The relationship between balance disorder, brain tractography and volume measurements in fibromyalgia syndrome: a cross-sectional study

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Abstract

Objective

Balance disorder is one of the most common symptoms in patients with fibromyalgia syndrome (FM) and its prevalence ranges between 45% and 68%. Therefore, the aim of this study is to reveal the possible effects of FM on these structures by measuring the volumes of the VIII-X lobes and vermis of the cerebellum using bilateral tractography of the cerebellum's connections on brain MRI images of individuals with FM and healthy individuals.

Methods

The study consisted of 30 individuals with FM and 31 healthy individuals. All participants were female and aged between 18 and 65. All individuals in the groups underwent diffusion tensor imaging (DTI) of the brain. Tractography analysis was performed using the DSI Studio program, and volume analysis was performed using the VolBrain software program.

Results

In the study, it was determined that the fractional anisotropy (FA) value was lower in the FM group in the tractography analysis results of SCP, MCP, ICP, and vermis ($p<0.05$). In addition, it was found that the FM group had lower cerebellum VIII-X lobes and vermis volume in the volumetric analysis results ($p<0.05$).

Conclusion

In conclusion, this study suggests that the balance disorders observed in FM may be a result of lesions and volumetric atrophy occurring in central nervous system (CNS) structures. Furthermore, it indicates that the decrease in FA values observed in individuals with FM provides evidence that FM affects the CNS.

Key words
fibromyalgia syndrome, tractography, diffusion tensor imaging

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Background

Fibromyalgia syndrome (FM) is a chronic and multisystemic disease with an unexplained cause and is characterised by numerous psychosomatic symptoms such as widespread pain, fatigue, sleep disturbances, balance problems and psychological symptoms (1, 2). Although the pathophysiology of FM has not been fully elucidated, it is reported to be associated with hypersensitivity of the central nervous system (CNS) to pain signals (3). In the clinical picture, widespread pain, muscle spasms, headache and balance disorders are among the most common symptoms that significantly affect quality of life (4).

The global prevalence of FM is 2.7% and approximately 80–90% of those diagnosed are middle-aged women (5). Disabling FM symptoms include physical disabilities that make it difficult to carry out activities of daily living and reduce quality of life (6). The impact of these symptoms results in a high cost per diagnosed patient in developed countries and a related secondary socioeconomic burden represented by high levels of unemployment, early retirement and a greater number of sick leave days (6).

Balance impairment is one of the most common symptoms in patients with FM, with a prevalence ranging from 45-68%. Previous studies have shown that women with FM with impaired balance have a higher risk of loss of balance and falls than healthy individuals. In fact, 1.75 falls per person per six-month period have been reported in individuals with FM. These balance problems also negatively affect individuals' physical functioning, gait patterns and quality of life (7).

Achieving postural control requires the integration of afferent stimuli from the visual, vestibular, auditory and proprioceptive systems in the central nervous system and the generation of appropriate motor responses in line with this information (8, 9). Communication between these systems is provided through the white matter structures of the brain. White matter consists of lipid-rich axons surrounded by myelin sheaths, which provide fast and efficient information transmission between cortical and subcortical regions. The microstructural organisation of white matter, especially its properties such as myelination and axonal integrity, can be evaluated by diffusion tensor imaging (DTI) (10). The DTI method provides information about the structural integrity and microstructural properties of white matter through the diffusion orientation of water molecules in the tissue (10).

In this context, it is thought that balance disorders in individuals with FM may be due to faulty sensory input, abnormal sensorimotor integration and microstructural disruptions of central nervous system structures. It is hypothesised that these balance disorders may cause involvement of central nervous system (CNS) structures and consequently volumetric atrophy. The aim of our study was to determine the differences between the groups by comparing the total fibre counts, fractional anisotropy (FA), mean diffusity (MD), axial diffusion (AD) and radial diffusion (RD) values of these pathways with bilateral tractography of the superior cerebellar peduncle (SCP), middle cerebellar peduncle (MCP), inferior cerebellar peduncle (ICP) and vermis on brain MR images of individuals with FM and healthy individuals. In addition, the volumes of lobes VIII-X of the cerebellum and vermis of the groups were measured to reveal the possible effects of FM on these structures.

