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Spatio-temporal gait disorder and gait fatigue index in a six-minute walk test in women with fibromyalgia

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ABSTRACT

Background: Gait disorders in fibromyalgia patients affect several gait parameters and different muscle recruitment patterns. The aim of this study was to assess the gait differences observed during a six-minute walk test between fibromyalgia patients and healthy controls.
Methods: Forty-eight women with fibromyalgia and 15 healthy women were evaluated. Fibromyalgia patients met the American College of Rheumatology criteria for fibromyalgia selected of an ambulatory care. Both patients and controls had a negative history of musculoskeletal disease, neurological disorders, and gait abnormalities. The 15 controls were healthy women matched to the patients in age, height and body weight. Spatio-temporal gait variables and the rate of perceived exertion during the six-minute walk test (all subjects) and Fibromyalgia Impact Questionnaire (fibromyalgia subjects) were evaluated. All walking sets on the GaitRITE were collected and the gait variables were selected at three stages during the six-minute walk test: two sets at the beginning, two sets at 3 min and two sets at the end of the test. In addition, the Fibromyalgia Impact Questionnaire was used for the fibromyalgia patients.
Findings: Fibromyalgia patients showed a significant decrease in all spatio-temporal gait variables at each of the three stages and had a lower walk distance covered in the six-minute walk test and higher rate of perceived exertion. No correlations were found between the Fibromyalgia Impact Questionnaire and gait variables. The fibromyalgia and control subjects showed lower gait fatigue indices between the middle and last stages.
Interpretation: Gait analysis during a six-minute walk test is a good tool to assess the fatigue and physical symptoms of patients with fibromyalgia.

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1. Introduction

Fibromyalgia (FM) is a chronic pain syndrome that is fundamentally different from rheumatic disorders in that the pain associated with FM is not due to tissue damage or inflammation (Spaeth and Briley, 2009). Patients with FM report a complex pattern of symptoms that can include physical, emotional, and functional limitations (Rooks, 2008). This syndrome is characterized by widespread musculoskeletal pain of at least three months' duration, fatigue, poor sleep, and tenderness on palpation in at least 11 of 18 specific tender point sites (Wolfe et al., 1990). The most common symptoms of FM are chronic widespread pain, fatigue, sleep disturbances, difficulty with memory, and morning stiffness (Wolfe et al., 1995; Abeles et al., 2007).

The ability to walk a set distance is a quick, easy and inexpensive way to assess physical function. It is also an important component of quality of life because it reflects the capacity to undertake day-to-day activities (Li et al., 2005). Because of this importance, walking tests have been used for many years to assess overall performance status of patients with different underlying diseases (Tueller et al., 2010). One of the most popular tests is the six-minute walking test (6MWT). It is a clinic-based, submaximal exercise test for functional capacity that provides a global analysis of the respiratory, cardiac, and metabolic systems (Solway et al., 2001). A literature review of the 6MWT has revealed its potential as a self-administered, home-based monitoring tool with minimal technological requirements (Du et al., 2010). The primary measurement in 6MWT is the total distance covered. Other measurements include heart rate, saturation of peripheral oxygen, muscle fatigue and dyspnea (Gontijo et al., 2011), but there are no studies that assess the kinematic gait variables in the 6MWT in FM patients. The validity, reliability and responsiveness of the 6MWT have been studied in depth in the general population and in patients with FM (Pankoff et al., 2000a;

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Pankoff et al., 2000b; King et al., 1999; Carbonell-Baeza et al., 2015). Previous studies reported a significant decrease in the distance covered in the 6MWT between FM patients and healthy women (Carbonell-Baeza et al., 2015; Latorre-Román et al., 2014).

Measurements of temporal and spatial parameters of gait are recognized to be clinically relevant in the assessment of motor pathologies (Macellari et al., 1999) and are commonly used to identify gait disorders (Dobbs et al., 1993) and classify subgroups of FM patients (Auvinet et al., 2011). Previous studies that used gait analysis in patients with FM reported that it affects several spatio-temporal gait parameters (Auvinet et al., 2006; Heredia-Jimenez et al., 2009; Heredia-Jimenez and Soto-Hermoso, 2014). On the other hand, Pierrynowski et al. (2005) reported that women with FM walked with similar spatio-temporal variables, joint angles and ground reaction forces as did the control subjects but the women with FM used different muscle recruitment patterns. MacPhee et al. (2013) reported similar gait mechanics as Pierrynowski et al. (2005)), with no difference in oxygen consumption or energy expenditure during walking between the FM and control groups. In addition, Du et al. (2010) reported similar energy expenditures at self-selected walking speeds in the FM and control groups. However, there are no previous studies that assess spatio-temporal gait parameters at different stages of the six-minute walk test (6MWT) and report the extent of gait fatigue during the test.

Therefore, the aim of the present study was to assess the differences in spatio-temporal gait variables and fatigue between patients with FM and healthy control subjects during the 6MWT. The relationship between gait variables and results from the Fibromyalgia Impact Questionnaire (FIQ) was also evaluated. We hypothesized that women with FM exhibit altered spatio-temporal gait variables and increased gait fatigue compared with healthy women during the 6MWT.

