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The Evaluation of Walking Energy Consumption and Plantar Pressure Distribution in Patients with Lumbar Spinal Stenosis: A cross-sectional, case control study

Lomber Spinal Stenozlu Hastalarda Yürüme Enerji Tüketimi ve Plantar Basınç Dağılımının Değerlendirilmesi: Kesitsel vaka kontrol çalışması

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ABSTRACT Objective: To evaluate the alterations of walking energy expenditure and plantar pressure distribution of patients with lumbar spinal stenosis. **Material and Methods:** Twenty-six subjects of both genders were included in the study, 13 patients suffering from lumbar spinal stenosis served as patient group and 13 healthy participants served as a control group. Preferred walking speeds were determined on the over ground. Oxygen consumption was recorded via a metabolic analyzer during walking on a treadmill for 2 km at preferred walking speed that determined on the over ground. Net oxygen consumption and oxygen cost were calculated for obtaining walking energy consumption. Plantar area was subdivided into six zones to measure plantar pressure distribution with a pedobarography device. **Results:** Compared with control group, patient group had significantly lower preferred walking speed (62.56±13.90 m/minimum and 76.66±10.90 m/minimum, p=0.008) and maximum walking distance [674.6 (105.0-2000.0) m and 2000.0 (2000.0-2000.0) m, p=0.019]. However, there were no statistically significant differences between groups in terms of energy expenditure parameters during walking at preferred walking speed (p>0.05). Similar findings were recorded between right and left foot with regard to weight distribution (%) to forefoot/hindfoot in patient group in the static pedobarographic measurements (p>0.05). Contact area value was significantly different between the affected and unaffected side at lateral forefoot in patient group (22.73±2.97 and 24.90±2.9, p=0.001). **Conclusion:** Patients with lumbar spinal stenosis do not exhibit more pressure on unaffected side compared to healthy subjects in both static and dynamic condition except contact area of lateral forefoot. Patient group optimized energy expenditure and oxygen cost by reducing their preferred walking speed owing to the pain.

Keywords: Spinal stenosis; pain; quality of life; energy metabolism

ÖZET Amaç: Lomber spinal stenozlu hastaların yürüme enerji tüketimi ve plantar basınç dağılımındaki değişiklikleri değerlendirmek. **Gereç ve Yöntemler:** Çalışmaya her iki cinsiyetten 26 kişi dâhil edildi, lomber spinal stenoza sahip 13 birey hasta grubu, 13 sağlıklı katılımcı ise kontrol grubu olarak çalışmaya dâhil edildi. Zeminde tercih edilen yürüme hızları belirlendi. Oksijen tüketimi, normal zeminde belirlenen tercih edilen yürüme hızında 2 km boyunca bir koşu bandı üzerinde yürürken, bir metabolik analizör aracılığıyla kaydedildi. Yürüme enerji tüketiminin belirlenebilmesi için yürüme sırasındaki net oksijen tüketimi ve oksijen maliyeti hesaplandı. Plantar bölge, bir pedobarografi cihazı ile plantar basınç dağılımlarını ölçmek için 6 bölgeye ayrıldı. **Bulgular:** Kontrol grubu ile karşılaştırıldığında, hasta grubunun tercih edilen yürüme hızı (62,56±13,90 m/minimum ve 76,66±10,90 m/minimum, p=0,008) ve maksimum yürüme mesafesi [674,6 (105,0-2000,0) m ve 2000,0 (2000,0-2000,0) m, p=0,019] anlamlı olarak daha düşüktü. Ancak tercih edilen yürüme hızındaki yürüme sırasında enerji tüketimi parametreleri açısından gruplar arasında istatistiksel olarak farklılık yoktu (p>0,05). Statik pedobarografik ölçümlerde hasta grubunda sağ ve sol ayak arasında ön ayak/arka ayak ağırlık dağılımı (%) açısından benzer bulgular kaydedildi (p>0,05). Hasta grubun etkilenen ve etkilenmeyen tarafa ait plantar bölge temas alanı sadece ön ayak laterali için anlamlıydı. (22,73±2,97 ve 24,90±2,9, p=0,001). **Sonuç:** Lomber spinal stenozu olan hastalar, yan ön ayak temas alanı dışında hem statik hem de dinamik durumda sağlıklı bireylerle karşılaştırıldığında etkilenmeyen ayağa fazla baskı uygulamazlar. Hasta grubu ağrı nedeniyle tercih ettikleri yürüme hızlarını azaltarak enerji tüketimini ve oksijen maliyetini optimize etmiştir.

