Research Article

Quantitative Changes in Gait Parameters after Cycling among Multiple Sclerosis Patients with Ataxia: A Pilot Study

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ABSTRACT

Introduction: Cerebellar ataxia is a common symptom of multiple sclerosis (MS), particularly in progressive forms, where gait and balance problems are the most debilitating symptoms. Exercise training is a critical component of rehabilitation in managing equilibrium dysfunction, and stationary bicycling is a safe, feasible, and effective method to reduce the symptom. Clinical walking performance tests are typically used to assess gait in these patients. However, gait analysis technologies are more sensitive and accurate at detecting subtle and subclinical changes. The purpose of this study was to determine the changes in gait parameters in MS patients with ataxic gait after using a stationary bicycle.

Materials and Methods: Ten secondary progressive MS patients with ataxic gait and a mean expanded disability status scale (EDSS) of four were recruited. The participants cycled on a stationary bike. Gait analysis was performed before and after 12 sessions of cycling. It included spatiotemporal and balance parameter measurements.

Results: Gait analysis showed statistically significant changes in spatiotemporal parameters, including speed (P=0.02, r=-0.51), and stride length (P=0.01, r=-0.63). Of balance-related indices, the mediolateral (ML) center of pressure (COP) displacement, anterior and posterior COP overshoot, and COP velocity changes were statistically remarkable after the intervention respectively. (P=0.01, r=-0.63), (P=0.02, r=-0.51), (P=0.03, r=-0.49), (P=0.01, r=-0.54).

Conclusion: Gait analysis is applicable to track changes following rehabilitation in individuals with MS. The results indicate that using a stationary bicycle can improve some spatiotemporal and COP-related parameters.

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1. Introduction

Multiple Sclerosis (MS) is a chronic, immune-mediated disease of the central nervous system (CNS) characterized by the destruction of the myelin sheath and neuro-axonal damage [1]. MS affects various areas of the nervous system and can manifest itself in various ways. Equilibrium dysfunction and gait abnormalities are two of the most debilitating symptoms, affecting approximately 75% of patients [2]. Around 80% of patients with MS experience ataxia at some stages of the disease progression [3]. Cerebellar ataxia is a frequent symptom of disease, particularly the progressive form of the disease [4]. Maintaining balance and a normal gait is critical to performing static and dynamic daily activities.

Various factors influence gait quality, including muscle strength and tonicity, balance, and environmental conditions [5]. Proprioception impairment is another factor affecting balance, although no significant difference is observed in a positional sense between patients with MS and healthy population [6]. Rehabilitation is a critical component of routine MS treatment. Due to the disease's heterogeneity, rehabilitation experts have used various interventions and exercises to treat changes in body structure, function, and activity limitations. These include resistance training, aerobic training, yoga, cycling, and body weight-supported treadmill training. Cycling is a combination of resistance and aerobic exercises that involves repetitive motion. It is widely regarded as an effective tool to improve function in people with MS [7]. Moreover, cycling is a safe and feasible form of exercise that increases aerobic endurance, muscle and bone strength, balance, and spasticity [8].

Visual evaluation of gait is frequently used to assess gait in patients with MS, and walking performance tests consist of maximum distance or timed walks. dynamic gait index (DGI) is another useful measurement in clinical and research settings [9]. While these are reliable measures, advanced movement analysis technologies have recently been developed to improve the objectivity, accuracy, quantification, and sensitivity of gait and balance assessments [10].

A multicenter study in Europe demonstrated that walking speed and stride length improved after aerobic and resistance therapy with different exercise frequency, intensity, and duration among MS participants with the expanded disability status scale score (EDSS 2-5.5). However, cadence and step length remained unchanged [11]. Pau et al. showed that applying adapted physical activity including aerobic and strengthening training three times a week for six months can improve stride length, cadence, and walking speed in MS patients with (EDSS 1.5-5.5) [12]. Negahban et al. reported that Center of Pressure (COP) parameters was not statistically significant after the balance-specific rehabilitation consisted three times per week for a month, among MS patients with (EDSS 2-5.5). They stated that due to the ceiling/floor effect, the changes were not detected in this population [13].

