Gait & Posture 68 (2019) 111–114

Contents lists available at ScienceDirect

Gait & Posture

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

Short communication

The effects of habitual footwear in gait outcomes in people with Parkinson's disease

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ARTICLE INFO

Keywords:
Parkinson's disease
Walking
Kinematics
Footwear
Barefoot
Asymmetry
Variability

ABSTRACT

Background: Gait is impaired in individuals with Parkinson's disease (PD). Although the effect of habitual footwear on gait spatiotemporal parameters has already been established in neurologically healthy individuals, its effects on people with PD is unknown.

Research question: This study aimed to investigate the impact of habitual footwear on the step spatiotemporal parameters in people with PD.

Methods: Sixteen individuals with PD (G-PD) and 15 neurologically healthy individuals (G-HC) were assessed. Participants walked on an 8 m long pressure sensitive walkway at their preferred speed with and without their habitual footwear (3 trials per condition). Footwear included flip-flops, shoes, sneakers and sandals. The average, variability and asymmetry for step length, width, duration, and velocity and the percentage time in the swing and stance phases were calculated.

Results: The results showed in both groups a reduced percentage time in the swing phase and an increased step width, duration and length with footwear ($F(1,29) > 5.64$; $p < 0.02$). Additionally, habitual footwear increased step width variability in G-PD and G-HC ($F(1,29) = 3.97$; $p = 0.06$). Interestingly, only G-HC showed a higher step length asymmetry in the footwear condition than in the barefoot condition ($p = 0.02$). Finally, only when habitual footwear was used, G-HC showed a higher step velocity asymmetry than G-PD ($p = 0.04$).

Significance: These results indicate a negative influence of footwear on gait spatiotemporal parameters in both groups. Furthermore, footwear induced differences between groups. These findings indicate that footwear use is an influencing factor in studies comparing people with PD and healthy elderly. Further data are needed before definitive recommendations are made.

1. Introduction

Walking is impaired in Parkinson's disease (PD) (i.e.: reduced step length and velocity and increased step time and higher step variability and asymmetry, among others; for review: [1]). These gait impairments lead to a reduction in quality of life and are related to a higher risk of falls [2], what underlies the need to investigate gait in people with PD. Although the impact of some influencing factors on parkinsonian gait is established (i.e.: the effects of medication and dual-tasking [3,4]), the use of footwear has gain little attention. For example, gait has been assessed with the use of habitual [5], whereas others have assessed barefoot gait [6]. This technical detail might compromise comparison among studies, especially when a cohort with gait disabilities is considered, as PD [1], since the use of footwear significantly alters gait spatiotemporal characteristics (for review [7]).

Some could argue that assessing barefoot gait in people with somatosensory impairments, as people with PD [8], might be more indicated, since footwear reduces peripheral feedback from the feet. Additionally, footwear use restricts feet structure and functionality [7,9]. Therefore, the use of habitual footwear might lead to results that do not represent 'pure' pathological processes. In another way, some could also argue that the use of footwear during gait assessments has an important ecological relevance, since barefoot gait does not represent a day-life experience, especially in western cultures.

Hence, it is important to consider footwear use as an influencing factor during gait assessments in people with PD; however, this has never been investigated. The aim of this study was to investigate the influence of habitual footwear (compared to barefoot walking) on gait spatiotemporal parameters in people with PD and healthy elderly. As hypothesis, it is believed that people with PD will be more influenced

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https://doi.org/10.1016/j.gaitpost.2018.11.013
Received 26 January 2018; Received in revised form 5 October 2018; Accepted 10 November 2018

by task condition (footwear *vs* barefoot).

2. Methods

A sample group of 16 people with PD (referred as G-PD) and 15 healthy controls (G-HC) participated in this study. Participants were included if: over 60 years of age, able to walk without the use of any aids, no cognitive decline (> 24 in the Mini Mental State Examination (MMSE – [10]), and no musculoskeletal, orthopedic and/or visual impairments. In addition, people with PD were included if they were: diagnosed with idiopathic PD and taking regular PD medication. The Unified Parkinson's Disease Rating Scale motor subscale (UPDRS III – [11]) was used to determine the severity of the disease in the G-PD. This study was approved by the local ethics committee and all subjects gave written informed consent prior to the experiment.

Participants received the instruction to walk on an eight meters pressure-sensing walkway at their self-selected speed in two conditions (three trials per condition, distributed in blocks - randomized across participants): walking barefoot and with habitual footwear (footwear most frequently used during day-life). Gait parameters were recorded using a GAITRite® system with a frequency of 200 samples/s. For both conditions, the average, variability and asymmetry for step length, width, duration, and velocity and the percentage time in the swing and stance phases were calculated.

