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Altered gait and balance in patients with fibromyalgia are associated with pain symptons

Isis da Silva Costa[1*], Antoni Gamundí [1], José Garcia Vivas Miranda[2], Lucas Gabriel Souza França[2], Charles Novaes de Santana[1], Pedro Montoya[1]

1 Research Institute on Health Sciences (IUNICS), University of the Balearic Islands, Palma de Mallorca, Spain

2 Department of Physics of the Earth and the Environment, Federal University of Bahia, Salvador, Brazil

Corresponding author: Pedro Montoya, Email address: pedro.montoya@uib.es

Abstract

Fibromyalgia is a common chronic pain condition, which is often associated with prominent negative consequences for participation in daily activities. Objectives: The main objective of the present study was to evaluate the kinematic and kinetic parameters of gait, functional performance and balance in women with fibromyalgia syndrome. Methods: The study included 17 female patients with fibromyalgia (48.1 ± 7.3 yrs) according to the criteria of the American College of Rheumatology, as well as 17 pain-free women (43.2 ± 8.3 yrs). Objective measures of gait and balance were analyzed using video recordings of patients performing several motor tasks. In addition, subjective measures of motor function and clinical pain were also obtained by using self-report questionnaires. Results: Walking speed was significantly diminished ($p < 0.001$) as result of reductions in stride length ($p < 0.001$) and cycle frequency ($p < 0.001$) in fibromyalgia patients as compared to pain-free controls. Analyses of balance revealed significant group differences between fibromyalgia and pain-free controls in medio-lateral and anterior-posterior body sways (all $p < 0.01$). Kinetic parameters of gait and balance in fibromyalgia

were significantly related to pain, fatigue, stiffness, but not to depression or anxiety. Conclusion: These results suggest that a precise evaluation to identify the impairments and strategies underlying functional performance in postural stability and gait is necessary for optimal balance rehabilitation and fall prevention in fibromyalgia.

Keywords: Fibromyalgia; Pain; Gait; Balance; Biomechanics

Introduction

Fibromyalgia (FM) is a chronic syndrome characterized by widespread pain, fatigue and problems awaking unrefreshed, as well as cognitive deficits and somatic symptoms [**?**]. Fibromyalgia has a high prevalence in the population (around 2%) and appears to affect women more frequently than men [**?**, **?**], with a peak age of onset in the range 30-50 years [**?**, **?**]. In addition, patients with fibromyalgia have 2-3 times higher healthcare costs [**?**, **?**] and report poorer well-being compared to healthy persons [**?**].

Although the etiopathogenesis of fibromyalgia is still not well understood, the syndrome has been associated with neuroendocrine function [**?**], brain activity [**?**,**?**,**?**,**?**], and several neurobiological abnormalities and gene polymorphisms [**?**, **?**].

Fibromyalgia also exerts a considerable impact on patients daily activities and quality of life. In particular, it has been frequently shown that fatigue in fibromyalgia is severe enough to limit motor activities and may lead to a sedentary lifestyle reducing physical abilities and increasing risk for disabilities [**?**, **?**]. Fibromyalgia patients often report functional limitations that are more debilitating or at least equal than those reported by persons with osteoarthritis or rheumatoid arthritis [**?**, **?**]. Furthermore, it has been shown that loss of function could be strongly associated with work disability in fibromyalgia patients [**?**, **?**]. Nevertheless, current data on levels of physical function in fibromyalgia are mostly provided by community studies using self-report measures [**?**, **?**].

Biomechanical analysis of gait constitutes a useful tool for the assessment of motor function, functional capacity and muscle fatigue [**?**], and muscle weakness [**?**] in fibromyalgia patients. Thus, previous studies have observed that fibromyalgia women display a reduced walking speed, which could be a consequence

of decreases in stride length and cycle frequency, as well as bradykinesia [**?**, **?**, **?**]. Furthermore, it has been reported that patients preferentially powered gait by using their hip flexors instead of their ankle plantarflexors, thus increasing their metabolic demands and fatigue when walking at a normal speed in comparison to healthy controls [**?**].