There is a lack of data in the spatiotemporal and COP evaluation following cycling in patients with MS. This study aimed to assess the changes in gait parameters following leg ergometry in MS subjects with ataxic gait via the laboratory gait analysis.

2. Materials and Methods

Study subjects

This pilot study was conducted in Djavad Mowafaghian gait laboratory in 2019. Subjects included 10 ambulatory MS patients suffering from cerebellar ataxia with secondary progressive MS (six men and four women). The eligible subjects were referred by the neurologist. They were in the age rangd 30-50 years, and their EDSS was 3.5≤EDSS≤5.

The exclusion criteria included severe illness resulting in the inability to walk, spasticity, lower extremity weakness, pregnancy, and accompanying underlying conditions with impaired functional motor status.

The patients were examined by a rehabilitation specialist, and the affected and less affected limbs were determined based on the manual muscle test (MMT). Subjects with MMT≤3 in the proximal and distal of the lower extremities were excluded. Spasticity severity was also assessed by the modified ashworth scale (MAS), and participants with MAS≥1 were also excluded.

The ethical committee approved the study protocol, and all participants signed written informed consent. The study adhered strictly to the principles outlined in the Declarations of Helsinki.

Study measurements

Gait analysis was performed on each patient one day before and after completing 12 sessions of cycling. The sessions were organized over six weeks (2 non-consecutive days per week) on a Technogym stationary bike (State Bicycle© Co. USA) with a workload of 33 W and an average cadence of 50-60 Rounds per Minute (RPM). Sessions were arranged in the morning and lasted about 40 minutes overall, including 10 minutes of cycling and 5 minutes of rest. Apart from the main training, every patient worked out 3-5 minutes of warm-up and cool-down. A talk test was applied to monitor intensity during exercise, and the subjects could talk easily during the activity, indicating mild to moderate intensity. All participants followed the same exercise protocol.

The SA 5.10©, a portable gait analysis tool with a sample rate of 500 Hz comprised of two-foot insoles, was used for this purpose. It was attached to a waist-worn recorder. The gait parameters were assessed using a ten-camera infrared optoelectronic video-based motion analysis system with a sample rate of 100 Hz (Vicon MXT40-S, Vicon Motion Systems©, Oxford, UK). The gait cycle events were determined via observation. For gait analysis, two categories of markers were determined as follows:

1. The "spatiotemporal" parameters, including cadence, speed, stride time, stride length, step width, and double support cycle calculated by the mean of both sides, along with step time, step length, single support cycle, and stance phase, were separately assessed in affected and less affected limbs. All subjects were asked to walk at their usual self-paced.

2. The "COP" parameters included COP velocity, COP displacement of the mediolateral (ML), and the anteroposterior (AP), as well as COP overshoot of the affected, less affected limbs, anterior, and posterior directions. Two force plates (9260AA3 and 9260AA6, Kistler©) were used to evaluate the subject's static balance in 60 s. In each trial, subjects stood with open eyes on double limbs while each foot was placed over the separate force plates and the arms hanging along the body. The mean of three trials was recorded. Nexus 2.9.2 was used to process the data, and MATLAB analysis software was applied to extract the parameters.

Statistical analysis

SPSS software, v. 20 was used to conduct the statistical analysis. Descriptive results were presented as Mean±SD. The Wilcoxon signed-rank test was used due to the small sample size and abnormal distribution of the variables. Statistical significance was defined as $P \leq 0.05$, and the effect size (r) was also carried out for each variable.

3. Results

The study included 10 subjects with secondary progressive MS suffering from ataxia (six men and four women), with Mean±SD age of 40.3±3.63 years. The Mean±SD weight of the patients was 65.3±11.80 kg, their Mean±SD height was 169.9±9.12 cm, their Mean±SD BMI (Body Mass Index) was 22.54±3.17 kg/m^2. Their Mean±SD disease duration was 9.7±2.0 years. The range of subjects EDSS scores was 4 and 5 (Table 1).

