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The relationship between fear of falling to spatiotemporal gait parameters measured by an instrumented treadmill in people with multiple sclerosis

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ABSTRACT

People with multiple sclerosis (MS) identify mobility limitations as one of the greatest challenges of this disease. Continued loss of mobility and falls are among their greatest concerns for the future. Our objective was to determine if fear of falling is associated with spatial and temporal gait parameters in persons with MS, when measured by an instrumented treadmill. This observational case control study was performed at the MS Center, Center of Advanced Technologies in Rehabilitation, Sheba Medical Center, Tel Hashomer, Israel. Sixty-eight relapsing-remitting patients diagnosed with MS, 38 women, aged 40.9 (S.D. = 11.9), participated in this investigation. Twenty-five healthy subjects, 14 women, aged 39.5 (S.D. = 9.4) served as controls gait controls. Gait spatiotemporal parameters were obtained using the Zebris FDM-T Treadmill (Zebris® Medical GmbH, Germany). The Falls Efficacy Scale International was used to assess the level of concern relating to falls. Forty-one people with MS were classified as highly fearful of falling. Twenty-seven patients were slightly concerned. Highly fearful of falling patients walked slower had a shorter step length, a wider base of support and prolonged double support phase compared to slightly concerned patients. Fearful patients also demonstrated elevated variability of the center of pressure (CoP) trajectory compared to slightly concerned MS patients. Fear of falling and spatiotemporal gait alterations in people with MS are linked. Additionally, variability of the CoP during walking appears to be connected with the level of concern.

1. Introduction

Multiple sclerosis (MS) is a neurologic disease affecting an estimated 2.5 million adults worldwide. Approximately 75% of individuals with MS experience clinically significant walking and balance disturbances [1] which may present even in the early stages of the disease and in individuals diagnosed with clinically isolated syndrome [2]. People with MS identify mobility limitations as one of the greatest challenges of this disease. Continued loss of mobility and falls are among their greatest concerns for the future [3].

Fear of falling refers to the apprehension felt by an individual with regard to falling during particular activities [4]. Tinetti and Powell defined fear of falling as "a lasting concern about falling that leads to an individual avoiding activities that he/she remains capable of performing" [5]. As a result of activity restriction, the fearful individual is at a high risk of loss of muscle force, cardiovascular diseases and reduced physical conditioning. In particular, activity limitations can be devastating in the MS population. Previous studies have demonstrated that reduced physical activity negatively affects fatigue, spasticity, depression, and quality of life in persons with MS [6].

Only a few studies have examined the relationship between fear of falling and mobility performance in individuals with MS. Peterson et al. [7] collected cross-sectional data from telephone interviews with 1064 individuals with MS, aged 45–90, concluding that fear of falling was positively correlated with a fall which had occurred during the previous 6 months, the use of a walking aid, female, and level of balance impairment. Recently, in a survey of 575 community-dwelling individuals with MS, 62% reported concerns of falling and approximately 67% reported activity restrictions related to their concerns [8]. It is noteworthy that in participants, who had not fallen, 25.9% reported a fear of falling and 27.7% reported activity restrictions related to their fear.

In this context, studies performed on different populations have shown that fear of falling is related to spatial and temporal gait parameter changes. Slower gait speed, shorter stride length, increased stride width, and prolonged double limb support time

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were found to be associated with a preexisting fear of falling in the elderly [9,10]. In contrast, Delbaere et al. found that fear of falling was not associated with walking velocity in community-dwelling older people ($n = 500$) under normal walking conditions. They reported that changes in gait parameters were only observed in individuals who were fearful of falling when threatening conditions were imposed [11].

Although, it is likely that associations between spatiotemporal gait parameters and fear of falling exist in the MS population, these relationships have never been extensively studied in people with MS. Therefore, the purpose of this study was to determine if fear of falling is associated with spatial and temporal gait parameters in persons with MS, when measured by an instrumented treadmill.