Anahtar Kelimeler: Spinal stenoz; ağrı; yaşam kalitesi; enerji metabolizması

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Lumbar spinal stenosis (LSS) is a clinical condition that is characterized by narrowing of the lumbar spinal canal or nerve foot foramen depending on different etiologies.[1] LSS is classified as either primary, arising from congenital or postnatal development or secondary, resulting from degenerative diseases of spinal canal.[2] Neurogenic intermittent claudication (NIC), the remarkable finding of LSS, is described as a progressive onset of pain, tingling, muscle weakness and numbness in the low back, buttocks, thighs, and legs.[3,4] These symptoms are generally exacerbated by standing, walking, or lumbar extension which lead to diminish the health related quality of life.[1]

Several investigators reported that patients with LSS may often have decreased walking speed due to the pain.[5-7] As such, patients with LSS experience alteration in walking pattern resulting from abnormal transmission of the forces from the upper body to lower body which may cause to alteration in plantar pressure distribution at the foot.[8] Walking is obviously critical for physical activity and performance for everyday life, and thus ambulation limitation is a severe health marker to be monitored.[8] Since walking limitations affect negatively the patients with LSS, the proper assessment of ambulation-related disability is necessity. Traditionally, walking has been assessed in patients with LSS via by self-reported questionnaires, laboratory walking test, and activity monitors.[1,2,7,9,10] But all these methods investigate walking capacity and/or performance with only testing walking speed, walking duration, walking distance, number of steps, etc. None of these methods provide actual measurement of walking capacity that evaluated by measuring O_2 consumption during activity.

Although plantar foot pressure distribution and walking energy expenditure have been investigated in relation to many diseases and conditions thus far, we could not find any studies on LSS. Thus, the purpose of this study is to determine the differences of walking energy expenditure, walking distance, the plantar pressure distribution between patients with LSS and healthy subjects and to evaluate the effect of these differences on the patients' quality of daily life. Our hypothesis was that plantar pressure and energy consumption parameters in LSS patients would differ from those of controls.

MATERIAL AND METHODS

SUBJECTS

Thirteen LSS patients and 13 healthy gender, age, height, and body mass index (BMI)-matched subjects were recruited for participation in this study (ages between 40-60 years, 9 women, 4 men in each group). All subjects gave their written informed consent, which was approved by Mersin University Clinical Research Ethics Committee (date: 02.08.2012, number: 2012/269) prior to the start of the experiment. This research was performed in accordance with the principles of the Helsinki Declaration. Power analysis was performed using the article of Dal et al. In order for the study to be performed at 80% power and 5% margin of error, if the oxygen cost value is 0.16 and the standard deviation is 0.02 in the control group, at least 7 individuals should be included in each group to detect a change of 0.03 in the oxygen cost value in both groups.[11]

Patients were included into the study if they fulfilled the following criteria: aged 40-60 years having clinical diagnosed of LSS by a physiatrist, sedentary life style for the 6 months before the enrollment, and sufficient mental status to participate to the study. Diagnosis was based on the physical examination findings, illness history, location and intensity of symptoms, and magnetic resonance imaging (MRI). MRI imaging was performed for 13 clinically diagnosed LSS patients to measure the level of the spinal stenosis. The cross-sectional area of the dural sac at levels of L1-L5 was calculated in square millimeters by a radiologist who was blind to the study groups. Spinal stenosis was defined as the dural sac area less than 130 mm^2.[12]

Study exclusion criteria included 1) Active infection which may influence the metabolic outcomes of the exercise test, any peripheral-vascular, metabolic disease and other autoimmune, chronic systemic inflammatory pathologies; 2) malignancy; 3) cognitive impairment; 4) previous spinal operation history; 5) vascular claudication; 6) lower extremity involvement, which may conflict with treadmill exercise testing; 7) presence of severe cardiopulmonary or endocrine diseases; 8) medical treatment for pain such as; gabapentin, pregabalin, and opioids.