Spatiotemporal variables

Among spatiotemporal parameters, changes in stride length and speed are statistically significant compared to the others (P=0.01, r=-0.63), (P=0.02, r=-0.51). Table 2 presents the spatiotemporal parameters' values based on Wilcoxon signed rank test and effect size.

As shown in Figure 1, speed and stride length increased after cycling based on the median value, depicting a thick horizontal line. Although step length in the less affected limb increased after cycling, no statistical significance was observed (P=0.24, r=-0.26).

Center of Pressure (COP) variables

As illustrated in Figure 2, all COP-related parameters decreased after the intervention. However, differences were statistically remarkable in some parameters based on the Wilcoxon signed-rank test and effect size (Table 3).

Regarding the effect size preferences, values were classified as follow:

- Mediolateral COP displacement: (P=0.01, r=-0.63), COP velocity (5% Max): (P=0.01, r=-0.54)

- Anterior COP overshoot: (P=0.02, r=-0.51), posterior COP overshoot: (P=0.03, r=-0.49)

Table 1. Baseline characteristics

Variables	No. (%)/Mean±SD/Median (Min-Max)	
	Male	Female
Sex	6 (60)	4 (40)
EDSS score	4	4(3.5-5)
Age (y)	40.3±3.63	40 (36-48)
Disease duration (y)	9.7±2.0	9.5(7-13)
Height (cm)	169.9±9.12	167.5(157-184)
Weight (kg)	65.3±11.80	62(48-87)
Total	22.54±3.17	22.1(18.3-29.4)

EDSS: Expanded Disability Status Scale; BMI: Body Mass Index.

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- COP overshoot was not statistically significant among affected and less affected limbs (P=0.33, r=-0.22), (P=0.11, r=-0.35).

4. Discussion

The current study aimed to assess the differences in gait parameters after six weeks of cycling in MS patients with an ataxic gait. Our results showed that balance-related parameters, including (COP displacement, overshoot, and velocity) were more influenced than the spatiotemporal indices, indicating balance improvement after the intervention. Among spatiotemporal parameters, speed and stride length changes were remarkable after cycling. Changes in spatial parameters may be affected by improving balance. Static balance is one of the factors strongly correlated with walking performance, especially gait speed in MS

Table 2. Spatiotemporal parameters differences after cycling

Parameters	Unit	z	P	Effect Size
Cadence	Step/min	-1.17	0.24	-0.26
Speed	cm/s	-2.29	0.02	-0.51
Stride time	s	-0.05	0.96	-0.01
Stride length	cm	-2.80	0.01	-0.63
Step width	cm	-0.97	0.33	-0.22
Double support cycle	No. (%)	-0.05	0.96	-0.01
Step time A	s	-0.8	0.44	-0.17
Step time LA	s	-0.97	0.33	-0.22
Step length A	cm	-1.48	0.14	-0.33
Step length LA	cm	-1.17	0.24	-0.26
Single support cycle A	No. (%)	-1.68	0.09	-0.38
Single support cycle LA	No. (%)	-0.87	0.39	-0.19
Stance phase A	No. (%)	-1.68	0.09	-0.38
Stance phase LA	No. (%)	-0.66	0.51	-0.15