2. Methods

2.1. Participants

As FM affects women more frequently than men, we studied 48 women who met the American College of Rheumatology's criteria for fibromyalgia (Wolfe et al., 1990) and belonged to the Fibromyalgia Association of Jaen (Spain). The mean age was 51.8 years (SD: 2.2), the mean weight 65.3 kg (SD: 10.1), and the mean height 1.57 m (SD: 0.03). In addition, 15 healthy women matched to the patients in age, height, and body weight were taken as a control group. The mean age of the control group was 50.3 years (SD: 1.7), mean weight 65.4 kg (SD: 8.6), and mean height 1.59 m (SD: 0.06).

All subjects completed a short anamnesis questionnaire and were excluded from the study if they had a previous history of musculoskeletal disease, neurological disorders, or gait abnormalities.

All participants provided informed consent for the clinical assessment before they enrolled in the study. Gait analysis was performed in both groups by the same researcher using the same equipment and measurement protocol. The research protocol was reviewed and approved by the Ethics Committee of the university.

2.2. Materials and protocol

The 6MWT was performed in an indoor setting and with a hard walking surface using the methodology specified by the recommendations of Rikli and Jones (1999). All subjects were told to avoid vigorous exercise within 2 h of the beginning the test. The subjects were instructed to undertake the test walking as fast as possible without running for six minutes, walking from one cone to another placed 4.75 m apart during the stipulated time along a 45.7-m rectangular course. Subjects were not encouraged during the test but were notified of the amount of time remaining. The same person gave this notification every 2 min during the test. Thirty minutes before starting the 6MWT, the FM group completed the Spanish version of the FIQ (Rivera and González, 2004). At the end of the 6MWT, both groups rated their level of RPE (Borg, 1982).

Gait analysis was performed using an instrumented walkway to measure the kinematic parameters of gait (GAITRite system; CIR Systems Inc., Clifton, NJ, USA). The measurements were made in the middle of the longitudinal walkway rectangle to avoid the non-stabilized walking periods at the beginning and end of the walkway. Participants walked in a quiet, well-lit room at a constant room temperature and wore their own footwear, according to the European guidelines for spatio-temporal gait analysis in older adults (Kressig and Beauchet, 2006).

For each subject, we selected the 2 first laps of the subjects at the beginning of the test (BEG), the 2 laps at the middle (MID) of the test (at the 3-min mark), and the last 2 laps at the end of the test (LAS) to record at least 8 steps of each set.

2.3. Outcome measures

We measured the distance in meters counting the numbers of laps that subjects walked and the number of meters in the case that subjects did not complete the whole last lap. Furthermore, the RPE score was asked to the subjects at the end of the test. FM patients completed the FIQ questionnaire and was analyzed the total score obtained. For each part of the 6MWT test, we recorded the following gait variables: velocity (the distance walked per second, cm/s), cadence (the steps per minute steps/min), stride length (the heel-to-heel distance of the same lower limb in the gait cycle, cm), single support ratio (the single limb support phase duration/gait cycle duration, %), double support ratio (the double limb support duration/gait cycle duration, %), swing phase ratio (the swing phase duration/gait cycle duration, %), and stance phase ratio (the stance phase duration/gait cycle duration, %). We calculated a gait fatigue index (GFI) (Eq. (1) based on the decrease in gait velocity, adapting the equations used previously in repeated-sprint studies (Oliver, 2009; Fitzsimons et al., 1993).

$$GFI_{total=}\ \left[\left(V_{best}{}^{*}3\text{–}SV\right)/V_{best}{}^{*}3\right]{}^{*}100 \quad (1)$$

$$SV = V_{BEG}+V_{MID}+V_{LAS} \quad (2)$$

where V_{best} is the highest of the stages' velocities and SV is the sum of the stages' velocities.

To calculate the GFI of each set (GFI_{BEG}, GFI_{MID}, and GFI_{LAS}), we replaced SV by the velocity of that set (BEG, MID, or LAS) (see Eq. (3) for an example).

$$GFI_{BEG=}\ [(V_{best}\text{–}V_{BEG})/V_{best}]{}^{*}100 \quad (3)$$

2.4. Statistical analysis

Statistical analysis was carried out using SPSS v.20 (SPSS, Chicago, IL, USA). Means and standard deviations were used to describe the variables. Normality was determined by the Shapiro–Wilk test. Kinematic variables and individual GFIs were analyzed by two-way repeated measures ANOVA, using the group and the time as fixed factors. RPE and total GFI were analyzed using an independent Student's *t* test. The Spearman correlation was used to analyze the relationship between the total FIQ score and the kinematic variables. Statistical significance level was set at $p \leq 0.05$.

3. Results

3.1. Between-groups analysis

Significant differences between the FM and control groups were found in spatio-temporal gait variables such as velocity, stride length,

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