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Gait and jogging parameters in people with minimally impaired multiple sclerosis

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ABSTRACT

Increasing awareness of the significance of ambulatory limitations in people with multiple sclerosis (MS) requires a regular assessment of walking ability in order to monitor disease dynamics. However, it is questionable whether the standard tools are sufficiently sensitive to detect mobility deficits in patients who are minimally impaired. Therefore, the main objective of this study was to examine an extended assessment tool characterizing spatio-temporal parameters of gait and jogging in people with minimally impaired MS. Twenty relapsing remitting patients diagnosed with MS, 8 women and 12 men, aged 36.3 ± 9.2y, EDSS mean score 1.8 ± 1.2, were recruited from the Multiple Sclerosis Center, Sheba Medical Center, Tel Hashomer, Israel to participate in the study. Twenty apparently healthy subjects (10 women and 10 men), aged 34.3 ± 7.4 years served as controls. Balance-, gait- and jogging-related spatio-temporal parameters were obtained using the Zebris FDM-T Treadmill (Zebris® Medical GmbH, Germany). Each subject completed a sequence of 3 jogging tests under different conditions. Gait and balance tests were performed prior and after jogging trials. When comparing gait evaluation, jogging revealed additional abnormalities in the MS group vs. the healthy controls. In addition to step time asymmetry and larger step width, jogging was associated with a slower self-selected velocity, shorter step length, longer stance phase and a prolonged double support phase. People minimally affected by MS have the ability to jog. However, clinician's should be aware of the possible deficits accompanying this popular activity.

1. Introduction

Multiple sclerosis (MS) is a demyelinating disease of the central nervous system (CNS) [1] with an estimated prevalence of 1 per 1000 persons in the United States [2,3]. The disease process generates a diversity of neuropathological changes in the CNS [1,4] typically manifested in heterogeneity symptoms (e.g. fatigue and depression) and an accumulation of physical and cognitive impairment over time. Symptoms usually develop between ages 15 and 45, whereas the average age of diagnosis is approximately 30.

Ambulatory limitations are a key component of disability in patients with MS. Approximately 75% of patients with MS experience clinically significant walking disturbances [5] which may present even in the early stages of the disease and in people with clinically isolated syndrome [6].

During the last decade, the scientific community endeavored to diagnose MS as early as possible. Due to progress in magnetic resonance imaging (MRI) techniques, the McDonald criteria have been revised. Also, the development of new immune-modulatory drugs supported by clinical trials, indicate that early medication reduces the frequency and severity of relapses, thus delaying disability [7]. Consequently, the mean age of MS diagnosis regressed to an earlier age and to people with fewer disabilities.

Accordingly, detection of mobility limitations in minimally impaired MS patients has become a challenge for clinicians. Precise walking determinants are required in order to carefully monitor disease dynamics and assess the efficacy of symptomatic and rehabilitation therapies in this MS subgroup.

To date, assessment of walking abilities in MS commonly consists of clinician-assessed rating scales, performance tests, and self-reporting questionnaires. However, it is questionable whether these tools are sufficiently sensitive to detect mobility deficits in patients who are minimally impaired. We present, herein, a few examples of mobility measuring tools and their disadvantages as to their capability in detecting minimal deviations of gait in people with MS.

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According to the standard expanded disability status scale (EDSS), an accepted method of quantifying disability in people with MS, ability of walking a distance of 500 m without assistance is considered fully ambulatory [8]. Thus, affirming that the EDSS is insensitive to walking beyond this distance which is a realistic activity for patients at the early stages of the disease [9]. Equally, the popular timed 25-foot walk test (T25FW) is limited due to a floor effect. In 151 people with MS, the T25FW ranged from 3.5 to 22.6 s, with a skewed distribution toward the lower end of the range. Most patients scored 4.5–7.5 s [10]. Furthermore, according to the MS walking scale questionnaire (MSWS-12), the score of a patient unable to participate in a common sports activity such as running, is reduced by only one (out of 60) points, not reflecting the decline in an essential activity [11]. Moreover, although the six-minute walk test is more appropriate for patients with a high activity level, people with MS who were able to cover a distance of 400 m in this time frame were considered fully ambulatory [12]. These examples indicate the limitations of MS gait instruments when attempting to assess minimally impaired MS patients using standard gait-dedicated parameters.

