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Original Article

Can Early Fatigue in Leg Muscles After Exercise Cause Postural Instability in Women With Fibromyalgia?

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Abstract

Objectives: This study aimed to investigate the effects of exercise-induced lower limb muscle fatigue on postural stability in female patients with fibromyalgia (FMS). **Method**: This study included 19 female patients diagnosed with FMS according to the 2010 American College of Rheumatology criteria and 19 age-matched healthy controls. Muscle fatigue was induced by chair sit-to-stand (STS) repetitions in all participants. Postural stability was evaluated before and immediately after muscle fatigue test (MFT) in standard bipedal and tandem stances with eyes open (EO) and eyes closed (EC), and in single leg stance with EO using a foot pressure platform. **Results**: The mean number of STS repetitions on MFT was lower in FMS patients ($p<0.001$). Before MFT, plantar center of pressure (CoP) excursions was greater in FMS patients versus controls in all postures tested except in EO bipedal stance (all $p<0.01$). Postural sway increased post-MFT in both FMS and control groups in all stances (all $p<0.001$). Post-MFT increase in postural sway was greater in the FMS group versus controls (all $p<0.05$). **Conclusion**: Lower limb muscle fatigue occurs earlier in FMS patients than in healthy individuals and exacerbates postural stability problems. This indicates the importance of planning tailored exercise programs for these patients.

Keywords: Fibromyalgia, Muscle Fatigue, Postural Balance

Introduction

Fibromyalgia syndrome (FMS) is a clinical chronic condition with cardinal symptoms of generalized body pain and fatigue, and is associated with a profound impact on quality of life[1]. The presence of balance disturbances in patients with fibromyalgia has been increasingly demonstrated by recent studies[2,3]. Many factors such as pain, muscle weakness, cognitive disorders, and use of psychotropic drugs have been examined in terms of their relationship with balance impairment[2,3]. Although some mechanisms have been proposed for the postural instability in these patients, the underlying causes are not well understood. Findings regarding the association of muscle weakness with balance in FMS patients are conflicting. While there are some studies associating reduced lower limb muscle strength with postural instability, others support the opposite argument[3,4].

Another clinical symptom commonly accompanying pain in FMS patients is fatigue[5]. It has been reported that fatigue affects up to 100% of FMS patients[6]. In addition to an overwhelming feeling of physical tiredness that patients experience even when they do not exercise, premature, debilitating fatigue after exercise represents an important clinical problem[6]. It has been shown that the preferred gait speed is low and the perceived level of exertion while walking is high in FMS patients in the absence of changes in oxygen delivery and consumption[7]. In a study in which quadriceps muscle was fatigued using isometric contractions, a significant reduction was observed in the evoked muscle responses recorded during the fatigue test. Based on this finding, the authors reported that fatigue is associated with neuromuscular factors in patients with fibromyalgia[8]. Much earlier development of fatigue was observed on 6-minute walk test (6MWT) in FMS patients compared to control group[9].

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There are findings on the negative effects of lower limb muscle fatigue induced by exercise on postural stability in healthy individuals[10]. Recently, some data were reported, which showed a decline in proprioception due to fatigue induced by repetitive muscle contractions[11]. It is believed that the accumulation of metabolites such as lactic acid triggers erroneous proprioceptive information in the muscles[12]. Since there are conflicting data in the literature on the relationship between muscle strength and balance in FMS, it was considered that the presence of muscle fatigue may be used as a parameter to elucidate this association. To our knowledge, there is no study in the literature investigating the effects of exercise-induced lower extremity muscle fatigue on postural stability in patients with FMS, regardless of the type of exercise.

This study aimed to evaluate the development of lower limb muscle fatigue through exercise and to investigate the impact of induced muscle fatigue on postural stability in FMS patients.

Materials and Methods

Participants

This study included 19 female patients (mean age, 32.5 years) who presented to the Physical Therapy and Rehabilitation outpatient clinic and were diagnosed with FMS according to the 2010 American College of Rheumatology (ACR) criteria. Age-matched 19 healthy individuals were enrolled in the study as control subjects.

