Proceeding

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Spatial-temporal gait parameters in RA post-menopausal women fallers and non-fallers

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ABSTRACT

This study aimed to compare spatial-temporal gait parameters and its intra-individual variability of RA post-menopausal women fallers with non-fallers. Twenty-six RA post-menopausal women were selected and answered the question: "How many times did you fall last year?". Subjects with at least one fall in previous year were allocated to fallers group. Health Assessment Questionnaire (HAQ) score was used to assess functional capacity. Optoelectrical 3D motion analyses were used to gait assessment (Vicon® system, 9 infrared cameras, 200 Hz). Subjects walked barefoot at natural and self-selected speed. Seven trials of the left and right foot-steps on a force plate were collected. Thirteen subjects had at least a fall in previous year. Fallers were older and showed higher HAQ scores ($p<0.05$). They yielded lower gait speed, lower cadence, lower stride length, higher stance phase, higher double support phase, and lower single support phase ($p<0.001$). Regarding intra-individual variability, the fallers group showed higher coefficient of variation values for all spatial-temporal gait parameters ($p<0.05$), except for double support phase. Age seems to be an important variable concerning falls in these patients. RA post-menopausal women with falls history yielded changes in spatial-temporal gait parameters and in its intra-individual variability, and presented a lower functional capacity. **Keywords**: Rheumatoid arthritis; Gait; Spatial-temporal parameters; Variability; Falls.

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INTRODUCTION

Rheumatoid arthritis (RA) is a chronic disease that affects joints, connective and fibrous tissues, muscles, and tendons (Aletaha et al., 2010). As could be observed in previous studies (Aydoğ, Bal, Aydoğ, & Cakci, 2006; Çimen, Deviren, & Yorgancioglu, 2001; Ekdahl & Broman, 1992; Hakkinen, Hannonen, & Hakkinen, 1995; Madsen & Egsmose, 2001; Meireles, Oliveira, Andrade, Silva, & Natour, 2002), the pathogenic process leads to loss of physical functions. The disease has a higher prevalence in females (Branco et al., 2016; Hochberg & Spector, 1990; Markenson, 1991) and the peak age for its onset is between the fourth and the sixth decades of life (Alarcón, 1995). These factors establish post-menopausal women as the greater percentage of RA patients.

The speed at which individuals walk is relevant to their functioning in the community (Bohannon & Andrews, 2011). According to the literature (Turner, Helliwell, Emery, & Woodburn, 2006; Turner, Helliwell, Siegel, & Woodburn, 2008), walking speed and percentage of the double-support phase are important parameters for measuring gait. Other parameter is also relevant to assess the gait function, namely the stance phase time (Winter, 1991). The loss of physical functions that can occur in RA patients may have led to the differences in spatial-temporal gait parameters yielded by these patients when compared with healthy controls: lower gait speed (Aleixo, Vaz Patto, Moreira, & Abrantes, 2018; Barn, Turner, Rafferty, Sturrock, & Woodburn, 2013; Eppeland, Myklebust, Hodt-Billington, & Moe-Nilssen, 2009; Turner et al., 2006, 2008; Weiss et al., 2008; Weiss, Broström, Stark, Wick, & Wretenberg, 2007), shorter stride length (Aleixo et al., 2018; Khazzam, Long, Marks, & Harris, 2007; O'Connell, Lohmann, Kepple, Stanhope, & Gerber, 1998; Weiss et al., 2008, 2007), lower cadence (Aleixo et al., 2018; Weiss et al., 2008), longer double-support time (Turner et al., 2006, 2008; Weiss et al., 2008), and longer stance time (Khazzam et al., 2007).

