking improved after a 6 months motor-cognitive intervention [22] while the variability of the other gait parameters does not change. These results show that 1) the control of MTC can be improved and 2) the control of MTC is prioritized to be addressed by an appropriate motor-cognitive dual-task intervention. Nevertheless, the relationship between the control of MTC (which is strongly associated with tripping risk [4]) and other gait parameters is not yet fully understood and should especially be examined in at-risk subjects to elucidate potential tripping mechanisms [23].

Patients suffering from chronic pain are such at-risk individuals (e.g. for falling) [24,25] and functional implications caused by pain have frequently been studied using dual-task paradigms. The stride-to-stride variability of trunk trajectories in chronic low back pain patients is reported to increase to a higher extent due to a dual-task situation as compared to healthy controls [26]. This might be because chronic pain contributes to a shift in the balance of gait control from automaticity to executive control. One mechanism, which could be responsible for that phenomenon, is the intentional avoidance of pain (executive locomotor control strategy) where individuals consciously adjust their movements in order to minimize the occurrence of pain [27]. Another reason explaining a more controlled movement might be the interference which exists between the neural control pathways for pain and automaticity [10] as pain exerts inhibitory effects on motor activity through cerebral and spinal mechanisms [10,28,29]. This, in turn, could explain why pain has disruptive effects on cognitive functions possibly leading 1) to a decreased capability to dual task [30] and 2) to increased motor-cognitive dual-task costs while walking. These dual-task costs could increase tripping risk especially if MTC control during walking is also negatively affected.

The aim of the current study is to investigate the variability of 1) MTC, 2) stride time and 3) stride length in normal walking and in a cognitive dual-task walking condition in patients suffering from chronic low back pain and healthy controls. As on the one hand, the variability of stride time and stride length increases during a dual-task condition but the MTC variability does not [19], and on the other hand, chronic LBP patients increase their trunk variability while healthy controls do not [26], we hypothesized that 1) only in chronic LBP patients, the MTC variability increases in the dual-task condition, and that 2) the variability of all gait parameters is higher in chronic LBP patients as compared to healthy controls.

2. Methods

The study has been approved by the local ethics committee at Otto von Guericke University, Magdeburg. Twelve healthy participants (mean age = 57 years, SD = 14 years) not suffering from orthopaedic or neurological diseases and twelve chronic LBP patients (self-reported pain lasting for three or more months as well as a visual analogue scale pain score (with "0" indicating no pain and "10" indicating maximal pain) of 4 or higher; mean age = 55 years, SD = 12 years) were recruited from a back therapy training course (which contains strength and mobility exercises) of a local health-orientated sports club. Each participant signed a written informed consent and the study has been carried out in accordance with the Declaration of Helsinki.

For 2 minutes, the participants walked on a 25 meter long track forth and back at their preferred walking speeds. They walked also for 2 minutes (after 3 minutes of rest) performing simultaneously the Regensburger word fluency test. This is a verbal fluency task, which is used for neuropsychological screenings for executive functioning and linguistic skills [31]. Here, subjects recite as many words as possible within 2 minutes beginning with a given letter in a time period of two minutes. No instruction was given with respect to what task (either walking or reciting words) the participants had to prioritize. The order of the two walking tasks was randomized.

To collect gait data, we used an inertial sensor (MTw, Xsens Technologies B.V., Enschede, The Netherlands) which was attached to each of the subjects' feet. The stride-to-stride variability was quantified using the standard deviations of stride time, stride length and MTC and calculated as described and evaluated in [20].

All data were checked for normal distribution (Kolmogorov–Smirnov test). As data were not normally distributed, the Mann–Whitney *U* test for independent groups was used to calculate differences between the variability in all three gait parameters. We used the Wilcoxon test to examine if differences are significant between normal walking and dual-task walking in each group. The level of significance was set to $\alpha = 0.05$. All calculations were done with IBM SPSS Statistics 22.

3. Results

Table 1 and Table 2 show the means and standard deviations as well as medians and interquartile ranges of gait measures in single- and dual-task walking in LBP patients and healthy controls. The median and interquartile values of gait variability measures of LBP and controls in single-task and dual-task walking are presented in Table 3.

As shown in Fig. 1, the variability of stride length of LBP patients were higher ($Z = -2.824$; $p = 0.005$) in dual-task walking, while a non-significant increase was observed in control group ($Z = -1.412$; $p = 0.158$). Furthermore, the dual-task condition increased stride

Table 1
Medians (Interquartile ranges; IQR) and means (standard deviations; SD) of gait measures of single-task walking walking in the low back pain (LBP) group and control group. SL = stride length; ST = stride time; MTC = minimum toe clearance.

Condition	Single-task walking					
Gait parameter	Median (IQR) of SL [m]	Median (IQR) of ST [s]	Median (IQR) of MTC [m]	Mean (SD) of SL [m]	Mean (SD) of ST [s]	Mean (SD) of MTC [m]
LBP group	1.411 (0.202)	1.047 (0.083)	0.021 (0.015)	1.348 (0.149)	1.054 (0.072)	0.020 (0.008)
Control group	1.455 (0.100)	1.009 (0.096)	0.023 (0.009)	1.487 (0.080)	1.004 (0.067)	0.023 (0.007)