Prior to initiation of the study, approval was obtained from the Ethics Committee of Research and Training Hospital (2015/0170). All individuals agreeing to participate in the study gave informed consent. All study procedures were conducted in accordance with the principles of the Declaration of Helsinki. Individuals with malignant, endocrinological, orthopedic, rheumatic, cardiac, pulmonary and neurological diseases, vision problems and vertigo were excluded from the study. Patients receiving medications which can affect balance such as benzodiazepines, opioids, antidepressants and anti-epileptics were not included in the study.

Age, height, body weight and the number of falls in the previous year were noted for all participants. The duration of disease was recorded for patients with FMS. The patients were asked to rate the severity of their current pain on a 10 cm visual analogue scale (VAS).

Revised Fibromyalgia Impact Questionnaire (FIQR)

This questionnaire (FIQR) is a self-report tool which was developed to measure the severity of symptoms in patients living with FMS and the impact of symptoms on activities of daily living (ADLs). The first domain consists of 9 items designed to measure the ability of the patients to perform ADLs. For the second domain with two items, the patients are asked to describe the "overall impact" of fibromyalgia. The third domain consists of 10 items intended to measure the severity of FMS symptoms. Each item of the questionnaire is rated on a 0-10 VAS. Higher scores indicate greater impact of the disease. Reliability and validity of the Turkish version of the FIQR have been demonstrated by Ediz et al.[13].

Assessment of Fatigue

Fatigue was assessed using the Multidimensional Assessment of Fatigue (MAF) scale. This tool consists of 16 items designed to measure the level of fatigue during various ADLs. Reliability and validity of the Turkish version of the MAF scale have been demonstrated by Yıldırım et al.[14].

Assessment of Fear of Falling

The Falls Efficacy Scale (FES) with 10 items was used to evaluate the fear of falling. The participants rate how confident they are while performing activities of daily living on a scale from 0 to 10. Reliability and validity of the Turkish version of FES have been demonstrated by Ulus et al.[15].

Assessment of Dynamic Balance

Dynamic balance of all participants was assessed using the timed up and go (TUG) test. In the TUG test, the total time a person takes to stand up from a chair, walk a 3 m distance, and return and sit on the chair again is measured in seconds[16].

Lower Extremity Muscle Fatigue Test

The lower extremity muscle fatigue test (MFT) was used to induce fatigue in the legs. For this test, the patients were asked to sit on and get up from a chair with 30 repetitions per minute until they felt exhausted. During the sit-to-stand task, it was ensured that the arms were crossed in front of the chest. A metronome was used while performing the test in order to standardize the sit-to-stand frequency per minute. The test was terminated when the participants stated that they could no longer continue due to exhaustion[17]. The number of sit-to-stand repetitions until the test was stopped was recorded.

Postural Stability Assessment

Postural stability of the patients was assessed by measuring plantar center of pressure (CoP) excursions. Win-Track (Medicapteurs, France) pressure platform was used for the measurement of CoP excursions. Win-Track is a 150 x 50 cm walkway that can measure vertical ground reaction force with sensors on its pressure-sensitive surface. Measurements were initially obtained in the stance position with weight distributed evenly between the heels and the toes on both feet (standard stance). While taking measurements in the standard stance position, a distance of 22 cm, 26 cm or 30 cm between the feet was ensured in patients with a height of 76-140 cm, 141-165 cm or 166-203 cm, respectively[18]. Then, measurements were repeated in the tandem stance. In these postures, measurements were performed twice, with eyes open and closed. Lastly, CoP excursions were measured with the participant standing on the dominant leg with eyes