Falls impose a significant social and economic burden for individuals, their families, community health services and the economy (Sherrington et al., 2017). RA patients (Stanmore et al., 2013) as well as post-menopausal women (Barrett-Connor, Weiss, McHorney, Miller, & Siris, 2009) showed an increased fall risk. Falls are known to occur during locomotion and an unsteady gait is an identifiable risk factor associated with falls (Rubenstein, 2006). In the best of our knowledge, there are no studies that compare RA patients fallers with non-fallers concerning spatial-temporal gait parameters. On the other hand, previous studies have shown that elderly fallers yield a lower gait speed (Aleixo, Vaz Patto, & Abrantes, 2017; Callisaya et al., 2011; Lázaro, González, Latorre, Fernández, & Ribera, 2011; Montero-Odasso et al., 2005; Newstead, Walden, & Gitter, 2007; Verghese, Holtzer, Lipton, & Wang, 2009), a shorter step/stride length (Callisaya et al., 2011; Newstead et al., 2007), a lower cadence (Newstead et al., 2007), a shorter single support phase (Newstead et al., 2007), and a longer double support phase (Callisaya et al., 2011; Newstead et al., 2007; Verghese et al., 2009) than non-fallers. Additionally, intra-individual variability of the spatial-temporal parameters is also observed in subjects with falls history (Callisaya et al., 2011; Hausdorff, Rios, & Edelberg, 2001; Maki, 1997; Toebes, Hoozemans, Furrer, Dekker, & Van Dieën, 2012; Verghese et al., 2009). However, the results are conflicting as to whether spatial-temporal gait measures are related with falls or not. Data from a previous study (Maki, 1997) showed that reduced speed, reduced stride length, and increased double-support time were associated with fear of falling but revealed little evidence of an independent association with falling. Conversely, increased stride-to-stride variability in gait speed, stride length, and double support time was associated with falling but showed little evidence of relationship to fear of falling. So, stride-to-stride variability of the spatial-temporal gait parameters is an independent predictor of falls and should be further studied to improve current fall risk assessments and tested as intervention targets (Verghese et al., 2009).

This study aimed to compare the spatial-temporal gait parameters and its intra-individual variability of RA post-menopausal women fallers and non-fallers.

METHODS

Experimental procedures were performed in accordance with the Declaration of Helsinki and approved by the Ethical Committee for Health of the Portuguese Institute of Rheumatology.

Subject selection

Twenty-six women, diagnosed with RA according to the *2010 Rheumatoid Arthritis Classification Criteria* (Aletaha et al., 2010), were recruited from the Portuguese Institute of Rheumatology, Lisbon, Portugal. The following inclusion criteria were used: (1) diagnosis of post-menopausal status (Harlow et al., 2012); (2) absence of early menopause (Shuster, Rhodes, Gostout, Grossardt, & Rocca, 2010); (3) lack of an unstable heart condition, chronic obstructive pulmonary disease, or cancer; (4) use of stable doses of disease-modifying antirheumatic drugs for at least four weeks before the experiment; this period of time was necessary to achieve the anticipated effects of medication on joint pain and disease activity, which may result in consequences regarding the spatial-temporal gait parameters; (5) absence of prosthetics in the lower limb joints; (6) nonparticipation in any kind of exercise program in the last 3 months; (7) documented ability to walk barefoot and unassisted for distances over seven meters (without current walking aids). Subjects reviewed and signed an informed consent form prior to entering the study.

Falls history assessment

Subjects answered to the following question: "How many times did you fall last year?". Falls history was considered when subjects with at least one fall in the previous year. The subjects with a falls history were allocated to the fallers group. A fall was defined as an unintentionally coming to rest on the ground, floor, or other lower level (Lamb, Jorstad-Stein, Hauer, & Becker, 2005).

Clinical Assessment

The demographic characteristics and the reproductive and medical history of each woman were collected (age, body mass, height, duration of menopause, and disease duration).

The Disease Activity Score-28 joints (DAS-28) was used to assess disease activity. This score was calculated from the number of swollen and tender joints, visual analogue scale to assess global health, and erythrocyte sedimentation rate (Smolen et al., 1995), which were assessed by the same experienced rheumatologist and in the same laboratory.