Current research has also revealed that fibromyalgia patients may also display balance deficits [**?**, **?**, **?**, **?**]. Balance or postural stability is a complex task that involves a rapid and dynamic integration of multiple sensory, motor, and cognitive inputs to execute appropriate neuromuscular activity [**?**]. Impaired balance has been reported as one of the top ten debilitating symptoms in fibromialgia with prevalence rates between 45% [**?**] and 68% [**?**]. Moreover, higher frequency of falls has been found in fibromyalgia patients (34.4%) [**?**] in comparison with persons aged 65 years or older (25-35%) [**?**], es well as persons with rheumatoid arthritis (RA) [**?**]. Nevertheless, most of previous research on balance and fibromyalgia are also based on retrospective reports or on self-report measures [**?**] rather than on objective measures of posture sway (e.g., computerized baropodometry, video analysis).

So, the aim of the present study was to analyze gait and balance parameters in fibromyalgia and to examine the possible relationships of subjective and objective measures of motor function with different subjective complaints in these patients. In particular, we hypothesized that fibromyalgia patients would display significant gait and balance deficits as compared with pain-free controls, and that these motor disturbances would be associated with increased patients ratings of pain, fatigue, morning tiredness, stiffness and physical impairment.

Material and Methods

Participants

Seventeen women diagnosed with fibromyalgia (FM) (mean age 48.1 ± 7.3) and 17 pain-free women (mean age 43.2 ± 8.4) with comparable sociodemographic characteristics (Table 1) were recruited from different health centers and patients associations in Majorca (Spain). FM patients were included in the study if they fulfilled the classification criteria of the American College of Rheumatology [**?**] and had

widespread pain as dominant symptom. Participants were excluded from the study if they had musculoskeletal disorders or any neurological disease. For medical and ethical reasons, subjects were asked to keep their medicines during the study (see Table 2 for current medication use). At the time of recruitment, participants were verbally informed about the details of the study and provided written consent. The study was in accordance with the Declaration of Helsinki (1991) and was approved by the Ethics Committee of the Balearic Islands (Spain) (reference IB-1284/09).

– Tables 1 and 2 –

Self-report questionnaires

Fibromyalgia patients and pain-free controls completed following standardized questionnaires:

- *Fibromyalgia Impact Questionnaire (FIQ)*: The FIQ is an extensively validated instrument [**?**, **?**] designed to quantify the overall impact of fibromyalgia over many dimensions (e.g. function, pain level, fatigue, sleep disturbance, psychological distress, etc.). The FIQ shows high sensitivity to change and high internal consistency (Cronbachs Alpha = 0.96) in a wide variety of intervention studies [**?**, **?**]. The FIQ is composed of 10 questions. The first question contains 11 items (each item is rated on a 4-point Likert type scale) related to the ability of performing motor tasks (physical impairment subscale). Questions 2 and 3 of the FIQ asks the number of days that participants felt well and the number of days they were unable to work (including housework) due to pain symptoms. Questions 4 through 10 are 10-cm visual-analogue scales for ratings of pain, fatigue, morning tiredness, stiffness, anxiety, depression and work difficulty. The maximum FIQ score is 100 with higher scores indicating greater impact. FIQ has shown excellent responsiveness to change in clinical studies and a good correlation with similar questionnaires such as the SF-36 [**?**]. In the present study, the Spanish validated version of FIQ [**?**] was used.

Motor function tasks

Gait and balance parameters were obtained in fibromyalgia patients and pain-free controls by using the following functional tasks:

- *Berg Balance Scale* [**?**]: This scale is a performance-based assessment tool developed to measure standing balance during functional activities such as reaching, bending, transferring, and standing. The test is often used for patients who exhibit a decline in function, self-report a loss of balance, or have unexplained falls. It has also been used for patients with other diseases such as Parkinson's disease, stroke, and multiple sclerosis [**?**]. The Berg Balance Scale consists of 14 functional tasks (e.g., sitting unsupported, change of sitting to standing position and viceversa, standing with both feet together, standing on one leg, turning 360 degrees) with scores ranging from 0 (unable to perform) to 4 (normal performance). Total scores range from 0 (severely impaired balance) to 56 (excellent balance). Scores below 46 have been discussed as good predictors for the occurrence of multiple falls [**?**].

- *Six-minute walking test (6MWT)*: The 6MWT is a functional walking test in which subjects are instructed to walk for 6 minutes as quickly as possible. This test has been used to assess individuals with stroke [**?**], head injury [**?**], and Parkinson's disease [**?**], pulmonary and cardiac diseases, as well as in persons with FM [**?**, **?**, **?**, **?**]. The 6MWT is considered a good indicator of exercise tolerance and aerobic capacity, since it causes a physiological stress without demanding maximum aerobic capacity [**?**]. Ratings of perceived exertion were obtained after the 6MWT by using the Borg Effort Scale [**?**], a 15-point scale ranging from 4 (complete lack of effort) to 20 (maximum effort or exhaustion).