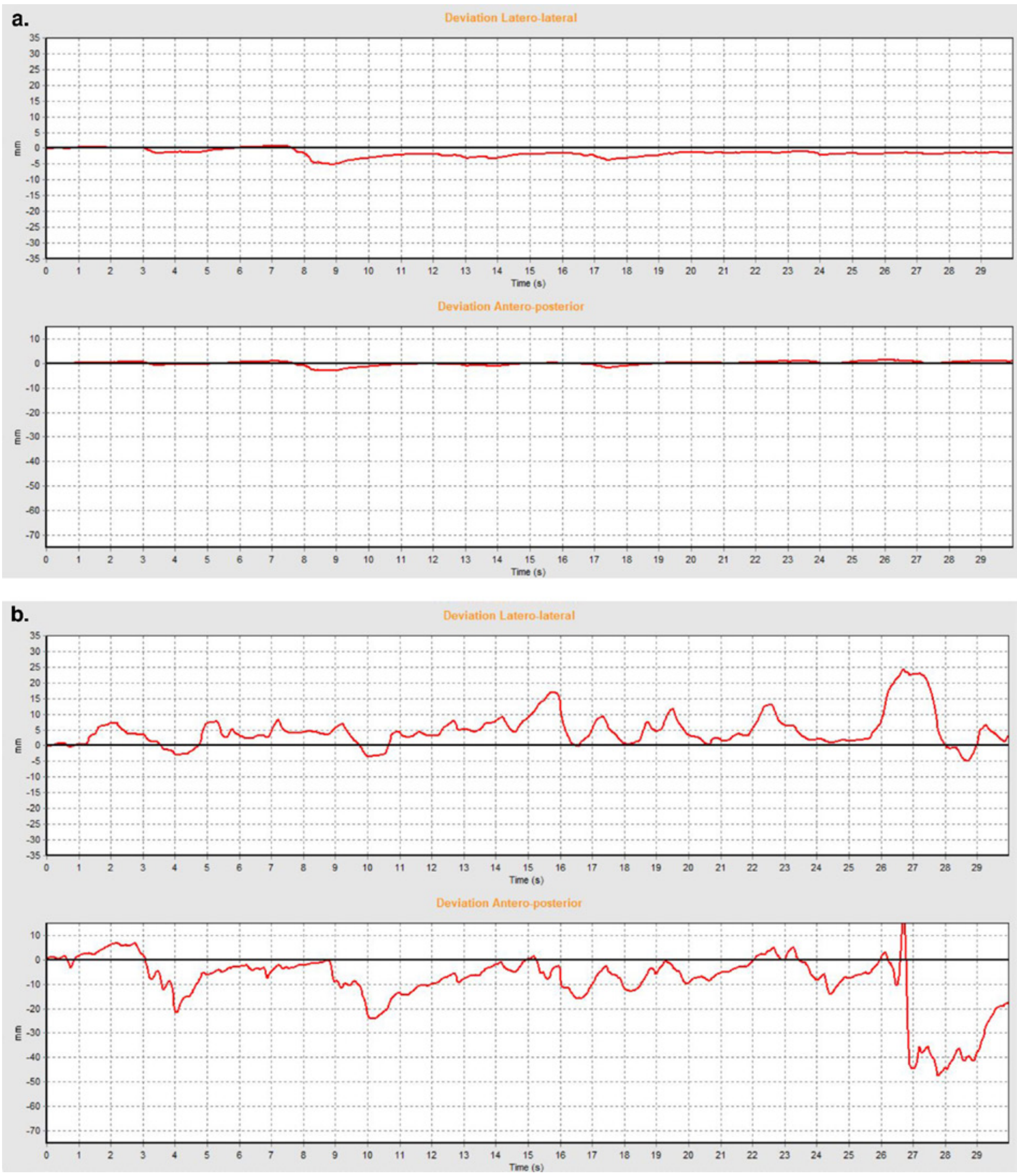

Figure 1. Graphical displays of CoP excursions before (a) and after (b) muscle fatigue test.

open. Care was taken to ensure the arms were held next to the body during all measurements. Postural stability data were obtained by recording CoP excursions on the pressure platform for 30 seconds. Total trajectory (T-Trajectory) values representing the trajectory lengths in all directions during CoP excursions were calculated with the Win-Track software. In addition, the anterior-posterior (AP) velocity and the medial-lateral (ML) velocity were analyzed, which indicate the CoP displacement velocity in the AP direction and ML direction, respectively. Postural sway assessment was performed twice, before and immediately after MFT (Figures 1a and 1b).