Pathological involvement of the lower limb joints was considered when at least one of the lower limb joints (hips, knees, ankles, tarsometatarsal joints, metatarsophalangeal joints, proximal interphalangeal joints) was assessed as a swollen or tender joint.

Functional Capacity Assessment

The Health Assessment Questionnaire (HAQ) (Fries, Spitz, & Young, 1982) was used to assess the functional capacity. This questionnaire was validated for the Portuguese population (Santos et al., 1996). It is a 20-item questionnaire covering activities of daily living in 8 domains: dressing, arising, eating, walking, hygiene, reach, grip, and errands and chores. There are 2 or 3 questions for each section. Scoring within each section is from 0 (without any difficulty) to 3 (unable to do) and the 8 scores of the 8 sections are summed and divided by 8. The final score is the functional disability index.

Gait biomechanical assessment

In order to assess the spatial-temporal gait parameters, optoelectrical 3D motion analyses were developed. These analyses were supported by the Vicon® Motion Capture MX System (VICON Motion Systems, Oxford, UK), which was based on 9 MX cameras (7×1.3 MP and 2×2.0 MP) connected to the MXUltranet controlling hardware. The system was prepared to record data at 200 Hz.

The same investigator placed the 39 spherical reflective markers (9.5 mm in diameter) on the anatomical landmarks of all subjects, according to the PlugInGait-Full Body model (Vicon Motion Systems, Oxford, UK). Some of these markers were used to analyse the following spatial-temporal gait parameters: gait speed ($m.s^{-1}$); cadence ($steps.min^{-1}$); stride length (m); percentage of stance phase (%); percentage of double support phase (%); percentage of the first double support phase (%); percentage of the first single support phase (%); percentage of the second double support phase (%); percentage of the second single support phase (%). These parameters were determined as described in the literature (Aleixo et al., 2018). Data acquisition and processing were developed using the *Vicon Nexus software (version 1.7.1).* The following protocol were used d*uring d*ata acquisition: (1) subjects walked barefoot through a walkway that was 7 m long and 2 m wide; (2) at the end of the walkway, the subjects turned around; (3) subjects were asked to walk at a natural and self-selected speed, representing the most comfortable walking speed that minimised either possible discomfort that could have been introduced by a pre-determined speed (Sekiya, Nagasaki, & Ito, 1997) and minimised the induction of the subjects into a transitioning stage, that is, a stage marked by an increased variability (Diedrich & Warren, 1995); (4) seven trials of the left and right foot-steps on a force plate were collected; and (5) to avoid gait performance deterioration related to fatigue, subjects rested for 2 min by sitting on a chair every 20 trials. For all trials, a quintic spline routine (Woltring filtering) was used.

Statistical analyses

During the gait biomechanical assessments seven trials of the left and right foot-steps on a force plate were collected. Intra-individual mean and the intra-individual coefficient of variation (CV) of the spatial-temporal gait parameters of the left and right foot-steps were calculated from these seven trials. CV was used to assess the intra-individual variability of the spatial-temporal gait parameters. For statistical analysis, left and right dataset was considered independently. We could have randomly selected and measured only one side per subject, however, we would have lost valuable information since the right and left lower limb joints of the RA patients can be affected in different ways. In healthy populations, the asymmetry between right and left lower limbs in regard to gait biomechanical parameters have been frequently reported (Sadeghi, Allard, Prince, & Labelle, 2000). Moreover, based on intra-individual analyses (*t*-test) we observed differences between right and left in respect to the spatial-temporal gait parameters assessed in this study. These intra-individual analyses allowed concluding that right and left strides were independent, and in these conditions, some authors suggest consideration of both sides in the analysis (Derr, 2006).