Demographic data were analyzed by independent-samples *t-test*. Step spatiotemporal parameters were analyzed by two-way ANOVA with group (G-PD x G-HC) and condition (barefoot x footwear) as factors, with repeated measures for the last. The Tukey post hoc test was used if needed. Significance was set at $p \leq 0.05$.

3. Results

The groups were similar for all demographic variables (Table 1). For the outcomes variables, ANOVA revealed group*condition interactions and main effects for Group and Condition (Table 2 and Fig. 1A). For the interaction, the Tukey post hoc test indicated an increased step length asymmetry in the footwear condition in comparison to barefoot only in the G-HC ($p < 0.01$). Additionally, footwear use induced a higher step velocity asymmetry in the G-HC compared to G-PD ($p = 0.04$). For the main effect of group, people with PD demonstrated lower step length and velocity when compared to G-HC. Furthermore, the use of habitual footwear increased step length, duration, width, step length asymmetry, and step width variability. Finally, footwear decreased swing duration and increased stance time. A Chi-Square test identified that the percentage of each footwear used was similar across groups ($X^2 = 0.37$; $p = 0.94$; Fig. 1B). For this last analysis, male and female shoes were combined.

4. Discussion

As main results, we observed a general impact of footwear on step spatiotemporal parameters, asymmetry and variability. Additionally, these effects were similar in healthy elderly and people with PD, with the exception of gait asymmetry that was higher with footwear only in G-HC.

The acute effects of habitual footwear observed in the step spatiotemporal parameters were similar to those reported previously [7,12]. The use of footwear increases pendulum effect due to extra weight given by the footwear [13] and to counteract these adaptations and to increase stability, participants increased step duration and the base of support in the antero-posterior (larger step length) and medio-lateral direction (larger step width) [14].

However, the most important finding of our study is that footwear induced differences between groups, as observed for step velocity asymmetry (Table 2). Considering that people with PD have a poorer mental flexibility [15], we believe that they were not able to shift the motor plan and therefore, maintained the same step asymmetry level in both conditions. Although we cannot confirm the reasons for a lack of condition effect on step asymmetry in G-PD, this results demonstrates the importance of standardizing one or another method (footwear or barefoot) in studies assessing gait in people with PD, especially when step asymmetry is considered. Based on our results and on the literature we suggest the assessment of barefoot gait based on: i) footwear apparently reduces participants' stability (i.e.: larger step width; Table 2, Fig. 1A); ii) footwear might over induce differences between groups, since they were not observed at baseline (Table 2) and; iii) footwear might reduce feet and ankle mobility [9]. However, these are preliminary data and further confirmation is needed before definitive recommendations.

Against the suggestion of assessing barefoot gait, some could argue that asking participants to walk barefoot might expose them to an unusual situation, since western cultures are accustomed to use footwear since childhood [7]. However, our data supports the opposite, since we found a higher step width variability (marginal effect) with the use of footwear, indicating the use of additional central processing in this condition [1].

This study has some limitations, as the low number of participants assessed and the absence of electromyography and kinetic assessments. Furthermore, distinct types of footwear were used without a standardized condition. However, we were successful to demonstrate that habitual footwear modifies gait pattern in both G-PD and G-HC. Nevertheless, our protocol did not expose participants to challenging situations, which might explain the low number of differences between groups and the low number of significant results on gait variability.

Table 1
Demographic and Cognitive characteristics per group.

	G-PD	G-HC	p-value
Gender (F/M)	9/7	9/6	—
Age (years)	69.19 ± 7.25	70.80 ± 5.51	0.33
Body weight (kg)	75.63 ± 26.68	77.27 ± 11.63	0.13
Body height (cm)	151.83 ± 43.99	163.64 ± 8.90	0.39
MMSE (0-30)	28.10 ± 2.13	27.67 ± 1.67	0.60
UPDRS III (0-108)	28.39 ± 7.28	—	—

MMSE: Mini Mental State Examination; UPDRS-III: Unified Parkinson's disease rating motor subscale.

5. Conclusion

We have demonstrated that footwear might alter gait pattern in people with PD and healthy elderly. Most important, we showed that footwear over induces differences between groups. However, further investigation is needed before definitive recommendations are made and therefore, we suggest that footwear should be considered as an influencing factor in future studies.

Conflict of interest

All authors disclose any financial and personal relationships with other people or organisations that could inappropriately influence (bias) this work.

Acknowledgements

The authors thank CAPES (Coordination for the Improvement of Higher Level -or Education- Personnel) for final support as scholarship (Grant #: N/A). Financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) [Finance Code 001].

Table 2
Average, variability and asymmetry of gait parameters per group and condition.