Methods

This study was a single-centre, prospective, cross-sectional case-control study conducted in the Physical Therapy and Rehabilitation Clinic of Kayseri Training and Research Hospital in accordance with the ethical principles of the Declaration of Helsinki. Informed consent was obtained from all participants. Our study was approved by Niğde Ömer Halisdemir University Non-Interventional Clinical Research Ethics Committee with protocol number 2023/72.

Determination of sample size and study groups

The sample size was determined using the G*Power 3.1.9.6 program. With

Fig. 1. Examination of balance and proprioception senses with HUR SmartBalance balance device.

an effect size of 0.80, 80% Power and 5% Type I error, it was calculated that at least 26 individuals in individuals with FM and control group individuals would be included in the study. In this context, 61 individuals (30 with FM and 31 asymptomatic controls) who underwent MR imaging between November 2023 and December 2023 and met the inclusion criteria, were included in the study. Since FM is significantly higher in women, only female individuals were included in our study.

Inclusion criteria:

- Having a diagnosis of fibromyalgia according to the American College of Rheumatology (ACR) 2016 diagnostic criteria.
- Having recently been diagnosed with FM.
- Being between the ages of 18-65.
- Being of the female gender.

Exclusion criteria:

- Having chronic systemic diseases
- Having inflammatory rheumatoid diseases (rheumatoid arthritis, ankylosing spondylitis, systemic lupus erythematosus, etc.).
- Having a history of malignancy.
- Having psychiatric disorders such as depression or schizophrenia.
- Having a history of autoimmune disorder.
- Regular or excessive alcohol consumption.

Assessment of balance and proprioception senses

The balance and proprioception senses of the participants were assessed with the HUR SmartBalance (HUR International, Finland) (Fig. 1). During the measurement, the sway area (cm^2), sway velocity (cm/s) and Romberg coefficient values were recorded in the following conditions: eyes open-stable ground, eyes closed-stable ground, eyes open-unstable ground and eyes closed-unstable ground.

Assessment of subjective balance perception

Participants' personal perceptions of their balance performance were determined with the Activity Specific Balance Confidence Scale (ABC). This scale, developed by Powell and Myers, includes 16 questions related to indoor and outdoor activities of daily living to measure balance confidence in individuals with various levels of functionality. Scores range from 0 (no confidence) to 10 (full confidence) for each question item. Higher scores indicate greater confidence (11).

Radiological imaging and analysis methods

Tractography analysis. Tractography of the targeted pathway from brain diffusion MR images was performed in the DSI Studio program downloaded from http://dsi-studio.labsolver.org/. Before starting the tractography process, in the "Fiber tracking" tab, "Threshold" was set to 0.20, "Angular Threshold" to 70 degrees, 'Smoothing' to 0.50, the shortest tract to 10 mm, the longest tract to 1000 mm, and "terminateif" to 100000 fibres. Specifically, bilateral tractography of the superior cerebellar peduncle (SCP), middle cerebellar peduncle (MCP), inferior cerebellar peduncle (ICP) and vermis and total fibre counts of these pathways, fractional anisotropy (FA), mean diffusity (MD), axial diffusivity (AD) and radial diffusivity (RD) values (Fig. 2) (12).

Volume analysis. Volumetric analysis was performed using the VolBrain software program using DTI data in DICOM format. The volumes of lobes VIII-X of the cerebellum and vermis were calculated with this program.