Table 1. Characteristics of fibromyalgia and control groups.

	FMS Group	Control Group	P value
Age (years)[a]	32.5±6.1	31.8±5.9	0.461
BMI (kg/m²)[a]	24.6±3.5	23.9±3.1	0.533
MAF scale	33.5 (24.5-50)[b]	1.0 (1-25)[b]	0.000**
IPAQ (MET/week)	231 (66-495)[b]	693 (462-3092)[b]	0.002**
TUG test (s)a	9.4±1.0	7.0±0.5	0.000**
Number of falls	0 (0-5)[b]	0 (0-1)[b]	0.072
FES	20 (10-80)[b]	10 (10-20)[b]	0.000**
Number of sit-to-stand repetitions[a]	43.8±15.9	64.2±14.2	0.000**
Disease duration, months	78 (24-180)[b]		
FIQR scale	52 (44-84)[b]		
VAS[a]	7.7±1.5		

***p<0.01, [a]Mean ± standard deviation, [b]Median (minimum-maximum). BMI: Body mass index, FES: Falls Efficacy Scale, FIQR: Revised Fibromyalgia Impact Questionnaire, FMS: Fibromyalgia Syndrome, IPAQ: International Physical Activity Questionnaire, kg: kilogram, MAF: Multidimentional Assessment of Fatigue, MET: metabolic equivalent of task, m: meter, S: second, SD: standard deviation, X: mean, TUG: Timed up and go test, VAS: visual analogue scale.*

Table 2. Comparison of CoP excursions between the groups in standard stance position.

	FMS Group X ± SD	Control Group X ± SD	P value
$EOCoP_{T\text{-}Trajectory}$	61.8 ± 21.7	49.3 ± 10.5	0.071
$EOCoP_{AP\text{-}Velocity}$	1.3 ± 0.6	1.1 ± 0.3	0.100
$EOCoP_{ML\text{-}Velocity}$	1.2 ± 0.5	1.0 ± 0.3	0.239
$ECCoP_{T\text{-}Trajectory}$	72.4 (53.6-222.7)[a]	56.6 (50.8-75.4)[a]	0.018*
$ECCoP_{AP\text{-}Velocity}$	1.7 (1.1-4.7)[a]	1.4 (0.9-2.6)[a]	0.020*
$ECCoP_{ML\text{-}Velocity}$	1.45 (1-4.9)[a]	1.2 (0.7-1.8)[a]	0.011*

**p<0.05. [a]Median (minimum-maximum). AP: anteroposterior, CoP: center of pressure, EC: eyes closed, EO: eyes open, FMS: fibromyalgia syndrome, ML: mediolateral, T:total, SD: standard deviation, X: mean.*

Statistical Analysis

Prior to initiation of the study, power analysis was performed using the G*power software to determine the sample size. The effect size was calculated as 1.21 using the mean (±standard deviation) CoP excursion data for the patient and control groups as described in the literature[2]. The power analysis showed that 19 subjects per group would be needed for the study, assuming α=0.05, 1-β=0.95. SPSS (Statistical Package for Social Sciences) for Windows, version 22.0 (IBM Corp., Armonk, NY) was used for the statistical analyses of the study findings. Descriptive statistics were reported as mean, median, standard deviation, and minimum-maximum. Comparisons of numerical data between groups were performed using Student's t-test for data with a normal distribution and Mann-Whitney U test for data with a non-normal distribution. For within-group comparison of repeated measurements, paired t-test was used for normally distributed data and Wilcoxon signed-rank test for non-normally distributed data. The results were analyzed with 95% confidence intervals and p values less than 0.05 were considered statistically significant.

Results

The characteristics of the study groups are shown in Table 1. The mean age and body mass index were comparable between the groups. On lower limb MFT, the average number of sit-to-stand repetitions was significantly lower in the FMS group (Table 1).

