Baltic Journal of Health and Physical Activity

Volume 14 | Issue 4 Article 2

2022

Assessment of posture, spinal mobility and EMG data in patients with spinal stenosis

Ahu ZILELI
Ministry of Health, Bilecik State Hospital, Bilecik, Turkey

Tamer ÇANKAYA
Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Bolu Abant Izzet Baysal University, Bolu, Turkey, tamercankaya@hotmail.com

Recommended Citation

Zileli A, Cankaya T. Assessment of posture, spinal mobility and EMG data in patients with spinal stenosis. Balt J Health Phys Act. 2022;14(4):Article2. https://doi.org/10.29359/BJHPA.14.4.02

Assessment of posture, spinal mobility and EMG data in patients with spinal stenosis

Abstract

Introduction: This study aims to analyze the difference in muscle activation, posture and vertebral mobility values between healthy individuals and patients with lumbar spinal stenosis. Material and Methods: This study involved 48 lumbar spinal stenosis (LSS) patients of the average age of 55.19 ± 10.41 years and 48 healthy individuals with of the average age of 58.15 ± 8.44 years. Posture and spinal mobility of the participants were measured in the standing position, and the maximum flexion posture with spinal mouse. Muscle activation of rectus femoris, biceps femoris, tibialis anterior and medial head of the gastrocnemius muscle was measured during the maximum voluntary contraction and gait with a surface electromyography device (sEMG). Results: Maximum trunk flexion, standing segmental posture and mobility were similar in both groups ($p > 0.05$). On the other hand, a significant difference was found in general mobility scores ($p < 0.05$), and a statistically significant difference was found in muscle activation parameters ($p < 0.05$) in both groups. Conclusions: When the LSS and the healthy groups were compared, it was found that segmental posture and spinal mobility were similar in both groups; muscular activity was lower in the healthy group, and total vertebral mobility was lower in the LSS group.

Keywords

pain, lower back, muscle activation, posture, lumbar spinal stenosis

Baltic Journal
of Health and Physical Activity
e-ISSN 2080-9999

Article

Assessment of posture, spinal mobility and EMG data in patients with spinal stenosis

Ahu ZILELI[1], Tamer ÇANKAYA[2]*

[1] Ministry of Health, Bilecik State Hospital, Bilecik, Turkey,
ORCID 0000-0002-9374-1371
[2] Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Bolu Abant Izzet Baysal University, Bolu, Turkey
ORCID 0000-0002-0871-2470

* Correspondence: Tamer Çankaya, PhD, Asst. Prof. Bolu Abant Izzet Baysal University, Health Sciences Faculty, Department of Physiotherapy and Rehabilitation, Gölköy/Bolu, Turkey, 14030;
e-mail: tamercankaya@hotmail.com

Abstract: Introduction: This study aims to analyze the difference in muscle activation, posture and vertebral mobility values between healthy individuals and patients with lumbar spinal stenosis. Material and Methods: This study involved 48 lumbar spinal stenosis (LSS) patients of the average age of 55.19 ± 10.41 years and 48 healthy individuals with of the average age of 58.15 ± 8.44 years. Posture and spinal mobility of the participants were measured in the standing position, and the maximum flexion posture with spinal mouse. Muscle activation of rectus femoris, biceps femoris, tibialis anterior and medial head of the gastrocnemius muscle was measured during the maximum voluntary contraction and gait with a surface electromyography device (sEMG). Results: Maximum trunk flexion, standing segmental posture and mobility were similar in both groups ($p > 0.05$). On the other hand, a significant difference was found in general mobility scores ($p < 0.05$), and a statistically significant difference was found in muscle activation parameters ($p < 0.05$) in both groups. Conclusions: When the LSS and the healthy groups were compared, it was found that segmental posture and spinal mobility were similar in both groups; muscular activity was lower in the healthy group, and total vertebral mobility was lower in the LSS group.

Keywords: pain, lower back, muscle activation, posture, lumbar spinal stenosis.

Citation: Zileli A, Cankaya T. Assessment of posture, spinal mobility and EMG data in patients with spinal stenosis. Balt J Health Phys Act. 2022;14(4):Article2. https://doi.org/10.29359/BJHPA.14.4.02

Academic Editor:
Agnieszka Maciejewska-Skrendo

Received: July 2021
Accepted: December 2021
Published: December 2022

Publisher's Note: BJHPA stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

Lumbar spinal stenosis (LSS) is characterized with the stenosis of the lumbar spinal canal, the nerve root canal or intervertebral foramen in any way [1]. Lumbar canal anatomical stenosis was primarily defined by Eisenstein [2]. LSS is a gradually progressing degenerative case generally affecting geriatric individuals and causing important functional disabilities [3]. LSS is one of the frequent reasons for spinal interventions [4].