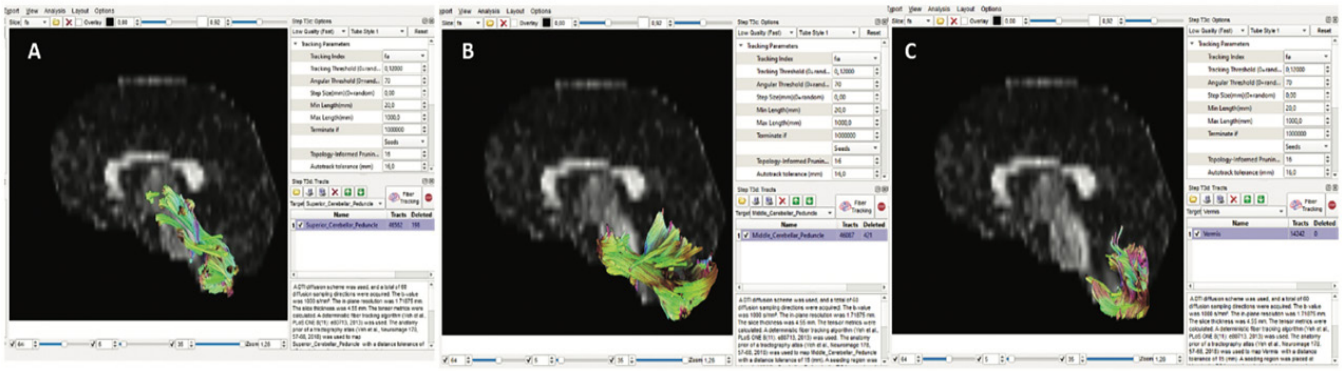

Fig. 2. Tractography analysis of cerebellar connections. **A**. Superior cerebellar peduncle. **B**. Middle cerebellar peduncle; **C**. Vermis.

Statistical analysis

Whether the numerical variables were suitable for normal distribution was evaluated by Shapiro Wilk test. For the numerical variables with normal distribution, they were summarised as Mean ± standard deviation and independent samples T test, which is one of the parametric tests, was used for comparisons between two groups. Statistical analyses of this study were performed with IBM SPSS version 22.0 (SPSS, Inc., Chicago, IL, USA). $p<0.05$ was accepted as statistical significance level.

Results

The age and body mass index (BMI) of the individuals participating in the study showed that the FM and control groups were similar ($p>0.05$). However, in terms of pain levels evaluated with visual analogue scale (VAS), it was determined that the FMS group had higher pain levels ($p<0.001$) (Table I).

The data obtained from the HUR SmartBalance balance device showed that the balance parameters of individuals with FM were statistically significantly worse. Stable and unstable ground sway area values were found to be higher in the FMS group both with eyes open and eyes closed ($p<0.05$) (Fig. 3). In addition, according to the ABC balance confidence scale data, the FM group had a lower balance confidence ($p=0.001$) (Table II).

When the results of tractography analysis were examined, it was found that the total fibre number of SCP was lower in the FM group compared to the control group ($p=0.001$). However, the fibre counts of MCP, ICP-R, ICP-L and vermis were similar between both groups ($p>0.05$). The FA values of MCP, ICP-R, ICP-L and vermis were lower in the FM group ($p<0.05$), while the FA value of SCP was similar between both groups ($p>0.05$) (Table III).

According to the volume analysis results, it was determined that the volumes of the VIII-X lobes of the cerebellum and vermis were lower in the FM group compared to the control group ($p<0.05$) (Table IV).

Additionally, the relationship between VAS, WPI, and SSS scores and neuroimaging and balance test findings is shown in Table V: no significant linear relationship was found between VAS, WPI and SSS scores and neuroimaging and balance test findings ($p>0.05$) (Table V).

The relationship between balance test results and neuroimaging findings is shown in Table VI: there was no significant linear relationship between balance and neuroimaging parameters ($p>0.05$) (Table VI).

Table I. Demographic data and clinical characteristics of the participants.

Parameter	FM (n=30) Mean ± SD	Control (n=31) Mean ± SD	*p*
Age (years)	46.80 ± 8.01	43.67 ± 10.12	0.856
Body mass index (kg/m²)	28.22 ± 3.99	26.43 ± 4.07	0.457
VAS (Pain)	7.43 ± 2.11	4.26 ± 2.70	**<0.001**

SD: standard deviation; VAS: visual analogue scale.

Table II. Comparison of balance between groups.

Parameters	FM (n=30) Mean ± SD	Control (n=31) Mean ± SD	*p*
Sway area (open eye - stable)	322.32 ± 19.78	289.71 ± 241.41	**0.043**
Sway area (open close - stable)	399.12 ± 301.07	315.15 ± 246.13	**0.037**
Sway area (open eye - unstable)	593.46 ± 395.62	432.98 ± 221.20	**0.048**
Sway area (open close - unstable)	886.66 ± 687.97	583.03 ± 324.69	**0.034**
ABC Balance Confidence Scale	120.60 ± 34.00	145.40 ± 21.80	**0.001**

SD: standard deviation.

