Multiple Sclerosis and Related Disorders 13 (2017) 13–20

Contents lists available at ScienceDirect

Multiple Sclerosis and Related Disorders

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

Gait pattern in patients with different multiple sclerosis phenotypes

Irena Dujmovic[a,b,*], Sasa Radovanovic[c], Vanja Martinovic[d], Jelena Dackovic[a], Gorica Maric[e], Sarlota Mesaros[a,b], Tatjana Pekmezovic[e], Vladimir Kostic[a,b], Jelena Drulovic[a,b]

[a] *Clinic of Neurology, Clinical Centre of Serbia, Dr Subotica 6, 11129 Belgrade 102, Serbia*
[b] *University of Belgrade School of Medicine, Department of Neurology, Dr Subotica 6, 11129 Belgrade 102, Serbia*
[c] *Institute for Medical Investigations, Dr Subotica 4, 11129 Belgrade 102, Belgrade, Serbia*
[d] *University of Belgrade School of Medicine, Dr Subotica 8, Belgrade, Serbia*
[e] *University of Belgrade School of Medicine, Institute of Epidemiology, Visegradska 26A, 11000 Belgrade, Serbia*

ARTICLE INFO

Keywords:
Multiple sclerosis
Disease phenotypes
Disability
Gait pattern
Cognitive-motor interference

ABSTRACT

Background: Gait pattern is frequently impaired in multiple sclerosis (MS), however gait characteristics in patients with different MS phenotypes have not been fully elucidated.
Methods: We analyzed spatio-temporal gait pattern characteristics in patients with relapsing-remitting (RR, n=52) and primary-progressive (PP, n=18) MS in comparison with age-matched healthy controls (HC, n=40). All subjects performed a standardized simple walking task, a dual motor- motor task, a dual motor-mental task, and a triple combined motor-mental task at a GAITRite electronic walkway of 5.5 m active area. We measured: cycle time (CT), stride length (SL), swing time (ST), double support time (DST), gait velocity (GV) and calculated symmetry index (SI) for CT, SL and ST.
Results: With each task performed, CT and DST in the total MS group were significantly longer while SL was significantly shorter and GV significantly lower than in HC. ST was similar in the total MS patient group and HC. In both MS patients and HC, CT and DST increased and SL and GV decreased over repeated assessments. Dual and triple tasks while walking influenced walking performance in both MS patients and HC. Although patients with PPMS differed significantly from those with RRMS in the majority of gait parameters, the subgroup analysis in patients matched for age and disability (Expanded Disability Status Scale Score -EDSS, 3.0–5.0) showed similar gait performance in RRMS and PPMS patients having the same level of disability, except for CT and ST- symmetry parameters that were more impaired in the PPMS group. The EDSS score correlated significantly with CT, DST, SL and GV, but no significant correlation was found with ST except at the triple combined motor-mental task.
Conclusion: A disturbed gait pattern in MS patients with different MS phenotypes depends on disability and reflects a cognitive-motor interference.

1. Introduction

Multiple sclerosis (MS) is a chronic, inflammatory, demyelinating and neurodegenerative disease of the central nervous system (Trapp and Nave, 2008) which may present as a relapsing-remitting (RR), secondary-progressive or primary progressive (PP) clinical phenotype (Lublin et al., 2014). Gait disturbance is common in MS (Bethoux, 2013) and walking performance is included in measures of MS-related physical disability, such as the Expanded Disability Status Scale (EDSS) (Kurtzke, 1983). Gait pattern characteristics were reported to be impaired in MS patients (Hamilton et al., 2009; Sosnoff et al., 2011; Monticone et al., 2014) even at the early disease stages (Kalron et al., 2010; Sosnoff et al., 2012).

Motor, sensory and cerebellar impairment primarily influence walking deficit in MS patients, but recent evidence suggests the impact of cognition on walking performance in this patient population (Sosnoff et al., 2011). Walking performance in MS patients may get disturbed while performing a cognitive task (e.g. counting, subtraction task, working memory tasks) at various disease stages (Hamilton et al., 2009; Kalron

Abbreviations: MS, multiple sclerosis; HC, (healthy controls); RR, relapsing-remitting; PP, primary-progressive; EDSS, Expanded Disability Status Scale; MMSE, Mini-Mental State Examination; CT, cycle time; SL, stride length; ST, swing time; DST, double support time; CV, coefficient of variation; GV, gait velocity; SI, symmetry index; CMI, cognitive-motor interference