LSS is prevalent among men over 50 years old. It mainly causes lower back and leg pain, a significant loss in gait capacity, numbness, and anesthesia [5]. LSS prevalence increases among people working in jobs with heavy physical demand and among people who live in rural areas. The condition of the spine as a result of ageing is another factor which causes a massive and dramatic burden in terms of financial costs and healthcare system [6]. Higher surgery prices are the major factor that increases the cost. Considering these, prevention of LSS and its progression comes into prominence. Especially, physiotherapy in the prevention of LSS becomes more important. The quality of assessment to create an efficient and correct treatment protocol has come into question in many studies related to the range of motion (ROM) of the vertebral column in the last 30 years. Most preferred methods are radiological analyses by computerized tomography (CT), plain and

two pole radiography. Due to the high rate of radiation, the use of these techniques is limited. For this reason, many non-invasive methods have been developed: goniometers, skin markers, inclinometers, spondilometers, measurement of posterior surface inclination and optoelectronic measurement and computer supported systems. Currently, non-invasive methods for spinal ROM are commonly used, as they are inexpensive and easy to perform [7].

Surface electromyography (sEMG) is suggested to assess localized muscle fatigue while searching for objective diagnosis in LSS [8]. sEMG is used for measuring and recording the active skeletal muscle fiber action potential. sEMG data gives assumptions about the muscle force, movement, and arousal areas. The most used areas of sEMG are kinesiology, biomechanics, sport sciences and neurophysiology [9].

Nowadays, methods which are technologically supported and characterized with more detailed results are added to conventional methods. Some of these are spinal mouse for postural assessment and sEMG for muscle activation assessment. The use of these methods in LSS is not common. For this reason, the aim of the present study is to assess posture, spinal mobility, and muscle activity of the patients with LSS by using sEMG and spinal mouse. In addition, this study also aims to compare the muscle activation and postural difference between healthy individuals and patients with LSS.

2. Materials and Methods

This study was conducted according to the principles of the Declaration of Helsinki. Ethical approval was obtained from Bolu Abant Izzet Baysal University Clinical Researches and Ethical Board (09.08.2018-2018/247).

2.1. Participants

According to the post-hoc power analysis, when the gastrocnemius medialis sEMG assessment was performed with 48 participants per group, the effect size was 0.69, and when $\alpha < 0.05$ was taken, the power of the study was 92%.

The control group consisted of healthy volunteer individuals who had no disorder related to the lower back region. Individuals diagnosed with LSS, independently standing and walking, were included to the LSS group. Individuals who had/were severe neurologic diseases, pregnant, chronic lung or heart disease, tumor in the lumbar, thoracic, cervical, or sacral region, vertebral fracture, or the history of lumbar operation in the previous year were excluded from the study. 58 patients diagnosed with LSS and 57 healthy individuals who applied to the neurosurgery clinic in Bilecik State Hospital were interviewed. During the interviews, it was found that 5 of the individuals from the LSS group and 5 of the individuals from the healthy group did not fit the inclusion criteria. Three of the individuals from LSS group and 3 of the individuals from healthy group withdrew from the study before the measurements were completed. Two of the individuals from the LSS group and 2 of the individuals from the control group were excluded from the study as sEMG signals were not appropriate. The study was completed with 48 patients from the LSS group and 48 individuals from the control group.

Age (year), body height (cm), body weight (kg), marital status, dominant hand, diagnosis, occupation, educational status, pre-existing disease, and surgical history of the participants were obtained through face-to-face interviews.

2.2. Measurements

2.2.1. Postural Assessment

Idiag Spinal Mouse device was used for postural assessment of the participants. Participants were asked to take off their clothes, stand barefoot symmetrically and bearing equal weight on their feet as possibly as they could. While a participant was standing, spinal processes of the C7-S3 were marked with a marker by the researcher. The spinal mouse

moved downward over the spinal process points. The measurement was taken from the individuals in two positions, consecutively. The first measurement was performed in the standing position. The patient distributed his/her bodyweight equally on both feet and was standing with feet about hip-width apart. Meanwhile, the knees were straight. They allowed their arms to hang relaxed at the sides of the body and they adopted their habitual posture. Finally, the patient was asked to look straight ahead. Participants were asked to maximally bend their lower back (lumbar flexion) for the second measurement. Keeping the knees and legs straight, the upper body was bent forward and downwards as much as possible. During this time, the patient should allow their head and arms to hang freely and adopt their habitual posture. Prior to the measurement, application was explained practically to the participants [7]. One measurement was taken in each position. In order to prevent distraction of the participants and the researcher, measurements were taken in a silent and well-lit place. Measurements were obtained in early hours of the day to prevent the difference in positions caused by fatigue, stress, and psychological factors. Data gathered from the spinal mouse were analyzed, and angular variation between each vertebrae was calculated and noted as degree [11]. Related parameters in each position (thoracic curvature angle, lumbar curvature angle, sacrum-hip angle, inclination angle and distance) by the spinal mouse device were recorded via bluetooth on a computer and analyzed. After measuring with the spinal mouse device, the device gives values for posture and mobility over 100 points. A higher score means better posture or mobility.

2.2.2. sEMG Measurement

Muscle activation was measured with an electromyography device (Delsys, USA). This device consists of two parts: the central station and 4 wireless sensors. A sample rate of the amplifier is 2000 Hertz, the penetration band 20–450 Hertz, and the average soundproof rate >80 decibel. A computer station universal serial bus (USB) and a computer with 16 gigabyte memory and 2.59 gigahertz processor was used to transfer the incoming muscle signal. "Delsys EMG works Acquisition 4.5.0'' software was used for raw data analysis.