The CoP excursion values obtained in the standard stance position before lower limb MFT are shown in Table 2. In this position, the amount of CoP excursions measured with eyes open was similar between the groups. However, greater

Table 3. Comparison of CoP excursions between the groups in tandem stance position.

	FMS Group X ± SD	Control Group X ± SD	P value
$EOCoP_{T\text{-}Trajectory}$	359.9±126.1	249.1±71.1	0.004**
$EOCoP_{AP\text{-}Velocity}$	9.5±3.8	5.9±2.1	0.002**
$EOCoP_{ML\text{-}Velocity}$	5.6±1.7	4.4±1.3	0.029*
$ECCoP_{T\text{-}Trajectory}$	1043.9±350.1	451.1±173.6	0.000**
$ECCoP_{AP\text{-}Velocity}$	27.2±9.3	10.5±4.4	0.000**
$ECCoP_{ML\text{-}Velocity}$	17.1±6.6	9.5±4.1	0.001**

**p<0.05, **p<0.01. AP: anteroposterior, CoP: center of pressure, EC: eyes closed, EO: eyes open, FMS: fibromyalgia syndrome, ML: mediolateral, T: total, SD: standard deviation, X: mean.*

Table 4. Comparison of CoP excursions between the groups in single leg stance.

	FMS Group X ± SD	Control Group X ± SD	P value
$CoP_{T\text{-}Trajectory}$	424.1 ± 116.1	312.6 ± 57.9	0.003**
$CoP_{AP\text{-}Velocity}$	9.8 ± 3.4	7.2 ± 1.4	0.015*
$CoP_{ML\text{-}Velocity}$	8.3 ± 2.8	5.6 ± 0.8	0.002**

**p<0.05, **p<0.01, AP: anteroposterior, CoP: center of pressure, FMS: fibromyalgia syndrome, ML: mediolateral, T: total, SD: standard deviation, X: mean.*

Table 5. Comparison of post-fatigue changes in postural sway between the groups.

	FMS Group Median (min-max)	Control Group Median (min-max)	P value
$EOCoP_T$ Standard stance	66.8 (9.4-526.5)	24.9 (4.2-62.6)	0.015*
$ECCoP_T$ Standard stance	38 (17.2-384.3)	28.7 (3.7-52)	0.003**
$EOCoP_T$ Tandem stance	90.5 (44.1-479.5)	45.7 (2.1-134.4)	0.001**
$EOCoP_T$ Single leg stance	124.6 (46.1-423)	71.9 (8.6-106)	0.001**

**p<0.05, **p<0.01. CoP: center of pressure, EC: eyes closed, EO: eyes open, FMS: Fibromyalgia syndrome, max: maximum, min: minimum, T: total.*

postural sway was observed in the FMS group compared to the control group when the test was performed with eyes closed (Table 2).

Table 3 shows the CoP excursion values obtained in the tandem stance position before the lower limb MFT. In this position, while the FMS group showed increased postural sway with eyes open compared to control group, more pronounced CoP excursions were observed when measured with eyes closed (Table 3).

The CoP excursion values obtained in the single leg stance before the lower limb MFT with eyes open are displayed in Table 4. Significantly greater postural sway was observed in the FMS group compared to the control group (Table 4).

In the FMS group, a significant increase in postural sway was found in all stances when measured after the lower limb MFT. CoPT-Trajectory values increased to a median of 112 (60-604.6) in the EO standard stance and 105.1 (76.1-607) in the EC standard stance following the fatigue test (all p<0.001). The median CoPT-Trajectory values were 517.4 (212.7-842.2) in the EO tandem stance and 559 (380.2-1005) in the single leg stance after exercise (all p<0.001). Increased CoPT-Trajectory values were also observed in the control group after the fatigue test, with mean values of 77.1±19.1 in EO standard stance, 88.6±14.9 in EC standard stance, 295.9±89.4 in EO tandem stance and 375.9±67.7 in single leg stance, respectively (all $p<0.001$). Post-fatigue test changes in the postural sway measures in both groups are presented in Table 5. It is noteworthy that significantly greater increases occurred in postural sway after fatigue test in the FMS group compared to the control group in all stances tested (Table 5).