		G-PD		G-HC		Group Effect	Condition Effect	Group*condition Interaction
		Footwear	Barefoot	Footwear	Barefoot			
Average	Step length (cm)	58.93 ± 7.37	56.71 ± 6.82	64.90 ± 8.72	62.28 ± 7.80	**$F_{(1,29)}$ = 4.60, p = 0.04**	**$F_{(1,29)}$ = 14.84, p < 0.01**	$F_{(1,29)}$ = 0.11, p = 0.74
	Step duration (s)	0.57 ± 0.05	0.55 ± 0.05	0.54 ± 0.06	0.54 ± 0.05	$F_{(1,29)}$ = 0.82, p = 0.37	**$F_{(1,29)}$ = 5.64, p = 0.02**	$F_{(1,29)}$ = 2.09, p = 0.16
	Swing phase (%)	34.71±2.08	36.31±1.88	34.75±2.61	36.19±1.45	$F_{(1,29)}$ = 0.16, p = 0.69	**$F_{(1,29)}$ = 25.88, p < 0.01**	$F_{(1,29)}$ = 0.01, p = 0.91
	Stance phase (%)	64.24±2.54	63.16±2.02	64.25±3.40	62.16±2.38	$F_{(1,29)}$ = 0.38, p = 0.54	**$F_{(1,29)}$ = 10.62, p < 0.01**	$F_{(1,29)}$ = 1.08, p = 0.30
	Step velocity (cm/s)	105.62 ± 17.98	105.24 ± 16.56	122.23 ± 20.70	117.53 ± 18.07	**$F_{(1,29)}$ = 5.25, p = 0.03**	$F_{(1,29)}$ = 1.73, p = 0.20	$F_{(1,29)}$ = 1.25, p = 0.27
	Step width (cm)	12.08 ± 2.62	10.68 ± 2.71	11.81 ± 2.37	10.87 ± 1.96	$F_{(1,29)}$ = 0.00, p = 0.96	**$F_{(1,29)}$ = 36.23, p < 0.01**	$F_{(1,29)}$ = 1.30, p = 0.26
Variability	Step length (a.u.)	3.32 ± 1.24	2.87 ± 0.65	3.02 ± 1.07	2.83 ± 0.72	$F_{(1,29)}$ = 0.37, p = 0.55	$F_{(1,29)}$ = 2.88, p = 0.10	$F_{(1,29)}$ = 0.47, p = 0.50
	Step duration (a.u.)	0.04 ± 0.02	0.04 ± 0.01	0.04 ± 0.02	0.04 ± 0.01	$F_{(1,29)}$ = 0.10, p = 0.75	$F_{(1,29)}$ = 0.48, p = 0.50	$F_{(1,29)}$ = 0.01, p = 0.91
	Swing phase (a.u.)	2.08±1.56	2.23±1.52	3.49±3.47	2.09±2.13	$F_{(1,29)}$ = 0.81, p = 0.37	$F_{(1,29)}$ = 2.19, p = 0.14	$F_{(1,29)}$ = 3.38, p = 0.07
	Stance phase (a.u.)	5.25±4.83	5.16±3.76	7.67±8.67	5.00±4.68	$F_{(1,29)}$ = 0.49, p = 0.48	$F_{(1,29)}$ = 1.11, p = 0.29	$F_{(1,29)}$ = 0.96, p = 0.33
	Step velocity (a.u.)	8.70 ± 3.12	9.72 ± 2.28	13.22 ± 11.91	10.31 ± 2.82	$F_{(1,29)}$ = 2.18, p = 0.15	$F_{(1,29)}$ = 0.41, p = 0.53	$F_{(1,29)}$ = 1.76, p = 0.19
	Step width (a.u.)	4.59 ± 2.02	3.68 ± 1.17	3.85 ± 1.24	3.75 ± 1.37	$F_{(1,29)}$ = 0.52, p = 0.48	**$F_{(1,29)}$ = 3.79, p = 0.06** [a]	$F_{(1,29)}$ = 2.40, p = 0.13
Asymmetry	Step length (cm)	1.71 ± 1.08	1.36 ± 1.11	2.78 ± 1.73 [b]	1.43 ± 1.47	$F_{(1,29)}$ = 1.80, p = 0.19	**$F_{(1,29)}$ = 11.59,p < 0.01**	**$F_{(1,29)}$ = 4.05, p = 0.05**
	Step duration (s)	0.02 ± 0.01	0.02 ± 0.02	0.02 ± 0.02	0.02 ± 0.01	$F_{(1,29)}$ = 0.03, p = 0.86	$F_{(1,29)}$ = 0.30, p = 0.59	$F_{(1,29)}$ = 0.31, p = 0.58
	Swing phase (%)	0.03 ± 0.03	0.03 ± 0.03	0.04 ± 0.04	0.03 ± 0.04	$F_{(1,29)}$ = 0.11, p = 0.74	$F_{(1,29)}$ = 0.06, p = 0.81	$F_{(1,29)}$ = 1.37, p = 0.25
	Stance phase (%)	0.041±0.02	0.058±0.03	0.069±0.08	0.045±0.03	$F_{(1,29)}$ = 0.10, p = 0.74	$F_{(1,29)}$ = 0.06, p = 0.80	$F_{(1,29)}$ = 1.37, p = 0.25
	Step velocity (cm/s)	4.08 ± 3.92	5.13 ± 4.02	9.25 ± 8.12 [c]	5.77 ± 3.90	$F_{(1,29)}$ = 3.53, p = 0.07	$F_{(1,29)}$ = 1.25, p = 0.27	**$F_{(1,29)}$ = 4.34, p = 0.05**
	Step width (cm)	1.70 ± 1.21	1.83 ± 1.66	1.52 ± 1.62	1.96 ± 1.95	$F_{(1,29)}$ = 0.00, p = 0.96	$F_{(1,29)}$ = 0.55, p = 0.47	$F_{(1,29)}$ = 0.17, p = 0.69