Before the measurement, the movement that was asked to be performed and the measurement positions were practically explained to the participants. The participants were asked to wear comfortable clothes that would not cause any obstacle to measurements. An application area was prepared before the electrode and sensors were placed. The measurement area was shaved and cleaned with spirituous cotton until the skin turned red to reduce skin resistance fully. In all measurements, silver-silver chloride (Ag-AgCl) single use bipolar sticky electrodes (Kendall Electrodes 57 mm x 34 mm) were used. Electrodes were placed parallel to the muscle fiber, and the distance between electrodes was 2 cm, which is proper to the SENIAM (surface electromyography for the non-invasive assessment of muscles), according to the literature [12].

Sensors were fixed to application area with Delsys sensor adhesive interface. Bilateral measurement was performed on all muscles. Synchronous measurement was made during gait in rectus femoris, biceps femoris, tibialis anterior and medial head of the gastrocnemius muscles. During recording, the computer screen was checked, and errors were corrected. As cell phone signals might adversely affect the recording, cell phones were kept away from the recording area.

2.2.3. Measurement Technique

Measurements were taken during the muscle function (gait) and MVC (maximum voluntary contraction). MVC measurements were obtained while applying 5 seconds maximal resistance to the individuals. MVC measures of all muscles were taken three times, the and maximal value was recorded in the MVC value.

In the function measurement, individuals were asked to walk a 10-m walking path with a speed that they wanted [13]. Before every trial, it was ensured that everybody started

walking with the same leg. Individuals walked every trial barefoot to eliminate the effect of shoes [14].

2.2.4. MVC and sEMG Measurement

For rectus femoris muscle activation measurement, individuals were positioned in a long sitting position by flexing the knee slightly, placing a pillow under the knee, and supporting the lower back. Electrodes were placed in the middle of the line that was drawn between the anterior superior iliac spine and the patella with 2 cm intervals where the muscle was the most swollen [12, 15]. Individuals were asked to extend their knees. Measurements were obtained while applying maximal resistance to the dorsum of the ankle [12].

For biceps femoris muscle activation measurement, individuals were placed in the prone position with their ankle out of the table. Electrodes were placed in the middle of the line that was drawn between the tuberositas ischium and the lateral epicondyle of the tibia where the muscle was the most swollen. [12, 16]. Individuals were asked to flex their knees. Measurements were obtained while applying maximal resistance in the extension direction [12].

Tibialis anterior muscle activation was measured while individuals were positioned in long sitting position by flexing the knee slightly, placing a pillow under the knee, and supporting the lower back. Electrodes were placed at one third of the line that was drawn between the distal end of the fibula and the medial malleolus where the muscle was the most swollen. Individuals were asked to dorsiflex their ankle and perform inversion [12, 17]. Measurements were taken while applying maximal resistance to the dorsum of the ankle in plantar flexion and the eversion direction [12].

Gastrocnemius muscle activation was measured while individuals were placed in the prone position with their ankle out of the table and a small pillow placed under the ankle. Electrodes were placed by palping the most swollen point of the muscle at medial. Individuals were asked to plantar flex their ankle [12, 18]. Measurements were obtained while applying maximal resistance in the dorsiflexion direction by holding the foot and the calcaneus [12].

2.2.5. Function sEMG Measurement

Individuals were asked to walk barefoot along a 10-m walking path at their natural pace for function measurement [13, 19]. The function data of the rectus femoris, biceps femoris, tibialis anterior and medial of the gastrocnemius muscle were recorded during the walk.

2.3. sEMG Signal Analysis

The duration between the third and the fifth second of the muscle contraction was taken into consideration in muscle contraction. Normalization of the EMG signals is usually carried out by dividing the duty-oriented EMG signals by the reference EMG value of the muscle. In function analysis, 10-second time was recorded prior to the muscle contraction in 10-m walking. After checking the signals visually, they were purified by 20-450 Hertz band-pass filter (sixth grade Butterworth), reducing the sample speed to 1000 Hz. Root mean square of the filtered signals were calculated in 0.1 s intervals. This value was recorded in volt and converted into microvolt (μV) with Microsoft Office Excel software [13, 14, 20]. MVC% value normalization process was calculated by using the MVC measurement value and the value measured during the function with the formula.

$$MVC\% = [\text{during function value } (\mu V) / \text{MVC value } (\mu V)] \times 100$$

2.4. Statistical Analysis

SPSS 22 package software (SPSS Inc., Chicago, IL, USA) was used for data analysis. Normal distribution of the data was determined with histogram, odd graphics, and Shapiro-Wilk tests. In cases where data distribution was normal, independent sample t test and chi square test were used to determine the difference between the control group and the LSS group.

In cases where the data distribution was not normal, the Mann-Whitney U test was used to determine the difference between the control group and the LSS group. Statistical significance value was taken as $p < 0.05$.