Discussion

In this study, worse static balance was found in the FMS patients compared to controls except for the bipedal stance with eyes open. Our findings showed that lower limb muscle fatigue occurs much earlier in these patients than in healthy individuals. Impaired postural stability was observed after fatiguing lower limb muscles in both FMS patients and healthy controls. Impairment of postural stability after MFT was more evident in FMS patients.

Recently, there has been a growing interest in balance problems in patients living with FMS. Trevisan et al. showed increased postural sway in patients with fibromyalgia in both bipedal and tandem stances compared to the control group. In that study, postural sway was more evident when tested with eyes closed[2]. Similarly, our findings indicate that postural instability was more pronounced in both tandem and standard bipedal stances with eyes closed. Akkaya et al. demonstrated impairment of balance in FMS patients using posturographic measurements. They reported that sleep disorders and fatigue level have negative effects on balance. In line with our results, comparable postural sway was found between FMS patients and controls when tested on a hard surface with eyes open[19]. Consistently, in a study by Muto et al., it was found that FMS patients had greater postural excursions, except when measured on a hard surface with eyes open[2].

Our study showed that there was no significant increase in the frequency of falls in FMS patients, which is in line with Bölükbaş et al.'s results[20]. Contrastingly, there are studies in the literature reporting a significantly increased prevalence of falls in FMS patients[21,23]. It should be noted that some of those studies included patients treated with drugs that may increase the risk of falling[19]. Our finding that fear of falling was significantly greater among FMS patients is in line with almost all of the previous reports[3,20,21].

It was observed that lower limb muscle fatigue developed much faster in the FMS group. Significantly reduced in lower limb functional capacity has been shown in FMS patients[23]. It is known that both physical and cognitive tasks cause severe fatigue in patients with FMS[6]. In a study by Goes et al. in which functional performance was assessed using 30-second sit-to-stand test, poor functional performance was observed in FMS patients[22]. It was found that patients with FMS experience reported higher levels of exertion while performing activities such as walking or climbing stairs[24].

The most important finding of our study was that, after lower limb muscle fatigue test, impairment of postural stability was more pronounced in FMS patients than in healthy subjects. Studies have shown that lower limb muscle fatigue adversely affects postural stability in healthy individuals as well[10,25]. Likewise, increased postural sway was also observed in the control group following fatigue test in our study. When evaluating the relationship between fatigue and balance in FMS, the effect of localized lower limb muscle fatigue seems more relevant rather than a generalized sensation of fatigue. Aron et al. showed that fatiguing upper limb muscles did not have a negative impact on balance in healthy individuals[26]. It was underscored that simple segmental movements strongly challenging postural tonic muscles are associated with impaired balance[25]. The negative effects of lower limb muscle fatigue on balance have also been shown in the elderly population[27].

Several mechanisms have been proposed to explain the negative impact of exercise-induced muscle fatigue on balance. These mechanisms include deficiencies in muscular function, impaired proprioception and changes in motor unit discharges as a result of vigorous exercise[11,12,25]. Although the exact cause remains unclear for the time being, our study showed that muscle fatigue after exercise significantly affects balance in FMS. This finding seems important for a number of reasons. As exercise training constitutes an important part of treatment of FMS patients, it seems necessary to consider the amount and intensity of exercises from various perspectives while planning physical therapy programs for these patients. In addition, there are many aspects that need to be clarified regarding the associations of exercise with muscle metabolism, organization of the central and peripheral nervous systems, fatigue and balance in FMS.

Balance is the ability of the body to maintain its position on a base of support with minimal postural sway. It is thought that a decline in the ability of the muscles to exert force as a result of fatigue will impair maintenance of balance[28]. Balance has vital importance for physical performance and sustained ability to execute ADLs. To avoid additional mobility problems, having good balance is particularly important for FMS patients who already experience considerable impairment of quality of life due to many reasons such as pain and fatigue. It has been shown that balance disturbances have a negative effect on functional independence in ADLs in patients with FMS[29].