2. Methods

2.1. Participants

This study was an observational case control study. Sixty-eight relapsing-remitting patients diagnosed with MS, 38 women and 30 men, aged 40.9 (S.D. = 11.9), were recruited from the Multiple Sclerosis Center, Sheba Medical Center, Tel-Hashomer, Israel and participated in this investigation. Inclusion criteria for participants required: (1) a neurologist-confirmed diagnosis of definite relapsing-remitting MS according to the revised McDonald criteria [12]; (2) <6 on the EDSS which is equivalent to the ability to walk without an assistive device (e.g. a cane or walker); and (3) relapse-free for at least 30 days prior to testing. Exclusion criteria included: (1) orthopedic disorders that could negatively affect mobility; (2) major depression or cognitive decline; (3) pregnancy; (4) blurred vision; and (5) cardiovascular disorders. Twenty-five apparently healthy subjects, 14 women and 11 men, aged 39.5 (S.D. = 9.4) served as controls. None of the healthy participants reported any medication intake and 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. Gait assessment

Gait spatiotemporal parameters were obtained using the Zebris FDM-T Treadmill (Zebris® Medical GmbH, Germany). The Zebris FDM-T is fitted with an electronic mat of 10,240 miniature force sensors, each approximately 0.85 cm × 0.85 cm, embedded underneath the belt. The treadmill's contact surface measures 150 cm × 50 cm and its speed can be adjusted from 0.2 and 22 km/h, at intervals of 0.1 km/h. When the subject stands/walks on the treadmill, the force exerted by his feet (the so-called reactive-normal force in directions x, y and z) 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 to facilitate even subtle changes in force distribution. Timing can also be monitored. Dedicated software integrates the force signals and provides 2-D/3-D graphic representation of major spatiotemporal parameters including center of pressure (CoP) trajectories during static stance and gait.

In 2012, Faude et al. reported high levels of between- and within-day reliability in healthy seniors for the majority of spatiotemporal gait parameters recorded by the Zebris treadmill system during walking, with coefficients of variation typically below 5% and 7%, respectively [13]. Recently, the instrumented treadmill has been found to be an appropriate tool for assessing ambulation capabilities in people with MS. Furthermore, spatiotemporal gait parameters collected by this device during barefoot walking seem to be valid markers of neurological impairment in the MS population [14].

The dedicated software also generates a graphic pattern termed the 'butterfly', representing a continuous trace of the CoP trajectory during walking (Fig. 1).

The following set of parameters was derived from the butterfly:

(1) Anterior/posterior variability (mm): defined as the standard deviation of the intersection point in the anterior/posterior direction.
(2) Lateral symmetry (mm): left/right shift of the intersection point; 'zero position' is equivalent to perfect symmetry.
(3) Lateral variability (mm): defined as the standard deviation of the lateral symmetry.

2.3. Concern and fear of falling

The Falls Efficacy Scale International (FES-I) was used to assess the level of concern relating to falls during 16 activities of daily living, ranging from basic to more demanding activities including social activities that may contribute to quality of life. Level of concern for each item was scored on a four-point scale (1 = not at all concerned, 4 = very concerned), within a total score range 16–64. The higher the score, the more fearful the subject was about falling. The FES-I was originally developed to assess concern relating to falls in the elderly [11,15]. Recently, van Vliet et al. demonstrated that the FES-I is valid, reliable and provides valuable information as to the fear of falling in people with MS [16].

2.4. Experimental design

Upon acceptance to the study, participants were instructed to fill out the FES-I form. Prior to the treadmill gait 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, belt speed was increased by 0.4 km/h, every 15 s, in a stepwise manner. When the participant informed the tester which speed best characterized his/her normal walking pace, it was designated as his/her comfort speed. Following this adaptation phase, each participant was

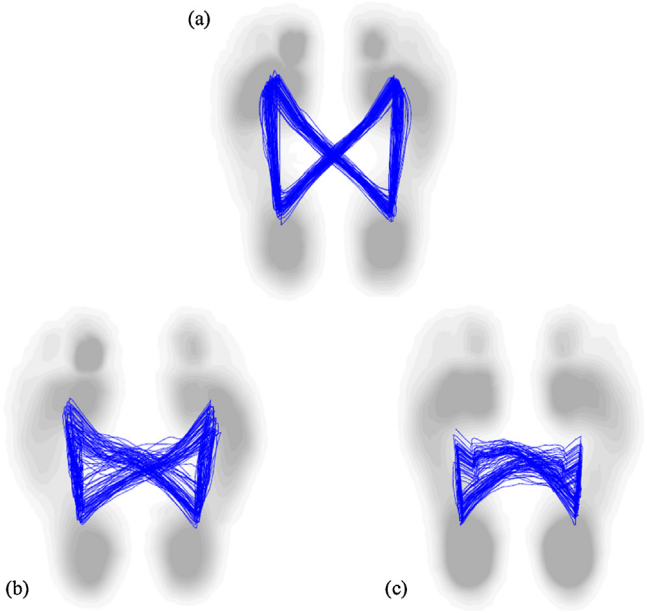

Fig. 1. Cyclogram (butterfly) diagrams derived from the instrumented treadmill: (a) healthy participant, (b) person with low concern about falling and (c) person with high concern about falling.