A: Affected; LA: Less Affected

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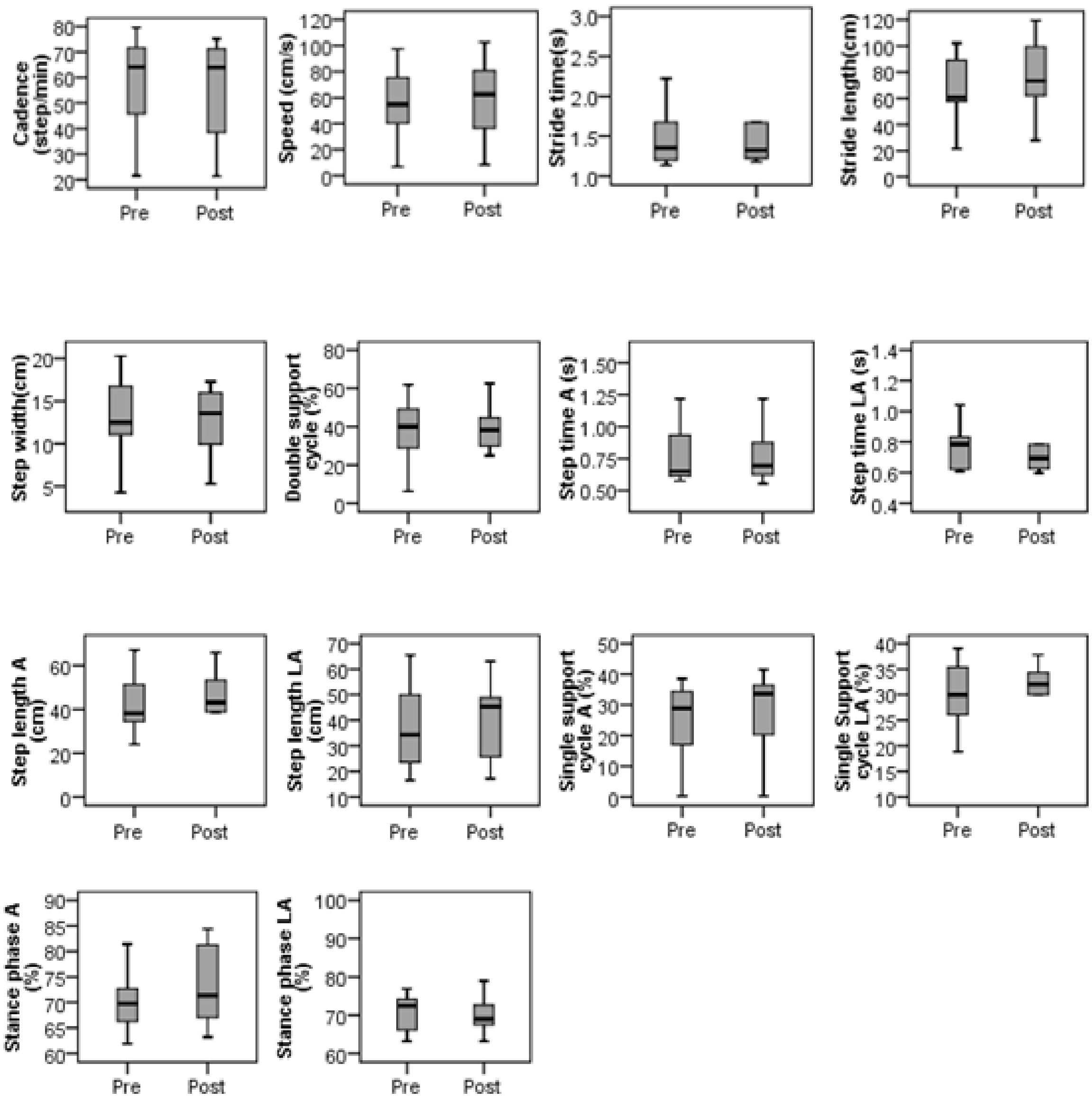

Figure 1. Boxplot of the spatiotemporal gait parameters before and after the intervention

A: Affected; LA: Less Affected

[14]. In other words, postural stability during walking leads to a faster speed. However, enhancing the stable posture is not the only reason that impacts walking speed. A constellation of kinetics and kinematics factors exists that play role in differing velocities [15]. Reducing COP-related parameters, including COP displacement in AP and ML directions, anterior and posterior overshoot of the COP, and COP velocity revealed better balance steadiness and subsequently better forward propulsion, increasing gait velocity. The changes in COP overshoot between affected and less affected were not noticeable, which may due to a slight difference in muscle strength of both limbs.