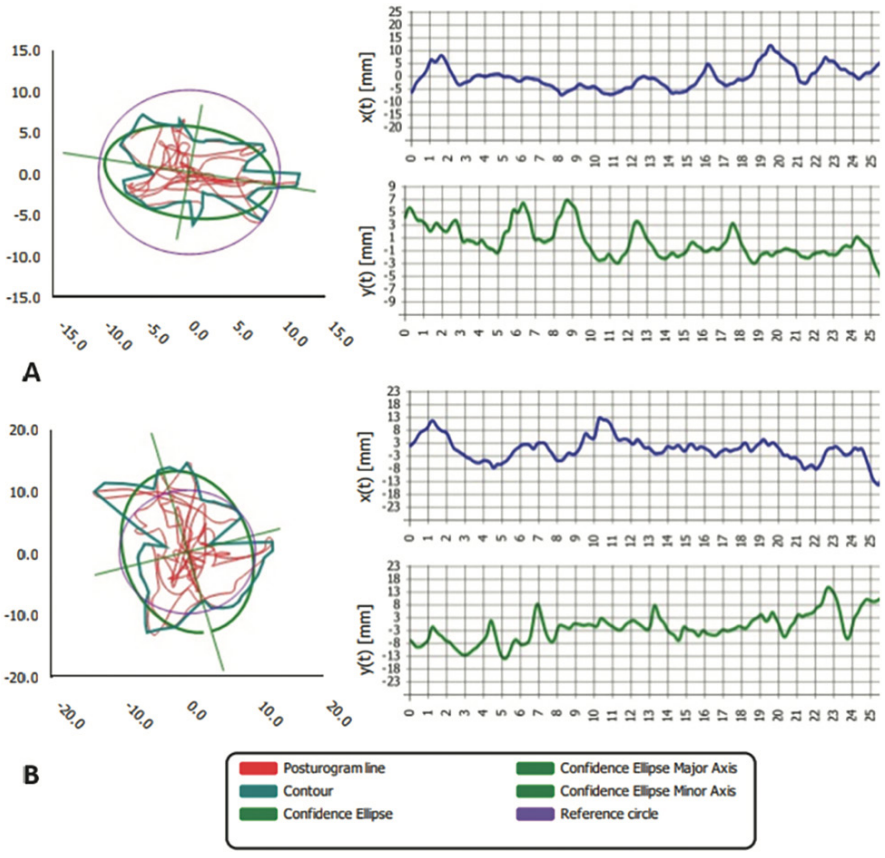

Fig. 3. Balance results of the groups on unstable ground with eyes open. **A**. Control group. **B**. FM group).

Discussion

This study was conducted to evaluate whether the balance disorders seen in

Table III. Comparison of the data obtained as a result of tractography analysis.

Parameters		FMS (n=30) Mean ± SD	Control (n=31) Mean ± SD	*p*
SCP	Number of fibres	59393.97±23965.30	78222.58 ± 22577.95	**0.001**
	FA	0.39 ± 0.03	0.40 ± 0.02	0.554
	MD	1.23 ± 0.09	1.25 ± 0.14	0.485
	AD	1.71 ± 0.09	1.72 ± 0.10	0.791
	RD	0.99 ± 0.09	0.98 ± 0.08	0.891
MCP	Number of fibres	41159.17 ± 12946.02	44832.97 ± 11244.01	0.241
	FA	0.42 ± 0.02	0.43 ± 0.01	**0.042**
	MD	0.90 ± 0.10	0.91 ± 0.09	0.877
	AD	1.33 ± 0.12	1.33 ± 0.11	0.965
	RD	0.69 ± 0.09	0.70 ± 0.08	0.863
ICP-R	Number of fibres	43016.40 ± 14188.90	43986.39 ± 15858.99	0.802
	FA	0.39 ± 0.02	0.41 ± 0.02	**0.033**
	MD	0.92 ± 0.05	0.92 ± 0.05	0.789
	MD	1.30 ± 0.05	1.31 ± 0.06	0.619
	RD	0.73 ± 0.05	0.73 ± 0.04	0.839
ICP-L	Number of fibres	31187.53 ± 12719.26	33743.13 ± 12237.72	0.653
	FA	0.39 ± 0.02	0.41 ± 0.11	**0.040**
	MD	0.91 ± 0.06	0.92 ± 0.06	0.691
	AD	1.30 ± 0.06	1.31 ± 0.08	0.812
	RD	0.71 ± 0.06	0.72 ± 0.06	0.663
Vermis	Number of fibres	11394.73 ± 2033.37	12142.00 ± 2631.29	0.151
	FA	0.22 ± 0.01	0.23 ± 0.01	**0.041**
	MD	0.81 ± 0.03	0.80 ± 0.03	0.924
	AD	0.99 ± 0.04	0.98 ± 0.03	0.860
	RD	0.71 ± 0.04	0.71±0.03	0.725