* Correspondence to: Irena Dujmovic, Clinic of Neurology, Clinical Centre of Serbia, Belgrade University School of Medicine, Dr Subotića 6, PO Box 12, 11129 Belgrade 102, Serbia.
E-mail addresses: irdujm@eunet.rs (I. Dujmovic), sasar@imi.bg.ac.rs (S. Radovanovic), vanjanmartinovic@gmail.com (V. Martinovic), jdackovic@gmail.com (J. Dackovic), goricamaric87@gmail.com (G. Maric), sharlotam@gmail.com (S. Mesaros), pekmezovic@sezampro.rs (T. Pekmezovic), vladimir.s.kostic@gmail.com (V. Kostic), jelena60@eunet.rs (J. Drulovic).

http://dx.doi.org/10.1016/j.msard.2017.01.012
Received 18 October 2016; Received in revised form 13 December 2016; Accepted 25 January 2017
2211-0348/

Table 1
Demographic and clinical characteristics of multiple sclerosis (MS) patients and healthy controls.

Study group	Number of patients (female: male gender ratio)	Age (years)[a]	Disease duration (years)[b]	EDSS[b]
Total MS	70 (1.41:1)	37.2 ± 10.5	5.3 (0.3–24.1)	3.5 (0–6.0)
RRMS	52 (1.74:1)	35.4 ± 9.3	6.0 (0.3–24.1)	3.0 (0–5.0)
PPMS	18 (0.80:1)	42.6 ± 12.2	5.1 (1.6–11.2)	4.5 (3.0–6.0)
Healthy controls	40 (1.84:1)	39.4 ± 15.3	/	/

[a] Mean ± standard deviation.
[b] Median (range); RRMS=relapsing-remitting MS; PPMS=primary-progressive MS; EDSS=Expanded Disability Status Scale

et al., 2010) and the effect of dual tasking on walking parameters has been shown to be more pronounced in MS patients than in healthy individuals (Kalron et al., 2010). To the best of our knowledge, the effect of triple task demand on walking performance in MS patients has not been evaluated yet. Additionally, also until now, gait pattern characteristics in patients with different MS phenotypes have not been fully elucidated.

We aimed to analyze spatio-temporal gait pattern characteristics in MS patients with RRMS and PPMS phenotypes and healthy controls (HC) under different walking paradigms (simple walking task, dual (motor/motor and motor/cognitive tasks) and triple combined (motor/cognitive) tasks).

2. Patients and methods

2.1. Patients

The study comprised 70 MS patients (52 RRMS, 18 PPMS) and 40 age-matched HC, whose demographic and clinical characteristics are given in Table 1. All MS patients included in the study were treated at the Clinic of Neurology, Clinical Centre of Serbia, Belgrade, Serbia, as in-patients or out-patients during the period from January 1, 2014 to December 31, 2015. Inclusion criteria for MS patients were as follows: diagnosis of MS according to the Revised McDonald Criteria (Polman et al., 2011), the ability to walk without rest and without any assistance for up to 50 m, no cognitive decline (Mini-Mental State Examination, MMSE score ≥28) at the time of gait assessment, and a signed informed consent. The inclusion criteria for HC were: the absence of neurological or psychiatric disease and MMSE score ≥28. MS patients suffering from another condition that could interfere with motor activity (other neurological disorders, orthopedic diseases or other general medical conditions) and those treated with symptomatic treatment affecting fatigue were excluded from the study. All MS patients and HC signed an informed consent prior to any study procedure. The study was approved by the Clinic of Neurology, Clinical Centre of Serbia Institutional Review Board.

Table 2
Gait parameters at measurements I-IV in the total group of multiple sclerosis (MS) patients and healthy controls (HC).