- *Timed up and go task (TUG)*: This task is a basic test for functional mobility including standing up, walking, turning and sitting down. The task is performed by using an ordinary armchair (45 cm in height) and a stopwatch. Subjects are seated with their back against the chair and instructed to stand up, walk three meters, turn around, walk back to the chair and sit down at an ordinary comfortable speed [**?**, **?**]. The stopwatch is started on the word "*Go*" and stopped as the subject sit down. The TUG time is measured in seconds and normal TUG time ranges from 5.4 to 40.8 seconds (mean=15 seconds, SD=6.5) [**?**, **?**]. TUG

time appears to be associated with gait speed, balance, functional level and the ability to go out [**?**, **?**]. After the TUG, overall fatigue and subjective perception of physical effort was measured by using the Borg Effort Scale [**?**].

- *Modified version of the Rombergs balance test*: The Rombergs test is an objective measure of patients standing balance [**?**]. For this purpose, participants were asked to remain in orthostatic position with their feet in parallel and separated, arms extended along the body and with eyes closed during one minute. The test is based on the fact that maintaining balance while standing with closed eyes should rely on intact sensorimotor integration and motor pathways. The test was repeated twice and motion on the frontal and sagittal planes was captured by using a digital video camera at 30 frames per second (Casio Exilim EX-FS10). For motion detection analysis, a plumb line hanging on the ceiling at a distance of 3 meters was used as reference. Participants were also asked to wear a cap with sticks positioned in the vertical and horizontal planes. For the analysis of body sway in the mediallateral direction, sticks were aligned with the anatomical position of the glabella of the frontal bone. For the analysis of body sway in the anteriorposterior direction, sticks were aligned with the anatomical position of the pinna (tragus).

- *Gait task*: Subjects were instructed to walk on a 3 meters carpet at their normal walking step, without shoes and with flexed arms positioned on the abdomen. Optical markers were attached at the following body positions: anterior superior iliac spine, posterior superior iliac spine, area between the lateral condyle of the femur and the fibular head, bottom of the patella, lateral and inner malleolus, heel (between the first and second metatarsal), and on the tip of the hallux. Subjects motion was digitally recorded with a video camera at 210 frames per second (Casio Exilim EX-FS10). The camera was positioned at a distance of 3 meters from the carpet to visualize changes in position, velocity and acceleration of anatomical points along the x-axis. Gait velocity (cm/second), walking duration (seconds), cadence (number of steps/minute), percentage of time in the two phases of the gait cycle (stance and swing phase), and percentage of time with single and double support were computed.

Data analyses

Three groups of variables were statistically analyzed in the present study:

- Raw scores obtained from self-report questionnaire (FIQ).
- Performance scores on standardized motor function tests (TUG, 6MWT, Berg Balance Scale, Borg Effort Scale).
- Kinetic parameters extracted from video recordings: gait velocity, gait duration, cadence, stride and step lengths, percentage of time in the stance/swing phase, and body sway variability in the anteriorposterior and mediallateral planes. A free open-source software for computer vision analysis of human movement (CvMob) was used [**?**,**?**]. The CvMob determines displacement, velocity and acceleration motion by using computer vision techniques. The software has also a high degree of accuracy for calculating the body position and movement in the X and Y cordinates recorded by conventional cameras [**?**].
- Hurst exponent analysis on the displacement data in order to evaluate the balance dynamics.

The Hurst exponent was observed in several natural phenomena and quantifies the long term correlations on a time series [**?**]. Its estimation for the relative position of the individual body on the horizontal axis, was made by the use of the Root Mean Square (RMS) method [**?**] that consists on calculate the deviation relative to the time series average value in a sliding window of size n. The RMS values are defined as follows:

$$\bar{W}(n) = \frac{1}{N_n} \sum_{u=1}^{N_n} \left\{ \frac{1}{m_n} \sum_{i \in n} \left[Z(x_i, y_i) - \bar{Z}_n \right]^2 \right\}^{1/2} \quad (1)$$

Statistical analyses were performed by using R (version 3.11), a free software environment for statistical computing and graphics. The null hypothesis that sample data came from a normally distributed population was examined by using Shapiro-Wilk test, and differences between patients and pain-free controls were analyzed by using Student t-tests and Pearson correlations were used to analyze the relationship between kinetic parameters and clinical symptoms in fibromyalgia.