All participants were asked to complete a Physical Activity Readiness Questionnaire (PAR-Q), which measured the readiness of the subject to engage in a physical activity.[13] PAR-Q has been arranged to identify adults for whom physical activity may be improper.

PAIN AND FUNCTIONAL CAPACITY

A Visual Analog Scale (VAS) that determine the pain on a scale ranging from 0 to 10 was used. Pain levels were evaluated separately during resting, walking, and at the end of the day.[14,15] The Oswestry Disability Index (ODI) is a ten-item questionnaire, which assesses the effect of low back pain to patients' daily activity.[16,17] Pain during flexion and extension was determined with clinical examination.

HEALTH-RELATED QUALITY OF LIFE

The short form (SF-36) questionnaire, consisted of 36 questions, was used to evaluate the physical and mental health of the subjects. Two summary scores were determined; a Physical Component Summary score (PCS) and a Mental Component Summary score (MCS).[18,19]

PLANTAR PRESSURE ASSESSMENT

Static and dynamic plantar pressure distributions were measured with a pressure plate (0.5 m×0.4 m, with 4.096 resistance sensitive sensors, 4 sensors/cm^2, Footscan® RSscan International, Olen, Belgium). Participants were asked to stand up on the pressure plate to determine the distribution of load as a percentage on forefoot and hindfoot (the foot divided into two equal parts from the center) at static condition. After then, subjects were asked to walk at their preferred walking speed (PWS) over the pressure plate to measure the dynamic plantar pressure. Ten measurements were recorded for each foot and the averages of 3 closest measurements were evaluated. Plantar surface was subdivided into 6 areas to assess the dynamic plantar pressure data based on the peak pressure footprint (Figure 1).[20-22] Contact area (%), peak pressure (N/cm^2), and impulse values (pressure time integral, Ns/cm^2) beneath these areas were recorded.

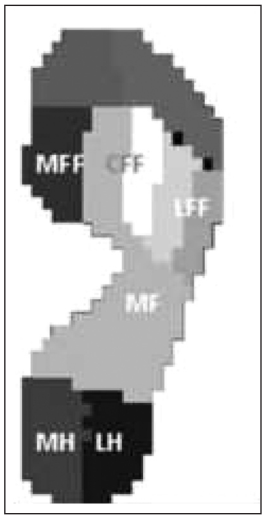

FIGURE 1: The location of six anatomical sub-areas on footprint.
(Footscan software 7, Footscan® RSscan International, Olen, Belgium).
MH: Medial heel; LH: Lateral heel; MF: Midfoot; MFF: Medial forefoot; CFF: Central forefoot; LFF: Lateral forefoot.

WALKING ENERGY EXPENDITURE

The determination of PWS was explained in detail in one of our previous study.[11] Energy expenditure measurements were assessed via an open-circuit indirect calorimetry (Vmax Spectra 29c; Sensormedics, Yorba Linda, CA, USA). The expired gases were collected breath-by-breath via by a face mask for 10 minutes to calculate resting energy expenditure (REE). The REE measurement was performed after a good night's sleep and at 4 hours of fasting. Subjects were informed to refrain from exercise, smoking and alcohol on the day before and on the test day.

Subjects accomplished an adaptation session on the treadmill for at least 10 minimum.[11] For the walking energy expenditure measurement, subjects were asked to walk on the treadmill at predetermined over ground walking speed until they felt they had to stop because of symptoms of LSS or until a distance limit of 2 km. The incline was set at 0% and the participant not allowed to hold on the rails while walking on the treadmill throughout the test. The last 2 minutes of oxygen sampling data were taken as steady state and analyzed at intervals of 10 seconds on average.[23] The respiratory exchange ratio values of walking trials on the treadmill were assessed to evaluate the intensity of the tests and also the Borg scale was applied to determine the perceived exertion at the end of each walking trial.[24] The trial was terminated in case of neurological claudication, low back pain or leg pain and walking distance were also recorded. The oxygen consumption per meter walked was calculated to determine oxygen cost. Net O_2 consumption was calculated for walking stage with following formula: Net O_2 consumption="Total O_2 consumption-resting O_2 consumption".