3. Results

This study was carried out with voluntary participation of 96 individuals aged 41–75 years. Physical characteristic of the individuals of the control group and the LSS group were compared and given in Table 1.

Table 1. Physical characteristics of the participants.

Variables	Group	n	Min	Max	$\bar{x} \pm sd$	*t*	*p*
Age (years)	Control	48	41	75	58.1 ± 8.4	-1.53	0.13
	LSS	48	39	78	55.2 ± 10.4		
Body height (m)	Control	48	150	186	159.0 ± 7.0	1.77	0.08
	LSS	48	145	181	161.8 ± 8.1		
Body weight (kg)	Control	48	45	110	74.7 ± 13.1	-0.15	0.88
	LSS	48	47	96	74.3 ± 10.4		
BMI (kg/m^2)	Control	48	20	45	29.5 ± 5.0	-1.13	0.26
	LSS	48	20	36	28.5 ± 3.9		

The participants' marital status, place of residence, occupation, education, smoking habits, chronic disease history was given in Table 2. Except for occupation, there is no statistically significant difference between the LSS and the control groups. In the control group, the number of workers was low, and the number of housewives was high ($p > 0.05$).

Table 2. Marital status, place of residence, occupation, education, smoking habit, chronic disease history of the participants.

		Group				*p*
		LSS		Control		
		n	%	n	%	
Marital status	Married	47	97.9	45	93.8	0.31
	Single	1	2.1	3	6.2	
Place of residence	Rural	6	12.5	8	16.7	0.38
	Town	16	33.3	10	20.8	
	City	26	54.2	30	62.5	
Occupation	Housewife	23	47.9	33	68.8	**0.04***
	Worker	14	29.2	4	8.3	
	Office employee	1	2.1	0	0	
	Retired	10	20.8	11	22.9	
Education	Primary school	30	62.5	39	81.2	0.16
	Junior high school	4	8.3	2	4.2	
	High school	9	18.8	6	12.5	
	University	5	10.4	1	2.1	
Smoking habit	Never smoked	29	60.4	30	62.5	0.36
	Smoked before	9	18.7	0	0	
	Daily use 15↓	7	14.6	7	14.6	
	Daily use 15 ↑	3	6.3	11	22.9	
Chronic disease history	None	30	62.5	26	54.2	0.63
	Hypertension	12	25	13	27.1	
	Diabetes	6	12.5	9	18.7	

Intergroup postural assessment data in the standing position (SP) was similar (Table 3). When the spinal mouse standing position (SP) measurement values of the LSS and control groups were compared, there was no statistically significant difference between the groups ($p > 0.05$).

Table 3. Spinal mouse standing position intergroup comparison.

SP	Control (n:48)		LSS (n:48)		*t*	*z*	*p*
	$\bar{x} \pm sd$	Med (Min – Max)	$\bar{x} \pm sd$	Med (Min – Max)			
T12–L1 (°)	-0.6±3.6	0(-7.0–7.0)	-0.1±3.2	0(-6.0–7.0)	0.72		0.48
L1–L2(°)	-2.9±3.7	-3(-10.0–5.0)	-3±3.5	-3(-10.0–5.0)	-0.14		0.89
L2–L3(°)	-6.0±4.8	-6.5(-17.0–9.0)	-4.7±4.4	-4(-14.0–5.0)	1.39		0.17
L3–L4(°)	-6.1±3.7	-6(-14.0–6.0)	-5.5±3.9	-5(-14.0–4.0)	0.80		0.43
L4–L5(°)	-7.4±4.8	-9(-17.0–7.0)	-6.4±4.6	-6(-17.0–6.0)	1.07		0.29
L5–S1(°)	-6.7±3.8	-6.5(-16.0–2.0)	-6.1±4.1	-7(-16.0–4.0)	0.86		0.39
S–H(°)	15.5±14.8	18(-8.0–86.0)	19.2±24.3	14.5(-9.0–96.0)		-0.47	0.64
Thoracic(°)	50.9±8.4	50(35.0–72.0)	45.6±16.1	47(2.0–72.0)		-1.56	0.12
Lumbar(°)	-29.9±16.3	-33(-54.0–24.0)	-25.2±16.4	-26(-58.0–21.0)		1.69	0.09
Inclination(°)	0.4±3.9	0.5(-11.0–9.0)	6.0±23.1	0.5(-7.0–97.0)		-0.14	0.87
Distance(mm)	462.3±41.0	464(335.0–565.0)	445.8±74.6	461.5(255.0–565.0)		-0.56	0.57

SP: Standing position, S–H: Sacrum–hip, n: Number of individuals, $\bar{x}$: Average, sd: Standard deviation, t: T test, z: Mann Whitney U test, p: Statistical significance.

Postural assessment data of both groups obtained in the maximum trunk flexion was similar. No significant difference was found in spinal mouse maximum trunk flexion of the groups (Table 4) ($p > 0.05$).

Table 4. Spinal mouse maximum trunk flexion data comparison.