Various studies are consistent with our results in terms of spatiotemporal changes, particularly speed and stride length [11, 12]. These two parameters are strongly affected by physical activity with different intensities [16]. Previous studies mainly focused on spatiotemporal variables. Although COP metrics showed relatively excellent accuracy in standing balance even three months after fulfilling the initial test [17]. In addition, COP displacement shows the distinction in minimally impaired people with MS which is not detected by a clinical test, such as the Berg balance scale (BBS) [18]. According to previous research, ambulatory patients with EDSS≤6 have shorter strides and slower walking speeds depending on the level of disability, compared to the general population [19, 20].

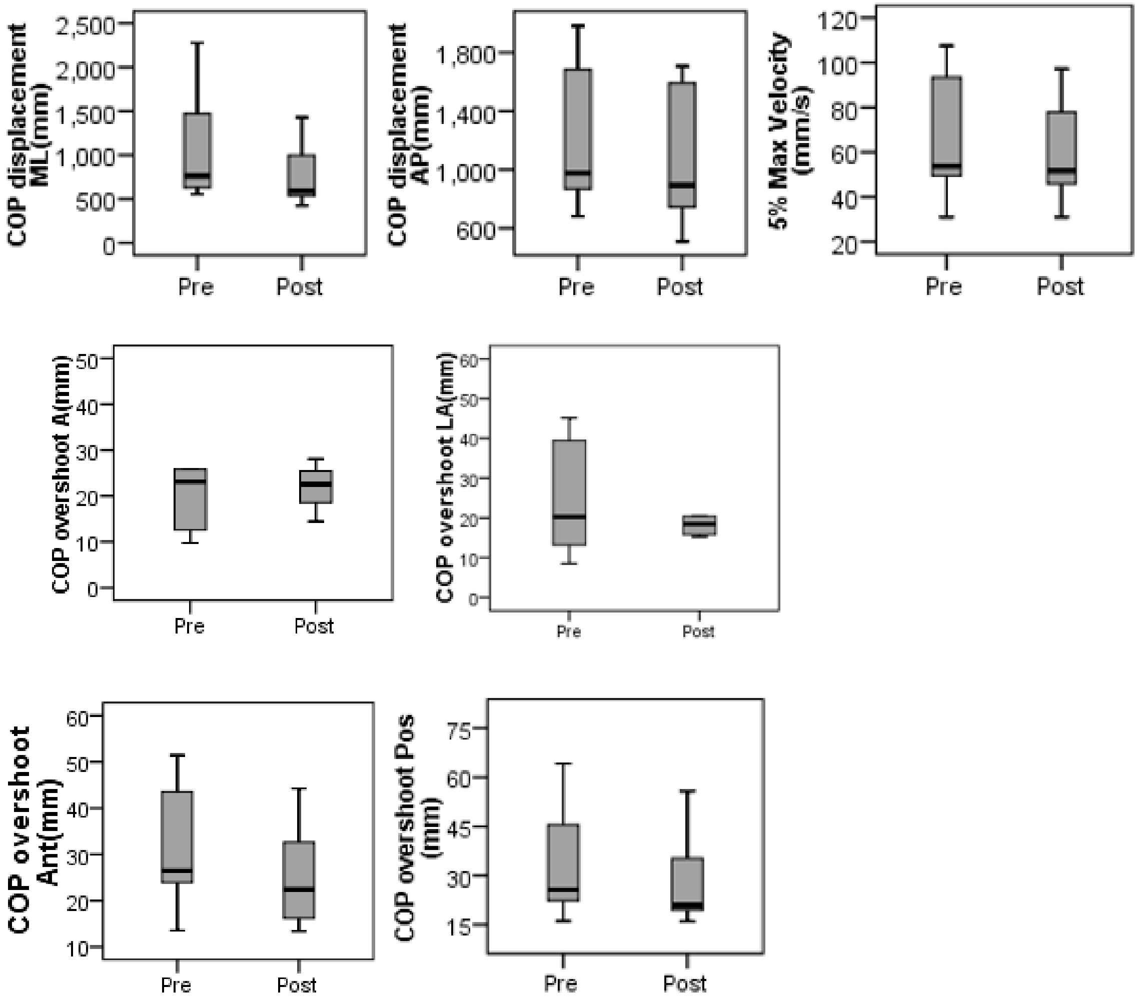

Figure 2. Boxplot of the center of pressure (COP) gait parameters before and after the intervention