DATA ANALYSES

The sample size was calculated by the package program, STATISTICA Version 13.3 (TIBCO Software Inc. (2017). Statistica (data analysis software system), version 13). Type I and II errors were set at 0.05 and 0.20, respectively.

Normal distributions of the data were assessed by using a Shapiro-Wilk's test. All measurements were expressed as means and standard deviations (SD) or median (minimum-maximum) according to the data distribution. Non-parametric Mann-Whitney U test was used to compare healthy and patient groups for lateral forefoot, lateral rearfoot and midfoot in impulse and medial, central and lateral forefoot and medial rearfoot in contact area variables that were not distributed normally. The continuous variables were analyzed across the groups using independent samples t-test. Paired sample t-test was applied to compare affected and unaffected side and also weight distribution between right and left forefoot and hindfoot in LSS patient group.

The statistical analyses were performed by SPSS version 11.5 for Windows. All measurements were expressed as means and standard deviation (SD) or min-max according to the data distribution. The significance level was set at $p<0.05$.

RESULTS

The mean±SD of demographic and anthropometric characteristics of the participants in each group were presented in Table 1.

There was an increase in pain with extension and a decrease with flexion in the waist in 10 patients.

TABLE 1: Demographic and anthropometric data of the subjects in LSS and control groups.

	Group	Mean±SD	p value
Age (years)	LSS	51.46±5.12	0.174
	Control	48.54±5.52	
Body weight (kg)	LSS	75.60±12.70	0.183
	Control	69.50±9.90	
BMI (kg/m²)	LSS	28.82±3.89	0.233
	Control	26.99±3.73	
Body fat mass (%)	LSS	51.46±10.67	0.259
	Control	47.26±7.64	
Lean body mass (kg)	LSS	24.11±10.04	0.589
	Control	22.17±7.87	

SD: Standard deviation; LSS: Lumbal spinal stenosis; BMI: Body mass index.

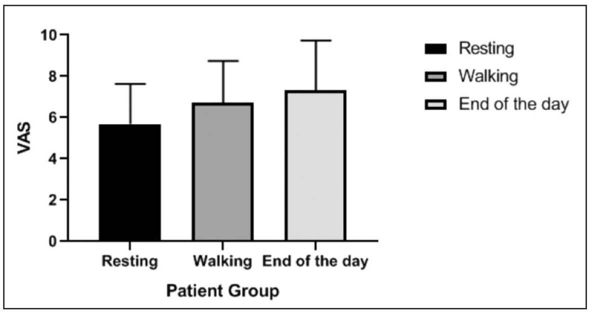

FIGURE 2: Visual Analog Scale scores of patient group.

Seven (53.8%) patients described night pain and 5 patients described morning stiffness (38.4%) in LSS group. Paresthetic complaints such as burning and tingling were present in 10 patients (76.9%) and NIC were present in all patients (100%).

The mean VAS scores were 5.69±1.94, 6.7±2.04 and 7.3±2.43 during resting, walking (provoked) and at the end of the day, respectively, in LSS group (Figure 2). Score for the ODI was higher in LSS group than control group [42.00% (32.00-56.00) and 6.00% (4.00-13.00), respectively] ($p<0.001$).

PCS scores are significantly higher in control group ($p<0.001$). However, no significant difference was found in MCS scores ($p=0.073$) (Table 2).

No statistically significant differences were found between right and left foot with regard to weight distribution (%) to forefoot/ hindfoot in LSS group in the static pedobarographic measurements

TABLE 2: SF-36 scores of LSS and control groups.

SF-36		N	Mean±SD	p value
PCS	LSS	13	41.89±5.24	<0.001*
	Control	13	53.58±3.23	
MCS	LSS	13	48.65±3.76	0.073
	Control	13	50.80±1.45	

*Statistically significant differences (p<0.05); LSS: Lumbal spinal stenosis; SD: Standard deviation; SF-36: The short form questionnaire; PCS: Physical Component Summary score; MCS: Mental Component Summary score.