MTF	Control (n:48)		LSS (n:48)		*t*	*z*	*p*
	$\bar{x} \pm sd$	Med (Min – Max)	$\bar{x} \pm sd$	Med (Min – Max)			
T12–L1(°)	3.8±2.9	4(-6.0–12.0)	3.5±3.5	4(-4.0–12.0)	-0.41		0.69
L1–L2(°)	3.0±4.0	4(-8.0–8.0)	3.2±3.0	3(-5.0–9.0)	0.26		0.79
L2–L3(°)	1.3±3.9	2(-7.0–11.0)	1.7±3.6	3(-6.0–11.0)	0.51		0.61
L3–L4(°)	2.44±4.0	3.5(-8.0–10.0)	2.0±4.4	2(-10.0–11.0)	-0.46		0.64
L4–L5(°)	-0.2±4.7	0(-15.0–10.0)	1.4±3.7	1(-8.0–12.0)	1.89		0.06
L5–S1(°)	0.6±4.8	0(-12.0–17.0)	0.2±4.6	0(-10.0–17.0)	-0.45		0.65
S–H(°)	56.1±12.6	55(22.0–96.0)	61.3±13.7	58(35.0–100.0)		-1.62	0.10
Thoracic(°)	56.8±12.2	59(11.0–86.0)	52.9±16.9	55.5(11.0–86.0)	-1.31		0.19
Lumbar(°)	9.1±16.6	9(-46.0–41.0)	10.7±13.9	11(-37.0–41.0)	-0.30		0.76
Inclination(°)	76.7±21.1	80(-10.0–113.0)	82.1±19.4	84(-6.0–116.0)		-1.50	0.14
Distance (mm)	499.7±43.8	493(413.0–602.0)	486.8±74.1	490(306.0–602.0)	-1.04		0.30

SP: Standing position, S–H: Sacrum–hip, n: Number of individuals, $\bar{x}$: Average, sd: Standard deviation, t: T test, z: Mann Whitney U test, p: Statistical significance.

A significant difference was found in mobility scores of spinal mouse general measurement values between groups ($p < 0.05$). There was no significant difference in the total and the posture values between groups (Table 5) ($p > 0.05$).

Table 5. Intergroup spinal mouse value difference

Variables	Control (n:48) $\bar{x} \pm$ sd	LSS (n:48) $\bar{x} \pm$ sd	*t*	*p*
Total (score)	46.6±16.2	42.4±14.3	-1.37	0.17
Posture (score)	48.7±17.8	46.3±17.6	-0.66	0.51
Mobility (score)	48.0±22.1	39.5±17.6	-2.08	0.04*

*n: Number of individuals, t: T test, p: Statistical significance, *statistical significance according to the t test $p < 0.05$.*

A comparison of the difference in the MVC% measurement values of the right and left rectus femoris, biceps femoris, medial part of the gastrocnemius and tibialis anterior muscles of the groups are given in Table 6. When the rectus femoris and biceps femoris, % MIC values of the LSS and control groups were compared, there was a statistically significant difference between the groups on both the right and the left side ($p = 0.01$, $p = 0.00$). When the LSS and control groups' medial gastrocnemius muscle and tibialis anterior % MIC measurement values were compared, there was a statistically significant difference between the groups on the right ($p = 0.01$, $p = 0.00$), while there was no statistically significant difference on the left side ($p = 0.08$, $p = 0.21$).

Table 6. Inter group rectus femoris, biceps femoris, medial gastrocnemius and tibialis anterior MVC % sEMG difference

		RIGHT				LEFT			
	Group	Min–Max	Median	z	p	Min–Max	Median	z	p
Rectus Femoris	LSS	27–55.2	37.2	-2.52	**0.01***	25–61.7	38.5	-2.52	**0.01***
	C	27–43.4	35.8			25–43.0	35.2		
Biceps Femoris	LSS	29.1–57.6	39.4	-3.32	**0.00***	29–55.2	39.2	-3.01	**0.00***
	C	28–44.8	35.0			27–46.9	35.7		
Medial Gastrocnemius	LSS	27–50	39.5	-2.68	**0.01***	32–50.2	41.6	1.78	0.08
	C	27–46.4	35.3			31–45.2	39.3		
Tibialis Anterior	LSS	27–52.8	41.2	3.96	**0.00****	30–51.3	40.6	-1.25	0.21
	C	27–42.1	38.4			30–47	39.8		

n: Number of individuals, z: Mann Whitney U test, p: Statistical significance,
** Statistical significance according to the Mann Whitney U test $p<0.05$, ** Statistical significance according to the t test $p<0.05$. LSS: Lumbar Spinal Stenosis Group, C: Control Group*

The difference between the right and the left rectus femoris, biceps femoris, medial gastrocnemius and tibialis anterior function yEMG (μV) measurement values of the groups is given in Table 7. When the function yEMG (μV) measurement values of the rectus femoris and medial gastrocnemius muscle of the LSS and control groups were compared, there was a statistically significant difference between the groups on the right ($p = 0.00$, $p = 0.02$) while there was a statistically significant difference between the groups ($p < 0.05$) and on the left ($p = 0.51$, $p = 0.20$) side. There was no significant difference

($p > 0.05$). When the biceps femoris function yEMG (μV) measurement values of the LSS and the control groups were compared, there was no statistically significant difference between the groups on both the right ($p = 0.56$) and the left ($p = 0.31$) side, while there was no statistically significant difference between the groups ($p > 0.05$), when the tibialis anterior function yEMG (μV) measurement values were compared. There was a significant difference ($p = 0.00$).