Therefore, we assume that in order to adjust gait evaluation tests to higher functional needs reflective of the necessities of many minimally impaired MS patients, it is essential to add demanding tests such as jogging where innovative technologies now afford an in-depth look into subtle features and their dynamics. This is of particular relevance to the domain of physical rehabilitation, where interventions are planned and assessed in accordance with the patients' specific goals and desires. Hence, the objective of this study was to examine an extended assessment tool characterizing spatio-temporal parameters of gait and jogging in people with minimally impaired MS.

2. Methods

2.1. Patients and subjects

Twenty relapsing remitting patients diagnosed with MS, 8 women and 12 men, aged 36.3 ± 9.2 years were recruited from the Multiple Sclerosis Center, Sheba Medical Center, Tel Hashomer, Israel and participated in the study. All patients were experienced in treadmill walking. Inclusion criteria included: (1) diagnosis of definite relapsing-remitting MS according to the revised McDonald criteria [13], (2) age range: 18–45 years, and (3) EDSS score (7) <4.0. The EDSS is an accepted method of quantifying disability in MS, composed of an eight-function system scale including motor, sensory, cerebellar, brain stem, visual, bowel and bladder, pyramidal and others. Each domain is graded from 0 = no disability to 5 or 6 = maximal disability. The EDSS spans a score range of 0 (normal examination) through 10 (death). Patients who are fully ambulatory score between 1.0 and 4.0 while those who present with an ambulatory impairment, score between 5.0 and 9.5. Exclusion criteria included: (1) orthopedic disorders that could negatively affect mobility, (2) major depression or cognitive decline and incapability of performing on a treadmill, (3) pregnancy, (4) blurred vision, and (5) cardiovascular disorders. Twenty apparently healthy subjects, 10 women and 10 men, aged 34.3 ± 7.4, served as a control group. None of the healthy participants reported any medication intake or relevant health impairments (e.g. orthopedic, neurological, or internal diseases). The study was approved by the Sheba Institutional Review Board. All participating subjects signed an informed consent form.

2.2. Jogging, gait and postural control analysis

Balance-, gait- and jogging-related spatio-temporal parameters were obtained while walking/jogging on the Zebris FDM-T Treadmill (Zebris® Medical GmbH, Germany). The treadmill is fitted with an electronic mat embedded underneath the belt consisting of 10,240 miniature force sensors, each approximately 0.85 × 0.85 cm. The treadmill's contact surface measures 150 × 50 cm and its speed can be adjusted from 0.2 and 22 km/h, at intervals of 0.1 km/h. As the subject stands/walks on the treadmill, the force exerted by his feet (the so-called reactive-normal force) is recorded by the sensors at a sampling rate of 120 Hz. Due to the high density of the sensors, the foot is mapped at a high resolution so that even subtle changes in force distribution and timing can be monitored. Dedicated software integrates the force signals and provides 2-D/3-D graphic representation of major spatio-temporal parameters including center of pressure (CoP) trajectories during static stance and gait. Major spatio-temporal data included the following values: velocity (km/h), cadence (steps/min), stance phase (% gait cycle (%GC)), single and double support phases (%GC), width between steps (mm), step/stride length (cm) and step/stride time (s). Additionally, step length differences and step time differences were calculated for each gait- and jogging trial. These parameters were calculated as the absolute value of the differences between the corresponding right and left values.

Faude et al. [14] reported high levels of between- and within-day reliability in healthy seniors for the majority of spatio-temporal gait parameters recorded by the Zebris treadmill system during walking, with coefficients of variation typically below 5% and 7%, respectively. All tests took place at the Institute of Motor Functions Sheba Medical Center.