Our study is valuable since it is the first study to demonstrate the adverse effect of lower limb muscle fatigue on postural stability in patients with FMS. However, there are some limitations of this study that should be noted. The sample size was not large and the prevalence of falls was not prospectively followed over a long-term.

There is a need for prospective studies in larger groups to evaluate the postural stability of patients after exercise programs in patients with FMS.

In conclusion, strenuous exercises cause premature fatigue in lower limb muscles in FMS patients. Due to high levels of perceived exertion and the development of premature muscle fatigue, prescribing exercises to these patients requires careful consideration of the intensity of exercises. Lower limb muscle fatigue is associated with significant impairment of postural stability in FMS patients. Therefore, it seems important to take into account muscle fatigue to avoid balance problems. Preventing vigorous exercise which may aggravate preexisting balance issues is important in reducing the risk of falls and improving adherence to exercise programs in FMS patients. It seems possible that planning exercise programs with this perspective could make important clinical contributions in patients with FMS.

References

1. Mease PJ, Clauw DJ, Arnold LM, Goldenberg DL, Witter J, Williams DA, Simon LS, Strand CV, Bramson C, Martin S, Wright TM, Littman B, Wernicke JF, Gendreau RM, Crofford LJ. Fibromyalgia syndrome. J Rheumatol 2005;32(11):2270-7.
2. Trevisan DC, Driusso P, Avila MA, Gramani-Say K, Moreira FMA, Parizotto NA. Static postural sway of women with and without fibromyalgia syndrome: A cross-sectional study. Clinical Biomechanics 2017;44:83-89.
3. Muto LHA, Sauer JF, Yuan SLK, Sousa A, Mango PC, Marques AP. Postural control and balance self-efficacy in women with fibromyalgia: are there differences? Eur J Phys Rehabil Med 2015;51(2):149-154.
4. Jones KD, King LA, Mist SD, Bennett RM, Horak FB. Postural control deficits in people with fibromyalgia: a pilot study. Arthritis Research & Therapy 2011; 13(4):R127.
5. Vincent A, Benzo RP, Whipple MO, McAllister SJ, Erwin PJ, Saligan LN. Beyond pain in fibromyalgia: insights into the symptom of fatigue. Arthritis Research & Therapy 2013;15(6):221.
6. Dailey DL, Keffala VJ, Sluka KA. Do cognitive and physical fatigue tasks enhance pain, cognitive fatigue, and physical fatigue in people with fibromyalgia? Arthritis Care & Research 2015;67(2):288-296.
7. Dal U, Cimen OB, Incel NA, Adim M, Dag F, Erdogan AT, et al. Fibromyalgia syndrome patients optimize the oxygen cost of walking by preferring a lower walking speed. Journal of Musculoskeletal Pain 2011;19(4):212-217.
8. Bachasson D, Guinot M, Wuyam B, Favre-Juvin A, Millet GY, Levy P, et al. Neuromuscular fatigue and exercise capacity in fibromyalgia syndrome. Arthritis Care & Research 2013;65(3):432-440.
9. Heredia-Jimenez J, Latorre-Roman P, Santos-Campos M, Orantes-Gonzalez E, Soto-Hermoso VM. Spatio-temporal gait disorder and gait fatigue index in a six-minute walk test in women with fibromyalgia. Clinical Biomechanics 2016;33:1-6.
10. Bisson EJ, Remaud A, Boyas S, Lajoie Y, Bilodeau M. Effects of fatiguing isometric and isokinetic ankle exercises on postural control while standing on firm and compliant surfaces. Journal of NeuroEngineering and Rehabilitation 2012;9:39.
11. Karagiannopoulos C, Watson J, Kahan S, Lawler D. The effect of muscle fatigue on wrist joint position sense in healthy adults. J Hand Ther 2020;33(3):329-338.
