An updated version of this article is avalaible at:
https://doi.org/10.17267/2238-2704rpf.2023.e5063

Journals BAHIANA
SCHOOL OF MEDICINE AND PUBLIC HEALTH

Original Article

Pilot study on lumbar canal diameter and walking distance in patients with lumbar spinal stenosis: a multivariate prediction model

Estudo piloto sobre diâmetro do canal lombar e distância percorrida em pacientes com estenose espinhal lombar: um modelo de predição multivariado

Gurjant Singh[1]
Aksh Chahal[2]
Manjeet Singh[3]

[1]Corresponding auhtor. Maharishi Markandeshwar (Deemed to be University) (Mullana-Ambala). Haryana, India. singh.guri547@gmail.com
[2]Maharishi Markandeshwar (Deemed to be University) (Mullana-Ambala). Haryana, India. drakshchahal@gmail.com
[3]Adesh Medical College and Hospital (Shahbad). Haryana, India. singhsingh001@yahoo.com

ABSTRACT | INTRODUCTION: Neurogenic claudication (NC) is the classic clinical presentation of patients with Lumbar Spinal Stenosis (LSS). These patients may or may not present with symptoms of leg pain and difficulty walking. These symptoms are exacerbated while walking and standing and are eased by sitting or bending forward. **METHOD:** Patients with LSS, having a lumbar canal diameter of ≤12mm, were recruited from a recognized Tertiary care hospital. Each subject's demographic characteristics and anthropometrics were noted, and the testing procedure was explained. The canal diameter was documented with the help of an MRI report. A self-paced walking test was used to assess the walking distance. **STATISTICAL ANALYSIS:** Depending on the normality of the data, the Pearson correlation coefficient (r) was used to find the correlation between canal diameter at different lumbar levels and walking distance in patients with LSS. **RESULT:** Pearson correlation coefficient (r) determined a fair positive correlation (r = 0.29) between lumbar canal diameter and walking distance. Stepwise multiple regression analysis was done, and a prediction equation was found for different levels of canal stenosis. **CONCLUSION:** Findings of our present study suggest a fair positive correlation between walking distance and canal diameter at L5-S1. This study may also be useful in predicting the approximate canal diameter by estimating the walking distance of the patient with symptoms of LSS and vice-versa.

KEYWORDS: Lumbar vertebrae. Magnetic resonance imaging. Neurogenic claudication. Spinal stenosis. Walking.

RESUMO | INTRODUÇÃO: A claudicação neurogênica (CN) é a apresentação clínica clássica de pacientes com Estenose Espinhal Lombar (EEL). Esses pacientes podem ou não apresentar sintomas de dor nas pernas e dificuldade para caminhar. Esses sintomas são exacerbados ao caminhar e ficar em pé e são aliviados ao sentar ou inclinar-se para a frente. **MÉTODO:** Pacientes com EEL, com diâmetro do canal lombar ≤12mm, foram recrutados em um hospital terciário reconhecido. As características demográficas e antropométricas de cada sujeito foram anotadas e o procedimento do teste foi explicado. O diâmetro do canal foi documentado com a ajuda de um relatório de ressonância magnética. Um teste de caminhada individualizado foi usado para avaliar a distância percorrida. **ANÁLISE ESTATÍSTICA:** Dependendo da normalidade dos dados, o coeficiente de correlação de Pearson (r) foi usado para encontrar a correlação entre o diâmetro do canal em diferentes níveis lombares e a distância percorrida em pacientes com EEL. **RESULTADO:** O coeficiente de correlação de Pearson (r) determinou uma correlação positiva razoável (r = 0,29) entre o diâmetro do canal lombar e a distância percorrida. Análise de regressão múltipla stepwise foi feita, e uma equação de predição foi encontrada para diferentes níveis de estenose do canal. **CONCLUSÃO:** Os achados de nosso estudo sugerem uma correlação positiva razoável entre a distância percorrida e o diâmetro do canal em L5-S1. Este estudo também pode ser útil para prever o diâmetro aproximado do canal, estimando a distância percorrida pelo paciente com sintomas de EEL e vice-versa.