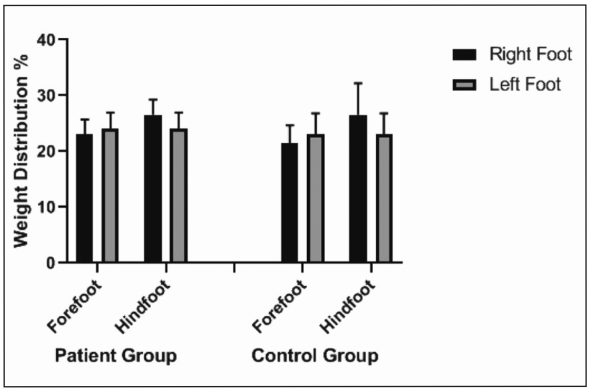

FIGURE 3: Weight distribution at right and left foot patient and control group.

(Figure 3). Dynamic plantar pressure data were presented in Table 3 and Table 4.

Statistically significant differences were found between the LSS group and the control group in terms of PWS and maximum walking distance [62.56±13.90 m/minimum and 76.66±10.90 m/minimum respectively. p=0.008, (Table 5)] and [674.6 (105.0-2000.0) m and 2000.0 (2000.0-2000.0) m. respectively, p=0.019 (Figure 4)].

There were no statistically significant differences between groups in terms of energy expenditure parameters (Table 5). Borg Scale values that assessed perceived exertion during the test [11.00 (6.00-19.00) and 8.00 (6.00-11.00) were not statistically different, respectively] (p>0.05).

DISCUSSION

In the current study, it was observed that the vast majority of patients with LSS preferred flexion posture because of the pain especially during standing and walking. It is thought that the center of gravity may be displaced in this population and alterations might be seen in plantar pressure distribution. However, there were no significant differences between left and right feet of LSS group in terms of the percentages of the total weight distribution on the forefoot and hindfoot. Among patients with LSS, no significant differences were observed in terms of plantar pressure parameters as peak pressure and impulse values between affected and unaffected side except lateral forefoot contact area during walking at PWS, even though the unaffected side generally showed a tendency of increase in these parameters. This may be explained by decreased walking speed in LSS patients due to the pain-influencing gait. As walking speed increases, forefoot foot-to-floor contact durations continuously decreases and vice versa. The foot moves quickly from heel strike to toe-off at higher walking speeds, taking less time weighting the forefoot area. Therefore, the increase in contact area at lateral forefoot might not reflect to the peak pressure value.

Fayez et al. concluded that patients with mechanical low back pain exhibit more weight on unaffected side when compared to healthy subjects in both static and dynamic conditions due to the pain.[6] It is possible that patients with low back pain have malfunction in their muscles and ligaments due the pain avoiding patterns and as a result, range of motions of lower extremities might be reduced.[6,25] On the other hand, our present finding is similar with the result of a study of Lee at al. in which no significant differences were found in plantar pressure distribution parameters in patients with low back pain.[5] In the current study, the PWS of LSS group was lower than control group. It's indicated that walking slowly with shorter step length might be the reason of these results in patients with pain.[5]

Several factors were indicated to affect the measurement of plantar pressure which includes walking speed, gait protocol and fatigue.[26-29] Patients with LSS typically walk slower with shorter steps due to the pain.[5-7] Rosenbaum et al. has reported that self-selected PWS gave more accurate pattern in different subject.[26] Therefore, in our study, plantar pressure measurement performed at PWS to minimize the effect of fatigue on reliability of measurement before

TABLE 3: Peak pressure (N/cm^2), contact area (%), and impulse (Ns/cm^2) data of affected and unaffected side in LSS group.