2.3. Experimental design

Prior to the measurement phase, all participants actively participated in an adaptation–familiarization trial in order to establish each individual's speed level. Starting at a fixed speed of 0.5 km/h, the belt speed was increased by 0.4 km/h every 15 s in a stepwise manner. Once the tester was informed by the participant of his/her appropriate normal walking pace, the selected speed was determined as the comfort speed. Following this adaptation phase, each participant completed a sequence of five consecutive tests under four different conditions with a 1 min break between conditions. Recording time in all tests was 1 min.

1. Comfortable walking – standing, wearing running shoes, belt speed was set to the patient's comfort level.
2. Normal jogging – identical conditions as in (1); starting from comfort level, speed was increased to preferred transition speed. This speed was defined as transition speed from walking to jogging.
3. Inclination jogging – identical conditions as in (2), speed set at preferred transition speed but belt inclination was increased to a 3° incline.
4. Faster jogging – identical conditions as in (2) but preferred transition speed was increased by 10%.
5. Termination – identical settings as in (1).

In addition to gait and jogging tests, balance measurements were performed twice, prior and immediately after all gait tests. Subjects stood shod on the treadmill (10 cm gap between heels; 5° toe-out position) with eyes open, while maintaining their posture as steady as possible for 20 s while focusing on a dot marked on a wall 1 m in front and away from the treadmill. A similar 30 s measurement has recently been suggested as a sensitive and accurate tool identifying people with MS who are at risk for accidental falls during a 3-month period, regardless of other clinical variables [15]. Three consecutive balance tests were performed with a 30-s inter-test break. Three CoP-based outcome measures were recorded:

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1. CoP path length (mm).
2. Ellipse area (mm^2).
3. Sway rate (mm/s), defined as the CoP path length divided by test duration.

The representative outcome parameter was defined as the average of the 3 tests.

2.4. Statistical analysis

Group differences in age and gender distribution were determined using an independent sample *t* and chi-square test, respectively. All spatio-temporal gait data were normally distributed and did not violate homogeneity of variance. The Mauchly sphericity test was used to examine covariance. Unpaired *t*-tests were used to compare outcome parameters between patients and controls. In order to determine whether a test condition affected spatio-temporal gait variables, a repeated measure analysis of variance (ANOVA) test was performed. The Bonferroni test enabled paired multiple comparisons between test conditions. An added mixed design and profile analysis determined whether the task effect was group dependent or not. All analyses were performed using SPSS software (Version 21.0 for Windows, SPSS Inc., Chicago, IL, USA). All reported *P*-values were two-tailed. The level of significance was set at $P < 0.05$.

3. Results

The patient group had a mean duration of 5.3 ± 2.7 years since diagnosis. The EDSS score was 1.8 ± 1.2, indicating minimal neurological disability. The mean pyramidal, cerebellar and sensory scores were 1.7 ± 1.3, 1.8 ± 1.3, 1.9 ± 0.7, respectively. Other participants' related clinical scores are outlined in Table 1.

Table 2 refers to the gait parameters during normal walking and maintenance of static balance. Significant differences between patients and healthy subjects were found with respect to step time difference, step width, ellipse area, sway rate, and CoP path length. No differences between groups were observed in terms of self-selected velocity, cadence, period of stance phase, double and single support phases.

Regarding transition speed from walking to jogging, although both groups increased their self-selected velocity, the increase was significantly different ($P = 0.02$, Table 3). While healthy subjects increased their speed by 101%, the parallel value for the patients was 87%. Moreover, compared to their healthy counterparts, the MS patients jogged with a wider step width, shorter step length and shorter stance phase. No differences between groups were observed in cadence, step and stride time parameters. Similar findings were demonstrated during the 3° upward slope jogging phase (Table 4).

Table 5 outlines group differences while jogging faster (condition 4). In addition to previous jogging condition findings, MS patients demonstrated a longer single support phase, larger step and length asymmetry compared to the healthy participants.

Regarding the double support phase, although running is defined by only displaying single footed contacts in transit from comfort gait to jog, people with MS reduced but did not eliminate the double support period. Mean outcomes of the double support phase in the MS group during comfortable gait, normal jogging, inclination jogging and faster jogging were 30.6, 8.24, 7.38, 5.54 (%GC), respectively. These results were significantly elevated compared with parallel findings of the healthy subjects, 28.6, 0.47, 0.38, 0.02 (%GC), respectively.