Table 7. Intergroup rectus femoris, biceps femoris, medial gastrocnemius and tibialis anterior function sEMG (μV) difference.

		RIGHT				LEFT			
	Group	Min–Max	Median	z	p	Min–Max	Median	z	p
Rectus Femoris	LSS	45–147	123.0	-4.06	**0.00***	41–154	115.5	-0.66	0.51
	C	109–152	135.5			97–163	116.0		
Biceps Femoris	LSS	31–102	76.0	-0.59	0.56	43–110	75.0	-1.02	0.31
	C	48–111	73.5			53–124	70.5		
Medial Gastrocnemius	LSS	35–110	73.5	-2.42	**0.02***	42–106	80.0	-1.28	0.20
	C	52–112	77.0			65–107	82.5		
Tibialis Anterior	LSS	31–167	134.5	-4.56	**0.00***	37–173	137.0	-4.26	**0.00***
	C	131–175	152			128–178	150.5		

n: Number of individuals, z: Mann Whitney U test, p: Statistical significance
** Statistical significance according to the Mann Whitney U test p<0.05. LSS: Lumbar Spinal Stenosis Group, C: Control Group*

4. Discussion

When healthy individuals and patients with LSS were compared, healthy individuals were found to have lower muscle activation. Posture and segmental vertebral mobility were similar in both groups. On the other hand, patients with LSS had less total vertebral mobility.

The spinal mouse device ($r = 0.91$) is a valid and reliable method [21]. In the present study, analysis of vertebral mobility of the LSS and the control group showed that both groups had similar vertebral mobility values in the standing position and the maximal trunk flexion position. It was found that the mobility score of the control group was higher compared to the LSS group. High mobility scores point to total vertebral mobility in positional changes of the individuals. It was observed that the control group had higher total vertebral mobility in positional changes compared to the LSS group. In the literature, there are studies that assess the efficiency of surgery in patients with LSS with a spinal mouse. Mannion et al. [22] performed measurements with a spinal mouse in the standing position, maximum flexion, and maximum extension to assess the relationship between objective and subjective assessment in lumbar decompression surgeries before and after two months. 43 healthy volunteers and 22 volunteers who had herniated disc and LSS with an average age of 57 years participated the study. They reported that pre-surgery spinal mouse measurement values of the patient group had lower lumbar, and trunk vertebral mobility and lumbar lordosis and flexibility of the patients were reduced [22]. Topalidou et al. [23] performed measurements with a spinal mouse in the standing position, maximum flexion, maximum extension, right and left lateral flexion to assess morphology and vertebral mobility in patients who had pedicle screw decompression and posterior fusion. 20 patients with LSS and 39 healthy volunteers participated in the study. They found that in spinal stenosis, spinal pain was directly related to the vertebral mobility, and the change

in the angle between the curves and vertebral mobility increased after surgery, although vertebral mobility increased. They also reported that patients had more restricted vertebral mobility compared to the control group [23]. It is a fact that patients with LSS hold their trunk in flexion and avoid the extension posture to ease their pain. There is no difference in the segmental vertebral mobility between the groups in our study. This may be because most of our control group consists of retired persons and housewives who may not have healthy spine. When examining the total spine mobility, it was seen that although segmental spine mobility was not affected due to stenosis of the LSS group, it narrows the vertebral canal even more during the whole movement of the spine, and individuals with LSS tend to limit their total spine movements.

The LSS group was found to have higher rectus femoris, biceps femoris, medial gastrocnemius and tibialis anterior muscle activation in MVC% compared to the control group. It was considered that patients with LSS may have nervous problems, which may result in muscle weakness and that may cause an increase in muscle activation. High muscle activation may mean that a muscle uses more energy during movement and stimulates more motor units. However, as sEMG is not a method that gathers every motor unit activation on its own, the point that sEMG may not give information about the force should be kept in mind [24]. The present study suggests that muscle force measurement should be performed to support sEMG. Besides, Li et al. [25] reported that as the Root Mean Square (RMS) of these muscles decreases, the energy consumption increases when compared with the asymptomatic side. Goto et al. [13] assessed the paravertebral and vastus lateralis sEMG of 6 patients between 60–78 years old in their study which they analyzed the lower limb and trunk muscle activation and postural changes during gait in patients with lumbar spinal stenosis before and after surgery. They performed paravertebral and vastus lateralis measurement in the second weeks of the pre- and post-operative period. In conclusion, they reported that in trunk flexion, paravertebral muscle activation reduces, and vastus lateralis muscle activation increases [13]. Hoffman et al. [26] measured rectus femoris, hamstrings, tibialis anterior and medial gastrocnemius sEMG in their study comparing physiotherapy and minimally invasive decompression in 10 geriatric patients with LSS and an average age of 83 years. They observed an increase in RMS amplitudes in right and left muscle groups in the standing position. Besides, they observed an increase in sEMG frequency and amplitude during sitting and standing exercises [26]. In light of aforementioned research, it seems there are not enough studies in the literature specific to the lower limb muscles in patients with LSS.