	Peak pressure (N/cm^2)			Impulse values (Ns/cm^2)			Contact area (%)		
	Affected	Unaffected	p value	Affected	Unaffected	p value	Affected	Unaffected	p value
Medial forefoot	6.39±2.53	5.70±1.96	0.455	1.72±0.62	1.47±0.55	0.332	15.28±5.13	14.49±3.02	0.550
Central forefoot	11.05±2.87	11.44±3.16	0.492	3.47±1.24	3.63±1.24	0.421	23.58±4.16	24.07±3.71	0.605
Lateral forefoot	6.44±2.80	7.49±3.10	0.272	2.20±1.12	2.71±1.38	0.179	22.73±2.97	24.90±2.93	0.001*
Midfoot	3.58±1.35	3.40±1.01	0.512	1.09±0.46	1.10±0.43	0.965	38.08±7.80	38.29±8.50	0.827
Medial rearfoot	9.25±1.33	9.35±1.47	0.779	2.81±0.81	2.55±0.72	0.101	19.48±2.72	20.94±7.72	0.495
Lateral rearfoot	8.85±1.93	8.53±2.45	0.622	2.58±0.90	2.34±0.78	0.244	17.05±2.44	16.38±2.33	0.075

*Statistically significant differences (p<0.05); Values are reported as mean±standard deviation unless otherwise stated; LSS: Lumbal spinal stenosis.

TABLE 4: Characteristics of plantar pressure measurements: difference between the left and right sides of the two groups.

	Peak pressure (N/cm^2)			Impulse values (Ns/cm^2)			Contact area (%)		
	LSS	Control	p value	LSS	Control	p value	LSS	Control	p value
Medial forefoot	0.68±3.19	-1.61±3.36	0.16	0.24±0.87	0.00±0.67	0.43	2,30 (-13.50:4.67)†	2.10 (-6.10:4.20)†	0,51
Central forefoot	-0.38±1.97	-1.19±1.88	0.30	-0.15±0.68	-0.29±0.51	0.58	0.40 (-9.90:2.50)†	1.07 (-0.60:10.2)†	0.28
Lateral forefoot	-1.05±3.18	-1.14±2.66	0.93	-0.14 (-3.00:1.17)†	0.24 (-3.17:0.43)†	0.88	-2.16 (-6.27:0.90)†	-0.66 (-2.80:8.10)†	0.01*
Midfoot	0.18±0.96	-0.43±1.05	0.13	0.06 (-1.60:0.56)†	0.00 (-0.40:0.53)†	0.72	-0.20±3.33	0.47±4.22	0.65
Medial rearfoot	-0.09±1.23	-1.07±1.48	0.07	0.26±0.53	-0.29±0.59	0.08	19.23 (14.70:44.30)†	17.86 (12.50:21.70)†	0.18
Lateral rearfoot	0.32±2.28	-0.00±1.32	0.66	0.00 (-0.43:1.80)†	-0.07 (-0.77:0.76†	0.44	0.66±1.23	1.88±1.98	0.07

*Statistically significant differences (p<0.05); Values are reported as mean (±standard deviation) unless otherwise stated; †Mann-Whitney U test median percentiles (25-75) median (minimum:maximum); LSS: Lumbal spinal stenosis.

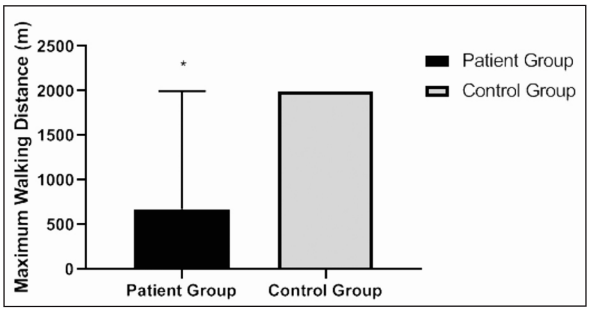

FIGURE 4: Maximum walking distance of patient and control groups.

treadmill walking test. The use of PWS also offers an advantage in standardizing individual differences and eliminates the effects of walking speed on the distribution of plantar pressure. A relationship between walking and pain was reported in literature. A negative correlation had been reported between pain severities and self-reported walking distance in patients with LSS.[30] Tomkins-Lane et al. found that the most powerful predictor of walking capacity was average pain which may limit the real performance of patients during treadmill walking. However, the presence of pain in the legs was not found to be a predictor of walking capacity or performance.[7] Yamakawa et al. reported that pain was most closely linked to ambulation in LSS.[31] As anticipated, the PWS of LSS group was slower than control subjects in the present study. However, 53% of the LSS group was unable to complete the treadmill walking test secondary to leg pain. Even though there was no significant difference between groups for values of perceived exertion during walking test, the LSS group expressed difficulty in walking test. These findings are consistent with previous studies suggesting significant walking limitations in patients with LSS compared with healthy controls.[2,7,32]