Although three jogging tests were performed between the initial and concluding gait trials, no significant differences were

Table 1
Demographic, anthropometric and clinical characteristics of the study population.

Variable	Mean (S.D.)/range		*P*-value
	MS group ($n = 20$)	Healthy subjects ($n = 20$)	
Age (years)	36.3 (9.2)	34.3 (7.4)	0.29
Gender	8 females 12 males	10 females 10 males	
Ratio (female/male)	0.67: 1	1:1	
Disease duration (years)	5.3 (2.7)		
Height (cm)	173.9 (8.2)	172. 8 (8.1)	0.45
Body mass (kg)	73.2 (13.0)	68.4 (10.0)	0.58
BMI	24.2 (3.5)	22.9 (2.0)	0.49
EDSS	1.8 (1.2)/0–3.5		
Pyramidal	1.7 (1.3)/1–3		
Cerebellar	1.8 (1.3)/1–2		
Sensory	1.9 (0.7)/1–3		

BMI, body mass index; EDSS, expanded disability status scale

Table 2
Spatio-temporal gait and static postural control parameters at baseline.

Variable	Mean (S.D.)		Mean difference (95% CI)	*P*-value
	MS ($n = 20$)	Healthy subjects ($n = 20$)		
Gait				
Self paced gait (km/h)	3.24 (0.96)	3.52 (0.78)	0.28 (−0.28, 0.84)	0.32
Cadence (steps/min)	99.0 (14.5)	100.4 (12.1)	1.4 (−7.18, 9.92)	0.75
Step time R (s)	0.62 (0.09)	0.61 (0.08)	0.01 (−0.06, 0.05)	0.76
Step time L (s)	0.63 (0.10)	0.60 (0.07)	0.02 (−0.08, 0.04)	0.52
Step time difference (ms)	20.5 (20.1)	6.5 (8.1)	14.0 (4.2, 23.8)	0.01*
Step length R (cm)	53.9 (10.1)	57.8 (9.1)	3.9 (−2.2, 10.0)	0.21
Step length L (cm)	53.5 (10.6)	58.5 (8.9)	4.9 (−1.35, 11.2)	0.12
Step length difference (cm)	2.43 (2.2)	1.80 (1.4)	0.63 (−1.8, 0.56)	0.29
Stance R (%GC)	65.6 (1.7)	64.4 (2.1)	1.2 (−2.42, 0.04)	0.58
Stance L (%GC)	65.1 (2.4)	64.3 (2.2)	0.8 (−2.3, 0.7)	0.29
Single support R (%GC)	34.9 (2.4)	35.7 (2.2)	0.8 (−0.7, 2.3)	0.29
Single support L (%GC)	34.4 (1.7)	35.6 (2.1)	1.2 (−0.3, 2.4)	0.57
Double support (%GC)	30.6 (3.8)	28.6 (4.2)	2.0 (−4.6, 0.60)	0.13
Stride time (s)	1.24 (0.19)	1.21 (0.15)	0.03 (−0.14, 0.08)	0.62
Step width (cm)	14.1 (4.8)	10.9 (3.0)	3.2 (0.56, 5.70)	0.02*
Static postural control				
Ellipse area (mm^2)	87.3 (75.6)	42.0 (26.3)	45.3 (−82.3, −8.3)	0.02*
CoP path length (mm)	149.3 (68.5)	107.6 (32.5)	41.7 (−76.5, −6.9)	0.02*
Sway rate (mm/s)	7.6 (3.5)	5.5 (1.7)	2.1 (−3.9, −0.4)	0.02*

GC, gait cycle; CoP, center of pressure.
* $P < 0.05$.

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Table 3
Spatio-temporal normal jogging parameters.