COP: Center of Pressure; ML: Mediolateral; AP: Anteroposterior; A: Affected; LA: Less Affected; Ant: Anterior; Pos: Posterior; mm: millimeter.

Table 3. Center of pressure parameters change after cycling

Parameters (Unit)		z	P	Effect Size
COP displacement	Mediolateral (mm)	-2.80	0.01	-0.63
	Anterior posterior (mm)	-1.68	0.09	-0.38
COP overshoot	Affected side (mm)	-0.97	0.33	-0.22
	Less affected side (mm)	-1.58	0.11	-0.35
	Anterior (mm)	-2.29	0.02	-0.51
	Posterior (mm)	-2.19	0.03	-0.49
COP velocity	5% Max velocity (mm/s)	-2.40	0.01	-0.54

COP: Center of Pressure.

Additionally, COP displacement is more significant in patients with MS than in the healthy control group [21]. These changes may result in falling, emphasizing the critical nature of fall prevention interventions for people with MS. Several studies have demonstrated a relationship between COP in the ML trajectory and the risk of falling, rather than AP direction [22], and fallers showed greater ML sway amplitude with and without their eyes open [23]. Stability in the ML direction is critical for step initiation due to the reduced base of support and the requirement to maintain balance during this phase [24, 25].

To determine the COP-related parameters, static posturography was used via double force plates. This method is more reliable, sensitive, and accurate than a standard test, such as the BBS in MS [26], and the efficacy of rehabilitation can also be determined using this technique [27]. Moreover, fall risk is predicted by COP distance differences [28].

There are a variety of pharmacological and non-pharmacological strategies for managing ataxia and balance impairment in MS. On the other hand, exercise is the cornerstone of MS rehabilitation for balance and gait problems, and aerobic activity improves walking speed, endurance, and balance [29, 30]. Moreover, exercise training improves gait and balance asymmetry in patients with chronic neurological conditions [31]. Several randomized controlled trials have been conducted to determine the efficacy of cycling in improving balance in people with MS [30]. However, the balance-specific gait parameters have been omitted. Cycling is safe for individuals with balance deficits due to their inability to perform activities safely in a standing position, as it is performed in a seated position [32]. Furthermore, rhythmic movement while cycling and a combination of aerobic and resistance training can improve function in individuals with MS [7]. Although some studies recommended using combinational therapy, particularly task-specific training in ataxia management [33, 34]. Another study showed that progressive resistant training, including high-resistant cycling along with balance exercise, improves balance in MS [35]. However, the effect of leg cycling on gait parameters in people with MS has not been demonstrated.

In previous studies, cycling has been shown to improve muscle strength and spasticity in patients with MS [8, 35, 36]. Thus, subjects with severe muscle weakness and spasticity in the lower extremities were removed to rule out confounding characteristics associated with cycling and to examine the balance-related changes more precisely. As a result, patients with such characteristics are uncommon in MS; however, balance problems are not uncommon, though they are frequently associated with weakness or spasticity.

Study limitation

The small sample size may affect the significance of the results and affect the study's effectiveness and outcome.

5. Conclusion

Patients with ataxic MS showed a significant shift in some spatiotemporal and COP-related parameters after using a stationary bicycle, highlighted applying an objective tool, such as gait analysis to track changes following rehabilitation.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethical Committee of Tehran University of Medical Sciences (Code: ir.tums.ikhc.rec1398.241). Each participant signed a written informed consent form.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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