12. Peng B, Yang L, Li Y, Liu T, Liu Y. Cervical proprioception impairment in neck pain- Pathophysiology, clinical evaluation, and management: A Narrative Review. Pain Ther 2021;10(1):143-164.
13. Ediz L, Hiz O, Toprak M, Tekeoglu I, Ercan S. The validity and reliability of the Turkish version of the revised fibromyalgia impact questionnaire. Clin Rheumatol 2011;30(3):339-346.
14. Yıldırım Y, Ergin G. A validity and reliability study of the Turkish Multidimensional Assessment of Fatigue (MAF) scale in chronic musculoskeletal physical therapy patients. J Back Musculoskelet Rehabil 2013;26(3):307-316.
15. Ulus Y, Durmus D, Akyol Y, Terzi Y, Bilgici A, Kuru O. Reliability and validity of the Turkish version of the Falls Efficacy Scale International (FES-I) in community-dwelling older persons. Archives of Gerontology and Geriatrics 2012;54(3):429-433.
16. Collado-Mateo D, Domínguez-Muñoz FJ, Adsuar JC, Merellano-Navarro E, Olivares PR, Gusi N. Reliability of the timed up and go test in fibromyalgia. Rehabil Nurs 2018;43(1):35-39.
17. Barbieri FA, dos Santos PCR, Simieli L, Orcioli-Silva D, van Dieën JH, Gobbi LTB. İnteractions of age and leg muscle fatigue on unobstructed walking and obstacle crossing. Gait & Posture 2014;39:985-990.
18. Caffaro RG, França FJR, Burke TN, Magalhães MO, Ramos LAV, Marques AP. Postural control in individuals with and without non-spesific chronic low back pain: a preliminary case-control study. Eur Spine J 2014;23(4):807-813.
19. Akkaya N, Akkaya S, Atalay NS, Acar M, Catalbas N, Sahin F. Assessment of the relationship between postural stability and sleep quality in patients with fibromyalgia. Clin Rheumatol 2013;32(3):325-331.
20. Bolukbas Y, Celik B. Assessment of sleep quality in fibromyalgia syndrome and its effect on postural balance and functional status. J Back Musculoskelet Rehabil 2021;34(2):235-242.
21. Collado-Mateo D, Gallego-Diaz JM, Adsuar JC, Domínguez-Muñoz FJ, Olivares PR, Gusi N. Fear of falling in women with fibromyalgia and its relation with number of falls and balance performance. Biomed Res Int 2015:589014.
22. Góes SM, Leite N, Shay BL, Homann D, Stefanello JMF, Rodacki ALF. Functional capacity, muscle strength and falls in women with fibromyalgia. Clinical Biomechanics 2012;27(6):578-583.
23. Kapuczinski A, Soyfoo MS, De Breucker S, Margaux J. Assessment of sarcopenia in patients with fibromyalgia. Rheumatology International 2022;42(2):279-284.
24. Huijnen IPJ, Verbunt JA, Meeus M, Smeets RJEM. Energy expenditure during functional daily life performances in patients with fibromyalgia. Pain Practice 2015;15(8):748-756.

25. Bizid R, Margnes E, François Y, Jully JL, Gonzalez G, Dupui P, et al. Effects of knee and ankle muscle fatigue on postural control in the unipedal stance. Eur J Appl Physiol 2009;106(3):375-380.
26. Aron A, Powell J, Kim E, Gidu D, Jagger K, Paul A. The effect of localized upper extremity fatigue on balance in young and older adults. Physical & Occupational Therapy in Geriatrics 2020.
27. Nam HS, Park DS, Kim DH, Kang HJ, Lee DH, Lee SH, et al. The relationship between muscle fatigue and balance in the elderly. Ann Rehabil Med 2013;37(3):389-395.
28. Akyildiz C, Sözen H. The effects of lower extremity static muscle fatigue on balance components. Sport Sciences for Health 2022.
29. Pérez-de-HerediaTorres M, Huertas-Hoyas E, Martínez-Piédrola R, et al. Balance deficiencies in women with fibromyalgia assessed using computerised dynamic posturography: a cross-sectional study in Spain. BMJ Open 2017;7(7).