PALAVRAS-CHAVE: Vértebras lombares. Ressonância Magnética. Claudicação neurogênica. Estenose espinhal. Caminhada.

Submitted 09/07/2022, Accepted 11/10/2022, Published 12/13/22
J. Physiother. Res., Salvador, 2022;12:e4827
http://dx.doi.org/10.17267/2238-2704rpf.2022.e4827
ISSN: 2238-2704
Assigned editors: Ana Lúcia Góes, George Dias

How to cite this article: Singh G, Chahal A, Singh M. Pilot study on lumbar canal diameter and walking distance in patients with lumbar spinal stenosis: a multivariate prediction model. J Physiother Res. 2022;12:e4827. http://dx.doi.org/10.17267/2238-2704rpf.2022.e4827

Introduction

Lumbar spinal stenosis (LSS) is a progressive narrowing of the spinal canal consisting of compression of nerve roots, the dural sac, and the spinal cord.[1] LSS is a common disorder diagnosed in 13%-14% of individuals consulting for back pain.[2] Magnetic Resonance Imaging (MRI) is routinely used in clinical practice to diagnose LSS. Measurements of spinal canal diameter are better measured by MRI.[3,4] With the increase in age, the prevalence of LSS rises, being prevalent at 9.3% in the general population and as high as 47% in people older than 60 years of age.[5] In the age group of 65 years and higher, LSS is the most common cause of lumbar spine surgeries.[1,6]

The classic clinical feature of LSS is Neurogenic Claudication (NC).5 The symptoms of NC are described as pain, paraesthesia or cramping, numbness, and weakness in the calf, thighs, or buttocks. These symptoms are exacerbated while walking and standing and are eased by sitting or bending forward.[7] Anatomically, spinal stenosis can occur centrally, within the lateral recess, at the level of the intervertebral disc or in the foramen. The compression of the traversing nerve root occurs in lateral recess stenosis. LSS can be congenital or acquired or result from a combination of congenital and acquired. In the congenital type, etiology is the presence of short pedicles as in achondroplasia, and the acquired type primarily consists of degenerative diseases changes causing narrowing of the canal and leading to compression of nerve roots.[8,9]

As a result of the narrowed lateral and central vertebral canal in the lumbar spine, the lumbosacral nerve roots may get compressed. This physiological dysfunction is responsible for the pathogenesis of NC. The altered mechanics may also develop as a consequence of ischemia of nerve roots and/or degenerative changes in the spine. This leads to limited walking ability, thus causing functional impairment in a patient with NC.[9,10] To mark the Walking Distance (WD), Self-paced walking (SPW) could be a standardized method, being an inexpensive, feasible, and reproducible measure to assess the walking capacity in patients with LSS.[11] Also, it ensures a more practical functional assessment as compared to a treadmill, as the older population of India may not be familiar with treadmill walking. An X-ray may indicate some degenerative changes in the lumbar spine, and clinical assessment findings may direct the clinician to the possibility of stenosis. However, for the confirmatory diagnosis of stenosis, radiological investigations are necessary. The normal diameter of the lumbar canal ranges from 15mm-27mm; a canal diameter of less than 12mm is termed stenosis. Decreased WD is the primary complaint of patients with LSS. Various studies emphasized the decreased WD in LSS, but no literature has presented the impact of change in canal diameter on WD, and there is the need to have some predictive data by which clinicians can have an estimated walking distance according to the diameter of lumbar canal at the most stenotic level. Therefore, this study was planned to find the correlation between walking distance and lumbar canal diameter, with the purpose of deriving a prediction about the walking distance of the patients looking at the diameter of the lumbar canal at different levels.