Data were analysed by SPSS (version 17.0) and are presented as mean and standard deviation. Even if the distribution was not normal, the significance level of the *t*-tests would be almost exact for sample sizes >12 (Good & Hardin, 2003). A two-tailed independent-sample *t*-test was used to compare RA post-menopausal women fallers and non-fallers. Differences were considered statistically significant at p values < 0.05.

RESULTS

Thirteen subjects had a falls history in the previous year and were allocated to the fallers group. Table 1 shows the descriptive statistics of clinical and demographic data for fallers and non-fallers groups. Intergroup differences were found in age ($p < 0.05$) and HAQ score ($p < 0.01$). No subject had early RA (disease duration

< 2 years). Only three subjects in fallers group and one in non-fallers groups had no pathological involvement of the lower limbs joints.

As shown in Table 2, RA post-menopausal women fallers yielded lower gait speed, lower cadence, lower stride length, higher stance phase, higher double support phases, and lower single support phases ($p < 0.001$). Regarding intra-individual variability, the fallers group showed higher CV values for all spatial-temporal gait parameters ($p < 0.05$), except for double support phases.

Table 1. Clinical and demographic data

Variables	Fallers (n=13)	Non-fallers (n=13)	Differences
	Mean (SD)	Mean (SD)	P value
Age (years)	68.2 (7.3)	61.4 (7.6)	0.030*
Disease duration (years)	11.9 (9.2)	9.2 (9.9)	0.479
DAS-28 score	5.0 (1.2)	4.2 (1.3)	0.142
Nº swollen or tender lower limb joints	8.9 (9.3)	5.9 (6.7)	0.373
Duration of menopause (years)	19.6 (7.1)	13.8 (9.6)	0.091
Body mass (kg)	64.8 (9.3)	66.3 (16.1)	0.770
Height (m)	1.51 (0.03)	1.54 (0.07)	0.167
Body mass index ($kg.m^{-2}$)	28.6 (4.7)	27.9 (5.7)	0.769
HAQ score	1.3 (0.3)	0.8 (0.5)	0.002**

*DAS-28 – Disease Activity Score (28 joints); HAQ – Health Assessment Questionnaire; Nº – number; SD – standard deviation; *p < 0.05; **p < 0.01.*

Table 2. Spatial-temporal gait data

Variables	Fallers (n=26)	Non-fallers (n=26)	Differences
	Mean (SD)	Mean (SD)	P value
Gait speed ($m.s^{-1}$)	0.82 (0,19)	1,10 (0,11)	0.000*
Gait speed CV (%)	5.4 (2.8)	3.7 (2.0)	0.019**
Cadence ($steps.min^{-1}$)	101.5 (9.6)	117.3 (7.8)	0.000*
Cadence CV (%)	3.7 (1.6)	2.9 (1.2)	0.044**
Stride length (m)	0.97 (0.15)	1.12 (0.08)	0.000*
Stride length CV (%)	4.4 (3.0)	2.7 (1.4)	0.010**
Stance phase (%)	63.0 (2.6)	60.3 (1.7)	0.000*
Stance phase CV (%)	3.4 (1.5)	2.2 (0.9)	0.001***
Double support phase (%)	25.2 (4.8)	19.9 (2.8)	0.000*
Double support phase CV (%)	8.7 (4.0)	8.3 (3.6)	0.761
First double support phase (%)	12.8 (3.2)	10.0 (1.8)	0.000*
First double support phase CV (%)	11.9 (8.3)	10.6 (4.4)	0.471
First single support phase (%)	37.8 (3.2)	40.4 (1.9)	0.001***
First single support phase CV (%)	5.7 (2.0)	3.5 (1.8)	0.000*
Second double support phase (%)	12.4 (2.1)	9.8 (1.6)	0.000*
Second double support phase CV (%)	11.7 (4.9)	11.7 (4.8)	0.996
Second single support phase (%)	37.0 (2.6)	39.8 (1.7)	0.000*
Second single support phase CV (%)	5.8 (2.5)	3.3 (1.2)	0.000*