Results

Differences between fibromyalgia patients and pain-free controls on sleep quality and motor function.
Fibromyalgia (FM) patients also displayed a high impact on daily activities as measured by the Fibromyalgia Impact Questionnaire (FIQ) (Table 3).

– Table 3 –

FM patients also walked less distance in 6 minutes (6MWT) and took more time to stand-up and to walk a distance of 3 meters (TUG) as compared with pain-free controls (Table 4). Moreover, ratings on self-perceived effort (Borg Effort scale) after performance on 6MWT and TUG tests were significantly higher in fibromyalgia than in pain-free controls. Finally, FM patients reported increased risk of falls (measured by the Berg Balance Scale) in comparison with pain-free controls (t[27] = -19.71, $p < 0.001$).

Analyses of kinetic parameters further indicated that FM patients had significant deficits in gait and balance (Table 4). In particular, FM patients displayed significant reductions in gait velocity, cadence (steps/minute), stride and step lengths, and the percentage of single support and swing phase, as well significant increased gait duration in comparison with pain-free participants. Same effects were also yielded

when values were referenced to each subjects legs (distance between the greater Trochanter and the lateral Malleolus). Moreover, FM patients displayed greater body sway in the anterior-posterior (t[27] = -10.4, $p < .01$) and medial-lateral directions (t[27] = -15.2, $p < .01$) as compared with pain-free controls.

- Table 4 -

Relationship between fibromyalgia symptoms and motor function

In order to further assess if altered motor function was related to clinical symptoms of fibromyalgia, Pearson correlations between motor performance scores (standardized motor function tests, gait and balance parameters) and FIQ scores (pain intensity, depression, anxiety, physical impairment, fatigue and stiffness) were computed (Table 5). Results indicated that high pain ratings were significantly associated with higher risk of falls (Berg Balance Scale), increased time to perform the TUG test, reduced gait velocity, increased gait duration, reduced stride and step lengths, and increased body sways in the anterior-posterior and medial-lateral directions, whereas high fatigue and stiffness were related to reduced percentages of single support and swing phase of the gait cycle. In addition, stiffness was also positively associated with increased performance time of the TUG task and enhanced perceived effort after completion of 6MWT test. Moreover, high depression and anxiety scores were associated with high risk of falls, and performance time of the TUG and self-perceived effort after TUG were positively associated with depression and physical impairment, respectively.

- Table 5 -

Discussions

In the present study, we examined differences between fibromyalgia patients and age-matched pain-free controls on kinetic parameters of gait and balance (time upon completion of motor tasks, walking dis-

tance, body sway) and subjective complaints (ratings of perceived exertion, fatigue, pain). Our results indicated that both gait and balance were severely impaired in patients with fibromyalgia, suggesting a poor skeletal muscle performance as compared with age-matched pain-free participants. Moreover, we observed that fibromyalgia symptoms were significantly associated with a poorer physical performance.

Gait

Gait parameters such as speed, cadence, stride and step lengths, percentage of stance and swing phases, and support base during walking were significantly impaired in fibromyalgia patients. These findings are in accordance with previous studies showing that FM patients move at slower cadence compared to pain-free controls [**?**, **?**, **?**].

Moreover, it has been observed that fibromyalgia women spend more time in double support than in single support when walking, and less isometric strength in the lateral extensors of the leg, flexors and unilateral extensors of the knee [**?**, **?**]. The preferential use of the hip flexors to walk in comparison to the plantiflexors of the ankle in FM patients may result of special interest since the latter are also important to maintain balance during walking [**?**, **?**, **?**]. Thus, it has been suggested that these alterations during gait together with generalized pain and overweight could inhibit the single support of body and enhance the time of double support in FM patients [**?**, **?**]. Moreover, gait impairments in fibromyalgia resemble those already observed in older people [64]. In this sense, our finding that FM patients exhibited a 30% reduction in gait velocity and stride length compared to age-matched healthy individuals is even greater than the reported reduction of 20% in gait velocity and length of stride has been found in older people as compared with younger people [**?**].