G-PD: Group of people with Parkinson's disease; G-HC: Group of Healthy-Controls; a.u.: arbitrary units.
[a] indicates marginal effect.
[b] different from barefoot within the group.
[c] different from G-PD.

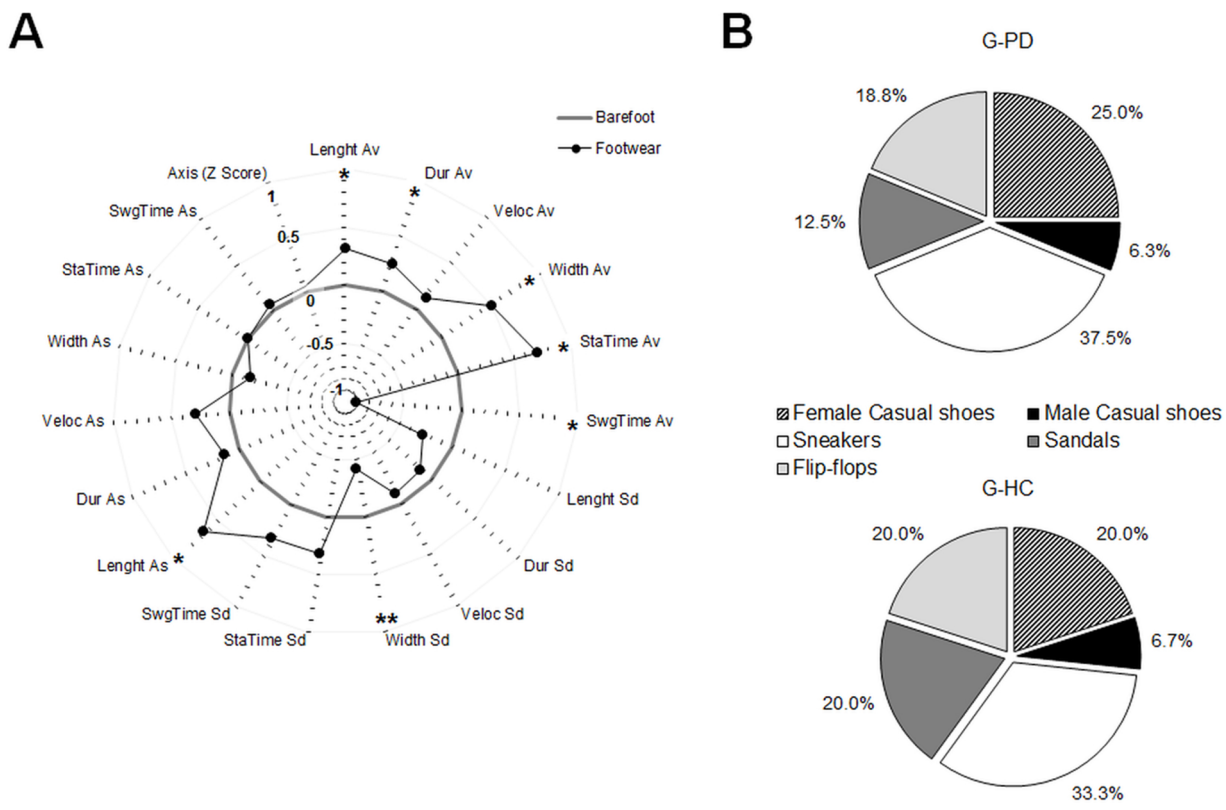

Fig. 1. General footwear effects and type used per group.
A: Satellite plot showing step spatiotemporal parameters deviations from barefoot gait (gray line). Av: average; Sd: variability; As: asymmetry; Dur: duration; Veloc: velocity; SwgTime: percentage of step in swing; StaTime: percentage of step in stance; * $p < 0.05$; ** marginal effect: $p = 0.06$. **B:** Type of footwear used per group.

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