SCP: superior cerebellar peduncle; MCP: middle cerebellar peduncle; ICP-R: inferior cerebellar peduncle-right; ICP-L: inferior cerebellar peduncle-left; FA: fractional anisotropy; MD: mean diffusity; AD: axial diffusivity; RD: radial diffusivity; SD: standard deviation.

Table IV. Comparison of data obtained from volume analysis.

Parameters	FM (n=30) Mean ± SD	Control (n=31) Mean ± SD	*p*
Cerebellum VIII-X lobes (cm^3)	2.55 ± 0.30	2.65 ± 0.26	**0.017**
Vermis (cm^3)	8.52 ± 0.90	10.56 ± 0.80	**0.031**

SD: standard deviation.

female subjects with FM are related to microstructural changes in the balance-related structures of the central nervous system. When the balance data, proprioceptive assessments, tractography and volume measurement results were analysed as a whole, it was found that balance performance was significantly impaired in the FM group, microstructural integrity of some cerebellar tracts was decreased, and volumetric losses occurred in certain regions of the cerebellum. Our data support the motor coordination and balance problems previously reported in the literature regarding FM (7).

Balance is one of the most critical functions that support normal activities of daily life in humans. Maintaining balance requires a complex integration and coordination of multiple systems in the body (such as the vestibular system, visual system and auditory system) (13). The cerebellum is strongly involved in the integration process associated with balance in the central nervous system (14), as demonstrated by previous functional magnetic resonance (FMR) imaging studies and clinical trials (15, 16).

Injury and degeneration of the cerebellum is of great importance in the underlying neuropathology of postural disorders in traumatic brain injury (TBI) patients. In particular, the cerebellum has been shown to play an important role in the neural control of postural control (17, 18). Other structures critical for the control of postural balance are located in the brain stem (Truncus encephali). Vestibular nuclei and pontine nuclei receive sensorimotor information and transmit it to the cerebellum via the cerebellar peduncles (19).

Some evidence from studies in TBI patients suggests that postural control deficits in TBI are associated with damage to the cerebellum and truncus encephali structures. Diffusion MRI studies in TBI patients have reported that the cerebellar white matter and peduncles have lower FA values. This has been shown to be significantly associated with impaired postural control in TBI patients (20).

SCP, MCP and ICP function as the primary site of sensory integration due to white matter connections that transmit multisensory information to the cerebellum and transmit motor corrections regulated by the cerebellum to regions within the CNS (21). Unconscious proprioceptive information conveying the position of the lower extremities passes through the posterior spinocerebellar tract to the spinal cord, reaches the nucleus fastigium in the vermis via the ICP, which sends projections to the brainstem and modifies the output of upper motor neuron pathways affecting postural muscle activity (22). Visual-spatial information from the retina is processed in the primary visual cortex and transmitted to the posterior parietal cortex. Ultimately, it reaches the deep cerebellar nuclei via cortico-pontocerebellar projections through the MCP. The MCP reflects this visual information to both the vestibular and reticular nuclei, reaching the nucleus fastigium via the reticulospinal and vestibulospinal pathways, which influence postural muscle activity. Vestibular information from the inner ear is transmitted to the nuc. fastigi via the ICP and integrated with neck proprioceptive information to create a sense of the direction of gravity (23). Studies in the literature indicate that damage to the cerebellum and its connections is associated with balance disorders such as increased postural sway, slow departure from an upright posture, ataxia, and hypermetric postural responses to disturbances. In this study, it was found that the total number of SCP fibres in the FM group was lower than in the control group. Additionally, lower FA values were observed in the vermis, MCP, and ICP in

Table V. The relationship between VAS, WPI, and SSS scores and balance test results and neuroimaging results in individuals with FM.