Moreover, the present data are consistent with previous studies showing that an altered pattern of activity in chronic pain patients may influence their daily functioning [**?**]. In this sense, it has been observed that patients with chronic pain display a different distribution of physical activity over a 24-hour period, with significantly less intensity levels of activity during the morning and the evening, compared to healthy controls [**?**, **?**]. A common assumption is that reduced physical activity might result from fear of pain and subsequent avoidance of activities that are known or believed to exacerbate pain (fear-avoidance

model) [**?**, **?**]. Although no measure of fear of pain was obtained in the present study, our data seems to indicate that gait deficits in FM patients were mainly associated with pain intensity, fatigue and stiffness, rather than with depression or anxiety.

In this sense, several factors such as level of physical activity, bradykinesia, overweight, fatigue and pain, along with a reduced isometric strength of the legs might be responsible for alterations in gait parameters and muscle recruitment patterns, resulting in low quality of life of patients with fibromyalgia [**?**, **?**, **?**]. Although we have no clear explanation for this lack of association, it could be possible that the observed changes in gait and balance parameters were not relevant in the daily routine of FM patients.

Balance

Analyses of global scores on the Berg Balance Scale, a performance-based assessment tool to measure standing balance during functional activities, revealed that balance was more impaired in fibromyalgia patients than in pain-free controls. Average global scores in fibromyalgia patients were lower than 46, indicating that patients had a high risk of falls. In this sense, our findings indicated that the risk of falls in patients with fibromyalgia was of 55% (according with criteria published by Berg et al. (1992) [**?**], similar to rates reported for older persons and Parkinson patients [**?**, **?**] and significantly higher than the one observed for pain-free controls (2%).

The motion analysis of the modified version of the Rombergs balance test further indicated that fibromyalgia patients displayed more impaired balance than pain-free controls. Although mean values of oscillations were minimal in both groups, body sways on the anterior-posterior and medial-lateral planes were significantly greater in fibromyalgia patients than in pain-free controls. These findings are consistent with previous studies [**?**, **?**, **?**]. In this sense, our findings provide support for the hypothesis that FM may affect many subsystems responsible for the postural control of the individuals [**?**, **?**]. A further support for the notion that fibromyalgia patients displayed an abnormal balance during task performance was provided by the results on the Timed up and go (TUG) test. We observed that fibromyalgia patients took significantly more time to complete the task (around 17 seconds) than pain-free controls (8 seconds). These values were similar to those obtained in a previous study [**?**] showing that frail older

people who took more than 13.5 seconds to perform the TUG were 3.7 times more likely to have suffered a fall in the previous 6 months than those who took less than 13.5 seconds.

Moreover, a survey of 2,596 persons with FM reported balance problems as one of the top 10 most debilitating symptoms with a reported prevalence of 45% [**?**]. Having into account that around 30% of people over the age of 65 living in the community fall at least once a year [**?**, **?**] and that the mean age of our patients was lower than 65 years, one may speculate that the risk of falls in FM patients could represent an important limitation in their elderly life.

Many medications, used by people with FM, could be also associated with side effects of postural instability. In this sense, opioids, tricyclics, hypnotics, benzodiazepines, and cardiac medications have been linked to falls in the elderly [**?**, **?**]. Nevertheless we can ensure that the loss of balance and gait these are not by a side effect of medication administered by each patient, since we find that there is no difference between signiticativas fall risk observed in patients who are part of this study with those types of medicaments in which they are used. However we can not say whether this relationship would remain if the number of subjects to increase.

Patients with balance and movement impairments such as those documented in this study should do exercises in order to improve their quality of life. However, due to safety concerns, these exercises should be ordered and supervised by appropriate physical and occupational therapists. These professionals can order feasible performance testing (such as the measures used in this study) and choose suitable exercises and environments for exercising according to specific necessities of each patient. We recomend that clinics focusing on care for persons with FM should have personnel available and recommended resources to help patients carry out recommended activities.

Limitations

This study had some limitations. First, the number of subjects in the study. Regarding the questionnaires, they were self-administered and not by personal inter-view, it is noteworthy that the evaluator was present all the time if there was any question of doubt; besides did not measure muscle strength of important groups in balance and motor performance.