Variable	Mean (S.D.)		Mean difference (95% CI)	*P*-value
	MS ($n=20$)	Healthy subjects ($n=20$)		
Self paced jogging (km/h)	6.06 (1.37)	7.07 (1.34)	1.01 (0.14, 1.87)	0.02*
Cadence (steps/min)	156.3 (13.8)	155.2 (8.8)	1.1 (−8.5, 6.3)	0.77
Step time R (s)	0.39 (0.02)	0.39 (0.02)	0.005 (−0.02, 0.15)	0.60
Step time L (s)	0.39 (0.03)	0.39 (0.02)	0.009 (−0.01, 0.02)	0.70
Step time difference (ms)	10.0 (9.2)	6.0 (6.0)	4.0 (−8.9, −0.9)	0.05*
Step length R (cm)	64.5 (14.3)	76.7 (16.9)	4.9 (2.3, 22.3)	0.02*
Step length L (cm)	65.1 (15.1)	76.2 (16.6)	5.0 (1.0, 21.2)	0.03*
Step length difference (cm)	2.68 (2.0)	1.80 (1.4)	0.88 (−2.0, 0.22)	0.11
Stance R (%GC)	52.1 (6.8)	42.4 (5.2)	9.7(5.8, 13.6)	0.001*
Stance L (%GC)	51.6 (7.2)	42.8 (5.1)	8.8 (4.81, 12.78)	0.001*
Single support R (%GC)	43.9 (3.3)	41.9 (4.5)	2.0 (−4.5, 0.6)	0.13
Single support L (%GC)	43.3 (3.4)	42.3 (4.3)	1.0 (−3.5, 1.5)	0.41
Double support (%GC)	8.24 (9.01)	0.47 (1.29)	7.77 (3.65, 11.89)	0.001*
Stride time (s)	0.77 (0.06)	0.78 (0.05)	0.01 (−0.03, 0.04)	0.93
Step width (cm)	10.4 (3.8)	7.2 (3.0)	3.2 (1.03, 5.46)	0.005*

GC, gait cycle.
* $P<0.05$.

observed in both healthy and patient groups in any gait and balance outcomes. The mean difference between the initial to concluding gait trials in the patient group were: velocity, 0.0015 km/h, $P=0.99$; cadence, 0.63 steps/min, $P=0.87$; mean step length, −0.42 cm, $P=0.75$; mean step time, −0.006 s, $P=0.70$; step time difference, −0.007 ms, $P=0.15$; step length difference, 0.12 cm, $P=0.79$; stance phase right, −0.014%GC, $P=0.98$; stance phase left, −0.15%GC, $P=0.84$; single support right, 0.19%GC, $P=0.80$; single support left, 0.03%GC, $P=0.96$; double support, −0.19%GC, $P=0.89$; stride time, −0.01 s, $P=0.84$; and step width, −0.28 cm, $P=0.77$.

In terms of balance variables, the differences between initial to concluding trials were: ellipse area, 10.2 mm^2, $P=0.12$; CoP path length, 15.1 mm, $P=0.09$; and sway rate, 0.9 mm/s, $P=0.15$.

4. Discussion

The main finding of this study is that people with minimally impaired MS choose a different jogging strategy compared to healthy subjects. According to the current study, people with minimally impaired MS prefer transition from walking to jogging at a slower speed and maintain a portion of their double support phase while doing so. Moreover, in this population, transition from walking to jogging was accompanied by an extension of step length and narrowing of step width. However, these adaptations were significantly less compared to parallel adaptations demonstrated by the healthy participants. Both groups performed similarly in terms of cadence, step and stride time.

Jogging requires greater balance control because of the rapidly changing accelerations of the center of mass [16]. In our opinion, the slower self-selected pace, shorter step length, wider step width and extended double support phase during the jogging trials were the result of compensation by the patients to reduce the risk of falling. The impaired balance control demonstrated by this group reinforces this statement.

Accordingly, we suggest the following explanation for why minimally impaired MS patients choose the observed strategy. Normal performance on a treadmill is characterized by a positive correlation between belt speed to step length and pace of steps [17]. Specifically, if the subject fails to increase at least one of these two gait elements as a response to an increase of speed, he is at risk of falling. An increase in speed and step length is associated with a decrease in the double support period [17]. Obviously, the double support phase is a relatively stable position compared with single support [16].

