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Construct validity of the walk ratio as a measure of gait control in people with multiple sclerosis without mobility aids

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ABSTRACT

Ambulatory limitations are a key component of disability in people with multiple sclerosis (PwMS). Various tools are employed to assess walking performance in PwMS; however, no ideal measure has as yet been attained. In this situation, a walk ratio might be more advantageous compared with other gait measures. The walk ratio, a simple index for describing temporal and spatial co-ordination, denotes the relationship between step length and cadence during walking. Hence, the primary objective of this study was to determine the relationship between the walk ratio and measures of other theoretically related constructs. The walk ratio was studied using the GAITRite™ system (CIR Systems, Inc. Havertown, USA). The study group included 229 PwMS (143 women) and a mean disease duration of 5.8 (SD = 7.1) years. The walk ratio score of the total sample was 5.3 (SD = 0.8). Significant differences based on the expanded disability status scale (EDSS) scores ($F = 11.616$, $P < 0.001$) were observed between the neurological disability subgroups. Scores of the very mild (EDSS 0–2.0), mild (EDSS 2.5–4.0) and moderate (EDSS 4.5–5.5) groups were 5.5 (SD = 0.7), 5.2 (SD = 0.7), 4.9 (SD = 0.9), respectively. In terms of fall status, the MS fallers demonstrated a significant lower walk ratio compared to the MS non-fallers; 5.1 (SD = 0.8) vs. 5.5 (SD = 0.7); $P < 0.001$. Modest significant correlation scores were found between walk ratio and ambulation tests. Scores were slightly higher in the short walking tests, timed 25-foot walk and timed up and go tests (Pearson's rho = 0.369, 0.364) compared to the 6 and 2-min walk time tests (Pearson's rho = 0.344, 0.308). Collectively, the current study supports the construct validity of the walk ratio index in PwMS without mobility aids.

1. Introduction

Multiple sclerosis (MS) is a demyelinating disease of the central nervous system with an estimated prevalence of 1 per 1000 persons in the United States [1]. The disease process generates a diversity of neuropathological changes in the central nervous system (CNS) [2] typically manifested by heterogeneity symptoms (e.g., fatigue and depression) and an accumulation of physical and cognitive impairment over time.

Ambulatory limitations are a key component of disability in patients with MS. After disease duration of 45 years, 76% of people with MS (PwMS) require an ambulatory aid and 52% need bilateral assistance or worse [3]. Causes of walking limitation in PwMS are multifactorial; among the major related factors are muscle weakness, spasticity, sensory deficit, fatigue and loss of balance [4]. Additionally, gait impairment has been noted as a risk factor for falls in PwMS [5]. Interestingly, Sosnoff et al. found that MS fallers experienced poor walking coordination without reduced walking speed, compared to non-fallers [5].

Various tools have been employed to assess walking performance and risk of falls in PwMS, however, no ideal measure has as yet been attained. In this situation, the walk ratio might be more advantageous compared with other gait measures.

Seika and Nagasaki defined the "walk ratio" as step length (m) divided by step rate (steps/min) and found that it was fairly constant in both males and females over a range of walking speeds from very slow to very fast [6]. Hence, the walk ratio is a simple speed-independence index for describing temporal and spatial co-ordination, i.e. walking pattern. Moreover, the walk ratio is invariant in terms of energy expenditure, stability, and attention during walking [7].

The main advantage of the walk ratio is its independence from walking speed. While the walking speed may be reduced due to

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diverse reasons (e.g., confidence, aerobic condition, balance, etc.), the overall bipedal mechanism of gait remains preserved. In contrast, a decreased walk ratio due to a walking pattern of shorter and more frequent steps is thought of as a nonspecific adaptive mechanism facilitating the neuromuscular control of walking, namely, reflecting the quality of gait control [7]. Therefore, the walk ratio can potentially separate the specific effects of intervention treatments on gait coordination from the effects on walking speed.

Studies performed on stroke survivors have demonstrated that the walk ratio decreases in these patients and can increase following a rehabilitation program [8]. Additionally, the risk of multiple falls has increased in older people with a reduced walk ratio [9].

Only a few studies have investigated the application of the walk ratio measure in PwMS [10,11]. Rota et al. reported that the walk ratio is a disability-sensitive index of neuromotor control of gait. They found that the mean walk ratio was 5.4 (SD = 0.9) in the MS group compared to 6.4 (SD = 0.7) demonstrated by the healthy controls. However, their MS sample group was relatively small ($n = 30$) and disability classification comprised only two groups. The scores of the EDSS < 3.5 and EDSS ≥ 3.5 groups were 6.0 (SD = 0.7) and 4.9 (SD = 0.7), respectively [10].