CONCLUSION

The present study revealed significant impairments of fibromyalgia patients during several gait and balance tasks by using standardized performance tasks. The ongoing assessment of balance and gait in clinical samples, such as fibromyalgia patients, often use high-cost methods, such as computerized baropodometria and expensive softwares.

Secondarily, the current study demonstrated that a low cost methodology based on video analysis of patients performing tests of balance and gait by using open-source computer vision software (CVMob) could be a reliable tool for gait and balance evaluation in clinical settings.

It is very common in the literature to use spatial and temporal parameters of the step patterns to identify gait disorders in order to determine the correct therapy and to monitor the evolution of patients motor diseases [**?**, **?**]. Our study provided similar results but using low-cost methods [**?**, **?**, **?**, **?**].

Nevertheless, future research should also determine the feasibility of this methodology to test the effectiveness of regular physical activity programs for modifying gait and balance parameters in fibromyalgia.

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Figures

Tables

Table 1. Demographic characteristics of participants

	Fibromyalgia patients N = 17	Pain-free controls N = 17	Kolmogorov-Smirnov test for equality F(p-value)
Age (yrs)	48.1 ± 7.3	43.2 ± 8.4	$0.46(0.07)$
Weight (Kg)	70.9 ± 11.1	66.6 ± 10.9	$0.36(0.24)$
Body Mass Index	27.1 ± 3.7	23.7 ± 3.9	$0.52(0.015)^{*}$
FM History (yrs)	7.5 ± 5.5	–	

Table 2. List of medication in FM participants

	Number of Patients
ANTIDEPRESSANTS	
Selective serotonin reuptake inhibitor	11 (64.7%)
Melatonergic receptor agonist (MT1 and MT2) and selective antagonist of the serotonergic	2 (11.7%)
Non-selective monoamine reuptake inhibitors	1 (5.9%)
ANALGESICS	
Clonixin, Tramadol hydrochloride, Paracetamol, Magnesium metamizol	11 (64.7%)
ANXIOLYTICS	
Diazepam, Lorazepam, Alprazolam	6 (35.3%)
ANTIINFLAMATORY AND ANTIRHEUMATIC, NON-STEROIDS	
Celecoxib, Etoricoxib, Dexketoprofen, Ibuprofen, Naproxen, Piroxicam	8 (47%)

Table 3. Mean and standard deviations of subscale in Fibromyalgia Impact Questionnaire (FIQ).

	Fibromyalgia patients N = 17	Pain-free controls N = 17
Fibromyalgia Impact Questionnaire (FIQ)		
Physical impairment (0-3)	1.4 ± 0.8	
Feel good (0-7)	5.1 ± 1.4	-
Work missed (0-7)	2.4 ± 2.6	-
Do work (10 cm VAS)	7.5 ± 2.7	-
Pain (10 cm VAS)	7.6 ± 2.2	-
Fatigue (10 cm VAS)	8.9 ± 1.2	-
Rested (10 cm VAS)	8.1 ± 3.0	-
Stiffness (10 cm VAS)	7.3 ± 3.0	-
Anxiety (10 cm VAS)	7.2 ± 2.8	-
Depression (10 cm VAS)	6.4 ± 3.4	-
Total FIQ score (0-100)	67.4 ± 1.7	-

Table 4. Mean and standard deviations of gait and balance parameters during motor performance in fibromyalgia patients and pain-free controls.

	Fibromyalgia patients N = 17	Pain-free controls N = 17	p-value
Standardized motor function tests			
Berg scale for risk of falls (0–56)	44.9 ± 5.7	55.41 ± 0.61	$p < .01$
TUG (secs)	44.9 ± 5.7	55.41 ± 0.61	$p < .01$
Perceived effort after TUG (4–20)	44.9 ± 5.7	55.41 ± 0.61	$p < .01$
6MWT (m)	44.9 ± 5.7	55.41 ± 0.61	$p < .01$
Perceived effort after 6MWT (4–20)	44.9 ± 5.7	55.41 ± 0.61	$p < .01$
Gait parameters			
Berg scale for risk of falls (0–56)	44.9 ± 5.7	55.41 ± 0.61	$p < .01$
TUG (secs)	44.9 ± 5.7	55.41 ± 0.61	$p < .01$
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Balance parameters			
Berg scale for risk of falls (0–56)	44.9 ± 5.7	55.41 ± 0.61	$p < .01$
TUG (secs)	44.9 ± 5.7	55.41 ± 0.61	$p < .01$