Parameters		VAS	WPI	SSS
SCP number of fibres	r	-0.043	0.165	-0.056
	p	0.821	0.384	0.768
	N	30	30	30
SCP FA	r	-0.040	0.300	-0.228
	p	0.833	0.108	0.226
	N	30	30	30
MCP number of fibres	r	0.027	0.017	-0.098
	p	0.887	0.927	0.606
	N	30	30	30
MCP FA	r	0.042	-0.175	0.009
	p	0.826	0.354	0.964
	N	30	30	30
ICP-R number of fibres	r	-0.040	0.035	0.022
	p	0.833	0.855	0.906
	N	30	30	30
ICP-R FA	r	0.016	0.225	0.013
	p	0.931	0.231	0.944
	N	30	30	30
ICP-L number of fibres	r	-0.274	-0.059	-0.076
	p	0.143	0.758	0.688
	N	30	30	30
ICP-L FA	r	-0.120	0.023	-0.124
	p	0.526	0.905	0.515
	N	30	30	30
Vermis number of fibres	r	-0.231	0.081	-0.151
	p	0.219	0.670	0.426
	N	30	30	30
Vermis FA	r	0.010	0.150	-0.149
	p	0.959	0.430	0.430
	N	30	30	30
Vermis volume (cm^3)	r	-0.215	-0.184	-0.100
	p	0.254	0.330	0.598
	N	30	30	30
Cerebellum VIII-X lobes volume (cm^3)	r	-0.230	-0.234	-0.061
	p	0.221	0.212	0.749
	N	30	30	30
Sway area (open eye - stable)	r	0.151	0.028	0.091
	p	0.425	0.883	0.634
	N	30	30	30
Sway area (open close - stable)	r	0.161	0.017	-0.024
	p	0.394	0.930	0.898
	N	30	30	30
Sway area (open eye - unstable)	r	0.427*	-0.047	0.176
	p	0.079	0.806	0.352
	N	30	30	30
Sway area (open close - unstable)	r	0.133	0.268	0.150
	p	0.484	0.152	0.430
	N	30	30	30
ABC Balance Confidence Scale	r	-0.256	0.113	-0.081
	p	0.512	0.551	0.669
	N	30	30	30

SCP: superior cerebellar peduncle; MCP: middle cerebellar peduncle; ICP-R: inferior cerebellar peduncle-right; ICP-L: inferior cerebellar peduncle-left; FA: fractional anisotropy; VAS: visual analogue scale; r: correlation coefficient; WPI: widespread pain index; SSS: Symptom Severity Scale.

the FM group compared to the control group. This suggests that the myelin sheath integrity of pathways carrying unconscious proprioception and balance sensations may be impaired in the FM group.

Visual-spatial information from the retina is processed in the primary visual cortex and transmitted to the posterior parietal cortex. Ultimately, it reaches the deep cerebellar nuclei via corticopontocerebellar projections through the MCP. The MCP reflects this visual information to both the vestibular and reticular nuclei and reaches the fastigial nucleus via the reticulospinal and vestibulospinal pathways, which affect postural muscle activity (23). This information shows that visual-spatial information from the retina affects postural muscle activity and is an important factor for balance. In this study, it was observed that balance impairment did not improve even when the eyes were open in the FM group. This may be due to a lesion in the MCP, which carries information from the retina to the relevant centers. This supports the most important finding of this study, which is that lesions in the CNS cause balance impairment in FM.

The cerebellum contains three functional areas that play a vital role in maintaining balance and motor control: the cerebello-cerebellum, spinocerebellum and vestibulocerebellum. In the spinocerebellum, the cerebellar vermis plays an important role in balance and motor control. Recent findings indicate that the vermis provides information about different stimuli related to proprioceptive sensations from the extremities, balance, visual, and auditory processes. This demonstrates that the cerebellar vermis is critical for maintaining balance, speaking, and coordinating eye and body movements (24). Additionally, the cerebellar vermis participates in anticipatory postural adjustments and compensatory postural adjustments to maintain balance during functional activities (25). Studies have shown that patients with lesions in the vermis predominantly exhibit balance disorders (26), while patients with lesions in the cerebellar hemispheres predominantly exhibit global coordination

Table VI. The relationship between balance test results and neuroimaging results in individuals with FM.