Methods

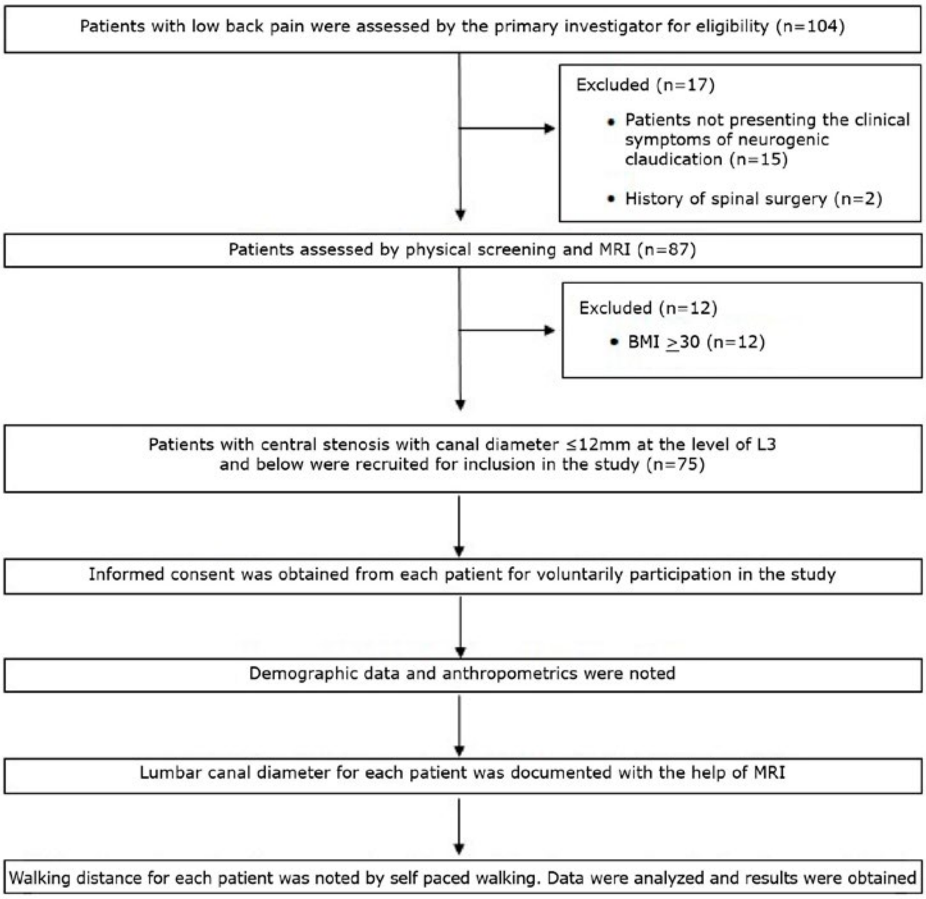
Ethical statement

Ethical approval of this study was obtained from the Institutional Ethics Committee of an esteemed university with IEC number MMDU/IEC/1826. The safety of the patients was ensured by the therapist (mentioned in the procedure), and the study procedure was planned to eliminate the negative effects on patients' health. The study was done in accordance with the Helsinki declaration revised in 2013[12] and the National Ethical Guidelines for Biomedical Research involving Human participants, 2017.

Screening

One hundred four patients were screened in the Orthopedic Outpatient department that came with complaints of back pain along with difficulty walking for a long duration. Both male and female patients within the age group of ≤70 years and with LSS at different lumbar levels along with symptoms of neurogenic claudication. During the screening, patients with a history of trauma or fracture, or any lumbar surgery in the past six months, or any congenital or acquired spine deformity were excluded (Figure 1).

Figure 1. STROBE Flowchart of the study



Source: The authors (2022).

Patients recruitment

Seventy-five patients with symptoms of neurogenic claudication were recruited for this study using purposive sampling. The written consent form was taken from the recruited patients for their voluntary participation. The entire demographic characteristics, such as age, gender, weight, and height of each patient, were noted. The canal diameter was documented with the help of an MRI. The SPW was done to find the WD for each patient.