It has been consistently reported that those who fear falling increase their double support period [18]. We suspect that during transition of walking to jogging, people with MS attempt to maintain their double support period as long as possible.

Table 4
Spatio-temporal inclination jogging parameters.

Variable	Mean (S.D.)		Mean difference (95% CI)	*P*-value
	MS ($n=20$)	Healthy subjects ($n=20$)		
Self paced jogging (km/h)	6.13 (1.41)	7.06 (1.34)	0.97 (0.53, 1.82)	0.04*
Cadence (steps/min)	158.2 (12.5)	156.2 (9.2)	2.0 (−9.0, 5.0)	0.57
Step time R (s)	0.39 (0.03)	0.38 (0.02)	−0.01 (−0.01, 0.03)	0.27
Step time L (s)	0.38 (0.03)	0.39 (0.03)	0.01 (−0.01, 0.01)	0.77
Step time difference (ms)	10.5 (9.4)	6.0 (6.8)	4.5 (−9.8, −0.8)	0.05*
Step length R (cm)	65.1 (13.3)	76.1 (17.0)	11.0 (1.2, 20.8)	0.03*
Step length L (cm)	64.0 (16.2)	75.7 (16.3)	11.7 (1.3, 22.1)	0.03*
Step length difference (cm)	3.31 (4.45)	1.91 (1.39)	1.40 (−3.51, 0.71)	0.19
Stance R (%GC)	51.1 (7.3)	42.4 (4.7)	8.7 (4.8, 12.7)	0.001*
Stance L (%GC)	51.1 (7.1)	42.8 (4.8)	8.3 (4.5, 12.2)	0.001*
Single support R (%GC)	43.7 (3.4)	42.0 (4.0)	1.7 (−4.1, 0.7)	0.16
Single support L (%GC)	43.7 (3.9)	42.4 (4.1)	1.3 (−3.9, 1.2)	0.29
Double support (%GC)	7.38 (9.1)	0.38 (1.11)	7.0 (2.87, 11.13)	0.003*
Stride time (s)	0.76 (0.56)	0.77 (0.05)	0.01 (−0.03, 0.04)	0.67
Step width (cm)	10.39 (4.05)	6.95 (2.96)	3.44 (1.17, 5.71)	0.004*

GC, gait cycle.
* $P<0.05$.

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Table 5
Spatio-temporal faster jogging parameters.

Variable	Mean (S.D.)		Mean difference (95% CI)	*P*-value
	MS ($n=20$)	Healthy subjects ($n=20$)		
Velocity (km/h)	6.8 (1.6)	7.7 (1.5)	0.9 (−0.05, 1.93)	0.04*
Cadence (steps/min)	161.3 (16.7)	156.9 (9.6)	4.4 (−13.1, 4.3)	0.31
Step time R (s)	0.37 (0.03)	0.39 (0.02)	0.02 (−0.003, 0.03)	0.65
Step time L (s)	0.38 (0.04)	0.39 (0.02)	0.01 (−0.02, 0.02)	0.10
Step time difference (ms)	12.5 (11.6)	2.5 (4.4)	10.0 (−15.6, −4.3)	0.001*
Step length R (cm)	70.1 (15.8)	82.8 (19.4)	12.7 (1.3, 24.0)	0.03*
Step length L (cm)	70.1 (16.9)	82.5 (18.6)	12.4 (1.0, 23.8)	0.03*
Step length difference (cm)	3.26 (3.43)	1.58 (0.96)	1.68 (−3.30, −0.08)	0.04*
Stance R (%GC)	48.8 (7.9)	39.8 (4.3)	9.0 (−13.0, −4.9)	0.001*
Stance L (%GC)	48.2 (7.9)	40.1 (4.4)	8.1 (−12.2, −3.96)	0.001*
Single support R (%GC)	43.2 (3.5)	39.8 (4.2)	3.4 (−5.9, −0.9)	0.008*
Single support L (%GC)	42.6 (3.8)	40.1 (4.4)	2.5 (−5.2, −0.9)	0.04*
Double support (%GC)	5.54 (8.2)	0.02 (0.06)	5.52 (−9.38, −1.67)	0.007*
Stride time (s)	0.75 (0.67)	0.77 (0.05)	0.02 (−0.02, 0.56)	0.32
Step width (cm)	10.42 (4.1)	6.96 (3.2)	4.44 (−5.8, −1.1)	0.005*

GC, gait cycle.
* $P<0.05$.