*CV – coefficient of variation; SD – standard deviation; *p < 0.001; **p < 0.05; ***p < 0.01.*

DISCUSSION

This study was designed to compare RA post-menopausal women fallers and non-fallers with respect to spatial-temporal gait parameters and its intra-individual variability. To the best of our knowledge, this was the first study that addressed this issue. The data of our study showed that RA post-menopausal women fallers yielded differences in spatial-temporal gait parameters, namely lower gait speed, lower cadence, lower stride length, higher stance phase, higher double support phases, and lower single support phases. These results corroborated those of previous studies (Callisaya et al., 2011; Lázaro et al., 2011; Montero-Odasso et al., 2005; Newstead et al., 2007; Verghese et al., 2009) that found similar results in elderly fallers. On the other hand, our data also point that RA post-menopausal women fallers yielded a higher intra-individual variability of the spatial-temporal gait parameters, corroborating previous studies that compared elderly with and without falls history (Callisaya et al., 2011; Hausdorff et al., 2001; Maki, 1997; Toebes et al., 2012; Verghese et al., 2009).

According to a previous study (Maki 1997), a reduced speed, a reduced stride length, and an increased double-support time were associated with fear of falling, while increased intra-individual variability in gait speed, stride length, and double support time was associated with falls. On the other hand, an increased intra-individual variability during gait, have been attributed to a possible loss of motor control (Buzzi, Stergiou, Kurz, Hageman, & Heidel, 2003). Relating these data to ours, we can speculate that the RA post-menopausal women fallers of this study had fear of falling and a reduction of motor control. So, strategies to reduce fear and increase motor control should be applied with this kind of RA patients.

In studies with postmenopausal women, reports of falling within the past year increased with age (Barrett-Connor et al., 2009; Geusens et al., 2002). Barrett-Connor et al. (2009) discussed that advanced age as an independent fall risk factor may reflect muscle weakness, poor balance, or gait problems that are not captured in surveys. According to our data, age also seems to be an important variable concerning falls in these patients. Moreover, we also found a reduction of the functional capacity in RA post-menopausal women with falls history. Thus, programs to increased functional capacity and to prevent falls should be used in this kind of RA patients, especially in patients with falls history and with an advanced age. According to a systematic review with meta-analysis (Sherrington et al., 2017), exercise as a single intervention can prevent falls in elderly. Furthermore, this systematic review suggested programmes that involve a high challenge to balance and include more than 3 hours/week of exercise have greater fall prevention effects.

Damage joints and joint pain are consequences of the RA pathogenic process (Aletaha et al. 2010) and a reduction of the gait speed is a compensatory mechanism for RA patients´ pain foot (Turner et al. 2008; Weiss et al. 2008). In our study was not found differences between fallers and non-fallers regarding the number of swollen or tender lower limb joints. Moreover, no statistically significant intergroup differences were found in DAS-28, pointing that the disease activity are not associated with falls. However, this is an important issue that should be clarified in future studies.

The variability of biomechanical data may be associated with greater ability of adaptation to the performance goal. However, the results obtained in present study, seem to demonstrate that the variabilities recorded do not exceed allowable values for the desired adaptability. Therefore, in performers who fell previously, but not during the reported data, the parameters did not exceed the limits that sometimes must have occurred when the performers fell, as result of the original survey of the present paper. A future study tends to understand which or which parameters whose variability, when over and above certain parameters values, causes falls.

CONCLUSIONS

RA post-menopausal women fallers were older and presented a lower functional capacity. They yielded changes in the spatial-temporal gait parameters: reduce gait speed, cadence and stride length; higher stance phase and double support phase; lower single leg support phase. This group of RA patients yielded higher intra-individual variability of the spatial-temporal gait parameters, except for intra-individual variability of the double support phases.

COMPETING INTERESTS

All co-authors have not conflicts of interest to disclose.

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