In our study, sEMG amplitudes of the right rectus femoris, right medial gastrocnemius, right and left tibialis anterior were higher in the LSS group compared to the control group during walking. Arjunan et al. [20] studied sEMG variety during gait analysis in patients with lower back pain and assessed erector spine and multifidus muscles with sEMG during walking or running. They found that both groups had similar results in walking, but the lower back pain group was significantly different compared to the healthy group in running. As a result, they suggested the use of lower back muscle sEMG measurement in examination of individuals with lower back pain [20]. In the study of Haddas et al. [25], walking of 15 healthy, 20 adult idiopathic scoliosis and 20 cervical spondylotic myopathy patients were analyzed. The authors reported that the activation time of rectus femoris, semitendinosus, tibialis anterior and medial gastrocnemius muscles in individuals with spinal disorders is long. In their study, they suggested that the spine health experts may use gait analysis in addition to clinical assessments [27].

Our study asserts that muscle activation time during gait and changes in the reaction time during walking are important in patients with LSS, and it is necessary to make assessments using integrated camera systems to determine these. In our study, we did not include these integrated camera systems and we did not take measurements in hyperextension and the lateral flexion position, which may be considered as a limitation of this study. Also, the limitation of this study was to eliminate measurements of the erector spine and multifidus muscles using sEMG.

5. Conclusions

In this study, which compares whether is there difference in muscle activation and vertebral mobility between patients with LSS and healthy individuals, higher muscle activation in the LSS groups suggests that they may have muscle weakness, and these muscles should be assessed for muscle strength. It is considered that the measurement of muscle strength with isokinetic devices is important to support the muscle activation measurements. This should be considered before planning the measurement, and muscle strength measurement should be performed to the muscle to which the sEMG was applied. Studies on the lower limb muscle activation and LSS are few in the literature. More comprehensive research should be conducted to reveal the relation between muscle activation and LSS.

References

1. Fritz JM, Delitto A, Welch WC, Erhard RE. Lumbar spinal stenosis: A review of current concepts in evaluation, management, and outcome measurements. Arch Phys Med Rehabil. 1998;79:700–708. DOI: 10.1016/S0003-9993(98)90048-X
2. Eisenstein S. The morphometry and pathological anatomy of the lumbar spine in south African negroes and caucasoids with specific reference to spinal stenosis. J Bone Joint Surg. 1997;59:173–180. DOI: 10.1302/0301-620X.59B2.873978
3. Burnett MG, Stein SC, Bartels RH. Cost-effectiveness of current treatment strategies for lumbar spinal stenosis: nonsurgical care, laminectomy, and X-STOP. J Neurosurg Spine. 2010;13:39–46. DOI: 10.3171/2010.3.SPINE09552
4. Barz T, Melloh M, Staub L, et al. The diagnostic value of a treadmill test in predicting lumbar spinal stenosis. Eur Spine J. 2008;17:686–690. DOI: 10.1007/s00586-008-0593-1
5. Backstrom KM, Whitman JM, Flynn TW. Lumbar spinal stenosis-diagnosis and management of the aging spine. Man Ther. 2011;6:308–317. DOI: 10.1016/j.math.2011.01.010
6. Kuittinen P, Sipola P, Aalto TJ, et al. Correlation of lateral stenosis in MRI with symptoms, walking capacity and EMG findings in patients with surgically confirmed lateral lumbar spinal canal stenosis. BMC Musculoskelet Disord. 2014;15:1–6. DOI: 10.1186/1471-2474-15-247
7. Post RB, Leferink VJ. Spinal mobility: Sagittal range of motion measured with the Spinal Mouse, a new non-invasive device. Arch Orthop Trauma Surg. 2004;124: 187–192. DOI: 10.1007/s00402-004-0641-1
8. Candotti CT, Loss JF, Torre M, Melo MO, Araujo LD, Marcks W. Use of electromyography to assess pain in the upper trapezius and lower back muscles within a fatigue protocol. Rev Bras Fisioter. 2009;13:144–151. DOI: 10.1590/S1413-35552009005000018
9. Aydın K, Sözbir K, Karlı Ü, Yüktaşır B, Yalçın HB, Yıldız N, Tiryaki RG. Comparison of EMG activities of knee extensor muscles between soccer players and sprinters during countermovement jump performance. Niğde University Journal of Physical Education and Sport Sciences. 2011; 5: 3:242–249.
10. Mannion AF, Knecht K, Balaban G, Dvorak J, Grob D. A new skin-surface device for measuring the curvature and global and segmental ranges of motion of the spine: reliability of measurements and comparison with data reviewed from the literature. Eur Spine J. 2004;13(2):122–36. DOI: 10.1007/s00586-003-0618-8
11. Verheyden G, Ruesen C, Gorissen M, et al. Postural alignment is altered in people with chronic stroke and related to motor and functional performance. J Neurol Phys Ther. 2014;38:239–245. DOI: 10.1097/NPT.0000000000000054
12. The SENIAM project (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles) is a European concerted action in the Biomedical Health and Research Program (BIOMED II) of the European Union. [Available at http://www.seniam.org] [Accessed September 8, 2018].
13. Goto T, Saka T, Enishi T, et al. Changes of posture and muscle activities in the trunk and legs during walking in patients with lumbar spinal stenosis after decompression surgery. A Preliminary Report. Gait Posture. 2017;51:149–152. DOI: 10.1016/j.gaitpost.2016.10.006
14. Song HS, Park SD. Change in onset times of the abdominal muscles following functional task in lumbar spinal stenosis. J Exerc Rehabil. 2014;10: 302–305. DOI: 10.12965/jer.140150