Exercise tolerance testing has become to be widely used in many diseases to determine cardiopulmonary capacity. But since all of test protocols involves progressive speed and ramp increases during the examination, patients with LSS might have had cardiopulmonary symptoms and had to stop test before their leg pain begin as reported in a study. Deen at al. used a walking speed of 1.2 mph and a ramp incline of 0º.[33] It was also reported that NIC would be better showed by walking at a slower and constant speed.[33] Therefore, in the present study, energy ex-

TABLE 5: Oxygen consumption result of patient and control groups.

		Mean	SD	p value
PWS (m/min)	LSS	62.56	13.90	0.008*
	Control	76.66	10.90	
Resting VO_2 (L/min)	LSS	0.22	0.03	0.238
	Control	0.21	0.02	
Resting VO_2 (mL/kg/min)	LSS	3.06	0.36	0.751
	Control	3.10	0.36	
Standing VO_2 (L/min)	LSS	0.27	0.05	0.077
	Control	0.24	0.03	
Standing VO_2 (mL/kg/min)	LSS	3.68	0.43	0.493
	Control	3.55	0.53	
Walking VO_2 (L/min)	LSS	0.94	0.19	0.987
	Control	0.94	0.20	
Walking VO_2 (mL/kg/min)	LSS	12.58	1.75	0.226
	Control	13.83	3.17	
Walking VO_2 cost mL/kg/m	LSS	0.21	0.05	0.084
	Control	0.18	0.03	
Walking RER	LSS	0.80	0.10	0.964
	Control	0.80	0.04	
Net VO_2 consumption (mL/kg/min)	LSS	9.51	1.73	0.239
	Control	10.72	3.14	
Net VO_2 cost (mL/min)	LSS	0.15	0.03	0.126
	Control	0.13	0.03	

*Statistically significant difference between LSS and control groups. SD: Standard deviation; LSS: Lumbal spinal stenosis; VO_2: Oxygen consumption rate; PWS: Preferred walking speed; RER: Respiratory exchange ratio.

penditure parameters of walking were evaluated during walking at PWS and 0^o ramp incline. To our best knowledge, this is the first study that evaluated walking capacity of patients with LSS by indirect calorimeter. In the current study, the PWS and maximum walking distance were significantly lower in LSS group than controls. However, no statistically significant difference was found between the two groups in terms of resting, standing, and walking energy expenditure parameters. However, resting and standing oxygen consumption, oxygen cost of walking are tend to be higher in LSS patients. The higher number of samples size might be more noticeable of this differences In our previously published work, we have observed that patients with fibromyalgia syndrome optimized energy expenditure and oxygen cost by reducing their PWS owing to the widespread pain.[11] Therefore, we believed that pain and NIC symptoms revealed these findings in LSS group and leaded to energy expenditure optimized by reducing the walking speed of the patients. Tomkins-Lane et al. studied with 3 groups and it was reported that patients with LSS had lower values for all walking parameters compared to the asymptomatic group.[7]

There were some limitations in our study. It was the first study that evaluated actual measurement of walking capacity by measuring O_2 consumption during activity. In the next study, the sample size can be increased to better explain the variation between groups in some parameters of energy consumption.

CONCLUSION

The strength of this study includes the use of an indirect calorimeter to evaluate oxygen consumption objectively during ambulation. Our present study may provide an objective perspective to researches about walking economy in patients with LSS. Patients with LSS do not exhibit more pressure on one foot compared to healthy subjects in both static and dynamic condition despite the severity of pain or disability level. Walking speed and distance were lower in LSS group. On the basis of these data, we conclude that patients with LSS optimized energy expenditure and oxygen cost by reducing their PWS owing to the pain.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

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