Therefore, although they increased step length, decreased double support and increased self-selected velocity in transition to jogging, it was significantly lower compared to the parallel adaptations demonstrated by the healthy control participants.

In this context, the width of base of support demonstrated by the patients during jogging can also be considered as a response to improve stability. Previous studies have indicated that a decline in medio-lateral stability during walking has been shown to be a major risk factor for falls in older adults [19]. We therefore believe that in order to restore the loss of medio-lateral stability, patients attempted to minimize the decrease in their base of support during jogging.

Interestingly, no significant changes were reported between the initial and concluding gait trials despite the in-between physical effort of the jogging tests; we therefore presume that fatigue was not the primary reason for the abnormal jogging performance. Nevertheless, examination of the effect of jogging on energy cost and fatigue requires further research.

Our patients' comfortable gait trial demonstrated abnormalities in two (out of 15) spatio-temporal parameters, increased step width and step time asymmetry. This observation is less compared to those reported in previous studies [20,21]. However, these studies analyzed spatio-temporal gait using overground measurement systems. Considering this major difference, we mention important aspects regarding treadmill walking.

Treadmill gait analysis poses a few problems as it may impede natural walking patterns. Indeed, some parameters (e.g. cadence, stance period) are modified and energy cost has been reported to be higher during treadmill walking than ground walking [22]. Kinematic parameters during both tasks are inconsistent [22,23]. Moreover, evidence suggests that due to the automatic and regular drive to the lower limbs, kinesthetic and external afferent impulses may differ between (both) tasks which may affect generation of locomotor patterns [22]. These aspects should be taken into consideration when interpreting gait and jogging findings while on a treadmill.

In our opinion, evaluation of jogging abilities with instrumentally-derived devices can be beneficial for several reasons. Firstly, the ability to jog, if only for a few steps, may be important for participation in many social and leisure activities. Secondly, as demonstrated by the current study, jogging can highlight abnormalities invisible during standard gait assessment. It is worth noting that detection of mobility abnormalities at the early stages of MS, when patients are fully active, is difficult. Hopefully, early identification and improved follow up procedures can promote intervention programs at a stage when patients can benefit the most, focusing on preserving functional abilities of young active adults. Previous studies support this contention, revealing improved balance and gait performance following specific training programs [24,25].

The present study has several limitations. Firstly, the study group was relatively small. Secondly, although this device is commonly used in the general population, jogging on a treadmill does not duplicate jogging in the natural environment. The main differences concern the afferent impulse and fixed speed. These distinctions may have had a substantial impact partly contributing to the differences demonstrated between the two groups. Finally, compared to previous reports, the current study's CoP sampling duration was relatively short, consisting of 3 consecutive repetitions of 20 s. Although evaluation of CoP excursions is a commonly used method for measuring postural stability in various pathological conditions, no standardization exists. While some studies suggest that reliable data may be obtained from sample durations of 10 s [26], others propose intervals of up to 120 s [27]. Moreover, the majority of these studies base their recommendations on the data collected solely from healthy subjects. To date, optimal sampling duration, necessary for static postural control evaluation in people with MS, is questionable.

In conclusion, to the best of the authors' knowledge, this study is the first to report jogging spatio-temporal findings in the MS population. Clinicians should be aware of the possible jogging deficits in the disease process, especially in the absence of clear clinical impairment. The addition of physically more demanding tests may enhance our ability to better understand the mechanisms underlying the evolution of MS and the possibility of improving the management of patients afflicted with this disease.

Conflict of interest statement

None declared.

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