15. Rutherford DJ, Moreside J, Wong I. Differences in hip joint biomechanics and muscle activation in individuals with femoroacetabular impingement compared with healthy, asymptomatic individuals: Is level-ground gait analysis enough? Orthop J Sport Med. 2018;6:1–10. DOI: 10.1177/2325967118769829
16. Khaiyat OA, Norris J. Electromyographic activity of selected trunk, core, and thigh muscles in commonly used exercises for ACL rehabilitation. J Phys Ther Sci. 2018;30:642–648. DOI: 10.1589/jpts.30.642
17. Byrne CA, O'Keeffe DT, Donnelly E, Lyons GM. Effect of walking speed changes on tibialis anterior EMG during healthy gait for FES envelope design in drop foot correction. J Electromyogr Kinesiol. 2007;17:605–616. DOI: 10.1016/j.jelekin.2006.07.008
18. Konrad P. The ABC of EMG. A practical introduction to kinesiological electromyography. Noraxon INC. USA. [Available at https://hermanwallace.com/download/The_ABC_of_EMG_by_Peter_Konrad.pdf] [Accessed February 18, 2018].
19. Nardo F, Strazza A, Mengarelli A, et al. Surface EMG patterns for quantification of thigh muscle co-contraction in school-age children: Normative data during walking. Gait Posture. 2018;61:25–33. DOI: 10.1016/j.gaitpost.2017.12.025
20. Arjunan SP, Kumar DK, Poon WM, et al. Variability in surface electromyogram during gait analysis of low back pain patients. J Med Biol Eng. 2010;30:133–138.
21. Büyükturan Ö, Büyükturan B, Yetiş M, Yetiş A. Yaşlı bireylerde cilt yüzeyi üzerinden torasik kifoz ve lumbal lordoz açılarının değerlendirilmesi: Spinal mouse geçerliliği ve güvenilirliği [Evaluation of thoracic kyphosis and lumbar lordosis angles over the skin surface in elderly individuals: Spinal mouse validity and reliability]. Dicle Tıp Derg. 2018;45:121–127. DOI: 10.5798/dicletip.410864. Turkish.
22. Mannion AF, Dvorak J, Müntener M, Grob D. A prospective study of the interrelationship between subjective and objective measures of disability before and 2 months after lumbar decompression surgery for disc herniation. Eur Spine J. 2005;14:454–465. DOI: 10.1007/s00586-004-0787-0
23. Topalidou A, Tzagarakis G, Balalis K, et al. Papaioannou A. Posterior decompression and fusion: Whole- spine functional and clinical outcomes. PLoS One. 2016;11:5–7. DOI: 10.1371/journal.pone.0160213
24. Cerrah AO, Ertan H, Soylu RA. Elektromiyografi ile kuvvetin değerlendirilmesi [Evaluation of force with electromyography]. Türkiye Klin J Neur. 2010;5:160–166. Turkish.
25. Li W, Liu YC, Zheng CF, et al. Diagnosis of compressed nerve root in lumbar disc herniation patients by surface electromyography. Orthop Surg. 2018;10:47–55. DOI: 10.1111/os.12362
26. Hoffman H, Bennett SS, Charles HL, Haakana P, Lu DC. Minimally invasive decompression and physiotherapy for lumbar spinal stenosis in geriatric patients. Cureus 10, e2785. DOI: 10.1016/j.ophtha.2015.02.029
27. Haddas R, Ju KL, Belanger T, Lieberman IH. The use of gait analysis in the assessment of patients afflicted with spinal disorders. Eur Spine J. 2018;27:1712–1723. DOI: 10.1007/s00586-018-5569-1

Author Contributions: Study Design, TC, AZ; Data Collection, AZ; Statistical Analysis, TC, AZ; Data Interpretation, TC; Manuscript Preparation, TC, AZ; Literature Search, AZ; Funding Acquisition, TC, AZ. All authors have read and agreed to the published version of the manuscript.

Acknowledgements: None.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Institutional Review Board Statement: This study was conducted according to the principles of the Declaration of Helsinki. Ethical approval was obtained from Bolu Abant Izzet Baysal University Clinical Researches and Ethical Board (09.08.2018-2018/247).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data available from the corresponding author on request.

Conflicts of Interest: The authors declare no conflict of interest.