		Sway area (open eye - stable)	Sway area (open close - stable)	Sway area (open eye - unstable)	Sway area (open close - unstable)
SCP number of fibres	r	0.109	0.028	0.173	0.014
	p	0.566	0.883	0.361	0.940
	N	30	30	30	30
SCP FA	r	-0.016	-0.024	-0.108	-0.049
	p	0.933	0.900	0.571	0.798
	N	30	30	30	30
MCP number of fibres	r	-0.174	-0.095	-0.218	-0.159
	p	0.357	0.617	0.246	0.402
	N	30	30	30	30
MCP FA	r	0.117	0.128	0.063	0.180
	p	0.538	0.501	0.740	0.342
	N	30	30	30	30
ICP-R number of fibres	r	0.007	0.137	-0.035	0.063
	p	0.969	0.472	0.856	0.740
	N	30	30	30	30
ICP-R FA	r	0.153	0.297	0.155	0.157
	p	0.421	0.111	0.414	0.408
	N	30	30	30	30
ICP-L number of fibres	r	-0.265	-0.220	-0.328	-0.182
	p	0.157	0.244	0.077	0.335
	N	30	30	30	30
ICP-L FA	r	-0.015	0.023	-0.110	0.119
	p	0.937	0.902	0.563	0.531
	N	30	30	30	30
Vermis number of fibres	r	-0.008	-0.147	-0.140	-0.092
	p	0.967	0.439	0.462	0.628
	N	30	30	30	30
Vermis FA	r	-0.072	0.016	-0.068	0.073
	p	0.705	0.935	0.719	0.703
	N	30	30	30	30
Vermis volume (cm^3)	r	0.101	0.069	-0.170	0.062
	p	0.594	0.717	0.368	0.744
	N	30	30	30	30
Cerebellum VIII-X lobes volume (cm^3)	r	-0.148	-0.171	-0.352	-0.179
	p	0.436	0.365	0.057	0.343
	N	30	30	30	30

SCP: superior cerebellar peduncle; MCP: middle cerebellar peduncle; ICP-R: inferior cerebellar peduncle-right; ICP-L: inferior cerebellar peduncle-left; FA: fractional anisotropy; r: correlation coefficient.

disorders (27, 28). Our study demonstrates impaired balance in individuals with FMS based on balance confidence test data and balance device measurement results. Additionally, in our study, vermian tract structure and volumetric measurement analyses were performed on participants' MRI images. The data obtained showed that the number of fibres in the vermis was similar between the FM group and the control group, but there was a decrease in the FA value of the vermis tracts in the FM group. According to the volumetric measurement data, the volume of the vermis was found to be lower in the FM group. These data support the notion that the vermis plays an important role in balance, as described in the literature, and indicate that individuals with FM have CNS involvement related to balance.

It has been reported that the IX and X lobes (uvula and nodulus) belonging to the vermis of the cerebellum and the X lobe (flocculus) belonging to the hemisferium cerebelli represent balance in three dimensions. In this context, it has been reported that these lobes play an important role in the regulation and maintenance of balance and visual adaptation (29). In this study, volumetric measurements of the VIII-X lobes of the cerebellum were performed. It was found that the volume of the VIII-X lobes of the cerebellum was smaller in individuals with FMS. These data support the notion that the cerebellum has an important function in balance, as described in the literature, and indicate that volumetric atrophy occurs in CNS structures related to balance in individuals with FM.

Limitations

The first limitation of the present study is that the potential impact of participants' educational or socioeconomic differences on the results must be noted. These factors have been reported to be associated with FM (30). Second, considering that FM affects women more than men, only female subjects were included in our study. Therefore, clinical inferences may be misleading when applied to male patients. Another limitation of the study is that the medication use status of the participants due to existing illnesses or other reasons was not investigated. Therefore, the results should be interpreted with caution.

Conclusion

The relationship between FM and balance disorders is an important area of research for understanding the pathophysiology of this syndrome and improving the quality of life of individuals with FM. This study, which includes data obtained from participants' self-assessments and brain MRI images, shows that balance disorders occur in individuals with FM. Consequently, it suggests that balance disorders occurring in FM may be a result of CNS involvement and volumetric atrophy. Furthermore, the decrease in FA values in individuals with FM provides clues that FM may affect CNS structures. Future studies with larger sample sizes are needed to investigate the relationship between FM and balance disorders. Furthermore, studies evaluating the effects of FM treatments on balance disorders should also be conducted.

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