Measurement	Group	CT (s)	SL (cm)	ST (s)	DST (s)	CV CT (%)	CV SL (%)	CV ST (%)	CV DST (%)	Gait velocity (cm/s)
Base walk	MS	1.13[b] (0.87–1.92)	122.10[b] (38.66–163.20)	0.39 (0.26–0.51)	0.35[b] (0.21–1.44)	3.09[b] (1.52–9.26)	3.76[b] (1.78–12.55)	5.17[a] (2.15–26.23)	8.40 (4.99–49.49)	106.60[b] (20.20–173.40)
(measurement I)	HC	1.03[b] (0.92–1.22)	140.60[b] (111.00–168.60)	0.39 (0.33–0.45)	0.25[b] (0.16–0.43)	2.23[b] (1.20–11.08)	2.20[b] (1.00–6.82)	4.38[a] (2.69–18.63)	9.78 (4.48–34.09)	138.60[b] (97.80–163.80)
Dual motor- motor task	MS	1.15[b] (0.86–1.66)	116.40[b] (50.47–158.80)	0.39 (0.31–0.49)	0.36[b] (0.21–0.71)	3.22[b] (1.14–14.46)	3.89[b] (1.26–13.11)	5.76[b] (2.76–16.04)	8.42 (4.67–29.33)	101.90[b] (38.50–168.60)
(measurement II)	HC	1.02[b] (0.91–1.22)	137.20[b] (101.00–159.10)	0.38 (0.33–0.45)	0.27[b] (0.16–0.42)	2.30[b] (1.31–6.55)	2.42[b] (1.21–4.99)	4.04[b] (2.40–17.88)	8.14 (4.82–34.17)	137.10[b] (92.50–157.70)
Dual motor- mental task	MS	1.17[b] (0.89–1.80)	117.20[b] (38.75–161.40)	0.40 (0.27–0.49)	0.39[b] (0.23–0.86)	4.33[b] (1.29–21.15)	4.63[b] (1.72–26.38)	6.55 (2.06–22.29)	10.88 (5.14–41.03)	96.10[b] (32.10–158.20)
(measurement III)	HC	1.06[b] (0.93–1.56)	134.80[b] (102.60–157.50)	0.39 (0.34–0.55)	0.29[b] (0.15–0.46)	2.37[b] (1.61–13.77)	2.77[b] (1.15–5.19)	4.72 (2.75–22.59)	9.20 (5.69–38.72)	129.30[b] (72.70–160.30)
Triple combined motor-mental task	MS	1.18[b] (0.92–1.90)	112.80[b] (40.40–163.10)	0.40 (0.27–0.49)	0.40[b] (0.23–0.92)	4.04[b] (1.38–36.24)	4.72[b] (1.85–18.93)	6.54[b] (2.80–32.24)	10.79 (5.71–43.74)	93.40[b] (32.00–161.10)
(measurement IV)	HC	1.07[b] (0.93–1.46)	132.50[b] (94.49–151.90)	0.39 (0.33–0.51)	0.29[b] (0.17–0.48)	2.47[b] (1.45–31.19)	2.61[b] (1.15–6.90)	4.57[b] (2.96–24.56)	9.22 (5.26–39.26)	121.90[b] (72.00–154.70)

Data are shown as median (range). CT=cycle time; SL=stride length; ST=swing time; DST=double support time; CV=coefficient of variation.
*statistically significant difference between repeated assessments ($p < 0.05$) (Friedman test with Dunn's multiple comparisons test); **statistically significant difference between repeated assessments ($p < 0.01$).(Friedman test with Dunn's multiple comparisons test).
In the MS group, the statistically significant change occured between repeated measurements (M): for CT (M-I to M-III**, M-I to M-IV**, M-II to M-IV**, M-III to M-IV**); for SL (M-I to M-II**, M-I to M-III**, M-I to M-IV**, M-II to M-IV**, M-III to M-IV**); for ST (M-II to M-III**, M-II to M-IV**); for DST (M-I to M-III**, M-I to M-IV**, M-II to M-IV**, M-III to M-IV**); for CV CT (M-I to M-III**, M-II to M-III**, M-I to M-IV**, M-II to M-IV**); for CV SL (M-I to M-III**, M-II to M-III**, M-I to M-IV**); for CV ST (M-I to M-III*, M-I to M-IV**, M-II to M-IV*); for CV DST (M-I to M-III**, M-II to M-III**, M-I to M-IV**, M-II to M-IV**); for gait velocity (M-I to M-II**, M-I to M-III**, M-I to M-IV**, M-II to M-IV**, M-III to M-IV**). In the HC group the statistically significant change occured between repeated assessments: for CT (M-I to M-III*, M-II to M-III**, M-I to M-IV**, M-II to M-IV**); for SL (M-I to M-II**, M-I to M-III**, M-I to M-IV**, M-II to M-IV**, M-III to M-IV**); for ST (M-II to M-III**, M-II to M-IV**); for DST (M-I to M-III**, M-II to M-III*, M-I to M-IV**, M-II to M-IV**); for gait velocity (M-I to M-III**, M-I to M-IV**, M-II to M-IV**, M-III to M-IV*); for CV CT, CV SL, CV ST and CV DST no significant changes occured in the HC group over repeated assessments.
[a] Statistically significant difference between MS and HC group ($p < 0.05$) (Mann-Whitney-*U* test).
[b] Statistically significant difference between MS and HC group ($p < 0.01$) (Mann-Whitney-*U* test).