In a different study, the walk ratio was measured in 120 PwMS at baseline and at a 1- and 2-year follow-up period. The authors reported that on average, the walk ratio remained stable at 6 (SD = 1). Nevertheless, no data was provided as to whether the walk ratio was related to other psychometric properties relevant for the MS population [11].

Hence, the primary objective of this study was to determine the relationship between the walk ratio and measures of other theoretically related constructs including measures of walking and balance in PwMS. Given that cognitive impairments negatively affect control of gait [12], we examined the correlation of the walk ratio with various cognitive domains. Additionally, we analyzed the relationship between the walk ratio to perceived fatigue and fear of falling. Our secondary aim was to determine the ability of the walk ratio parameter to discriminate between fallers, non-fallers and global disability status.

We hypothesized that the walk ratio would be moderately associated with valid measures of ambulation and moderately-weakly associated with non-ambulatory measures. Based on previous reports from PwMS [10], neurological populations [8] and elderly adults [9], we further expected that the walk ratio score would be significantly lower in fallers and moderately disabled PwMS, according to the EDSS. Verifying the hypotheses may improve management of gait difficulties in PwMS.

2. Methods

2.1. Study design and participants

The current study design was cross-sectional. We evaluated retrospective data collected from the Multiple Sclerosis Center, Sheba Medical Center, Tel Hashomer, Israel's computerized database, documenting demographic and clinical data of all MS patients followed at the Center from January 2012 through August 2015.

A computerized questionnaire was employed to select patients according to the following inclusion criteria: (1) a neurologist-confirmed diagnosis of definite MS according to the revised McDonald criteria [13]; (2) <6.0 on the EDSS [14], equivalent to the ability to walk at least 100 m without a walking aid; (3) relapse-free for at least 30 days prior to testing; and (4) outcome measures assessed within a 3-month interval and free of a relapse.

Exclusion criteria included: (1) orthopedic disorders that could negatively affect mobility; (2) pregnancy; (3) blurred vision; (4) cardiovascular disorders; (5) respiratory disorders; (6) or taking steroids or fampridine.

The integrity of the data registry was evaluated by a computerized logic-algorithm-questioning process, identifying data entry errors. The study was approved by the Sheba Institutional Review Board. All participating subjects signed an informed consent form giving permission to use their data in the research project.

2.2. Measures

2.2.1. Walk ratio

The walk ratio was studied using the GAITRite™ system (CIR Systems, USA) which consisted of a 4.6 m long electronic walkway containing compression-sensitive sensors arranged in a grid pattern. For the present study, we extracted the cadence and right/left step length scores.

A single valid walking trial was defined once the participant walked independently at his self-selected speed across the electronic mat in one direction without stopping. Each participant performed six consecutive walking trials. Step length and cadence scores were individually calculated for each pass. The values from all trials were then averaged to produce the final results. For each individual, the mean step length was calculated as the average of right and left step lengths.

The walk ratio was calculated according to the following formula: Walk ratio = mean step length (mm)/cadence (step/min). Additionally, we calculated the height-normalized walk ratio matching Rota et al.'s 2011 study [10].

2.2.2. Two-minute walk test (2mWT); six-minute walk test (6mWT)

Subjects were instructed to complete the test 'at their fastest speed' and cover as much distance as possible by walking back and forth down a 30 m hallway, circling cones at each end. Total distance was registered [15].

2.2.3. Timed up and go test (TUG)

The TUG requires both static and dynamic balance. The starting point was determined after the subject had been seated in a chair with their back flush against the chair. He/she was then instructed to stand, walk 3 m, turn around, walk back to the chair and sit down again. Timing began when the individual started to rise and ended when he/she returned to the chair and sat down [16].

2.2.4. Timed 25-foot walk (T25FW)

The T25FW was performed on a clearly marked 25-foot long path down a corridor cleared of obstructions. The T25FW was performed twice and the mean of the two trials was included in the analysis [17].

2.2.5. Multiple Sclerosis Walking Scale (MSWS-12)

The MSWS-12 is a patient-rated measure of walking ability [18]. The questions were based on the patient's walking limitations (due to MS) during the past 2 weeks. The higher the score, the more perceived walking difficulties.

2.2.6. Modified Fatigue Impact Scale (MFIS)

The MFIS is a valid 21-item questionnaire capturing information as to the effects of fatigue within physical, psychosocial and cognitive domains over a four-week period. The higher the score, the more perceived fatigue. Advantages of the MFIS include easy use, good reproducibility and a strong correlation with Fatigue Severity Scale results [19].