Procedure

The anthropometric data were collected by the primary researcher from the outpatient department of a recognized hospital.

Study Outcomes

Lumbar Canal Diameter

The patients exhibiting the clinical features of LSS were asked for an MRI, which was performed by an experienced radiologist, who was blinded to the walking distance of the patients. MRI was done through a 1.5 T Philips Multiva Magnetic Resonance Imaging system, and the imaging sequences, Sagittal T1, Sagittal T2, Coronal STIR, Axial T1, and Axial T2, were included. Antero-posterior canal diameter of 12mm or lesser at the most stenotic level from L3 and below was noted.[5]

Walking Distance

Self-Paced Walking was used to measure the walking distance.[11] Before measuring the WD, patients were informed about the procedure, and informed consent was obtained. Safety related to floor walking was ensured by eliminating slippery surfaces or footwear of the patients. Each patient was asked to walk at their own pace continuously over a marked track of 30m as far as possible without any discomfort due to pain. Track marking was done with the help of a marking cone. The primary researcher followed ach patient at approximately 1m distance behind him/her to eliminate the risk of falls. WD was measured with the help of a measuring wheel, and the distance (meters) where patients preferred to stop due to pain was noted for each patient.

Data analysis

Statistical analysis was done using the statistical package for social sciences (SPSS), version 16 (SPSS Inc. Chicago, IL, USA). A significance level of 0.05 was set. The normality of the data was determined by the Kolmogorov-Smirnov test, and the data was found to be normally distributed. Therefore, the Pearson correlation coefficient (r) was used to find the correlation between canal diameter at different lumbar levels and walking distance in patients with LSS. Stepwise multiple regression analysis was done to find the best predictor variables for the dependent variable, canal diameter. The percentage of the total variance in the canal diameter, accounted for by the predictor variables, was expressed as the adjusted square of the multiple correlation coefficient (R2).

Result

Seventy-five patients were recruited (51 males and 24 females) for this study. The participants' mean ± standard deviation age was 38 years 4 months ± 12 years 8 months. The participants' mean ± standard deviation of WD equalled 159.60 ± 49.61m (Table 1). The mean canal diameters at different lumbar levels and walking distance of the patients are mentioned in Table 1. The correlation between canal diameter and walking distance was measured using the Pearson Correlation Coefficient. Results showing the correlation (value of r) between canal diameter and walking distance are presented in Table 2. More significantly, among all the levels, the correlation at L5-S1 has shown a fair positive correlation (r = 0.29), which statistically indicates that the walking distance of the patient may decrease with a decrease in canal diameter and vice versa. The R-squared in this regression model was used for statistically determining the proportion of variance in the walking distance that can be explained by the value of canal diameter. R-squared has shown a low correlation between walking distance and canal diameter at all the levels except L5-S1. The value of R-squared has been found to be 0.08, signifying the level of correlation between the walking distance and canal diameter at L5-S1. In addition, the p-value (0.01) was found to be significant only at L5-S1.

The value of correlation coefficient (r) was interpreted as below –0.75: good to excellent negative correlation; from –0.50 to –0.75: moderate to good negative correlation; from –0.25 to –0.50: fair negative correlation; 0: no correlation; 0.25–0.50: fair positive correlation; 0.50–0.75: moderate to good positive correlation; and above 0.75: good to excellent positive correlation.[13]

http://dx.doi.org/10.17267/2238-2704rpf.2022.e4827 | ISSN: 2238-2704

Table 1. Descriptive statistics of all the variables

Variables	Mean ± SD	95 % CI
Age (Years)	38.27 ± 12.75	35.33 – 41.20
Height (m)	1.67 ± 0.09	1.65 – 1.69
Weight (kg)	70.39 ± 10.16	68.05 – 72.73
BMI (kg/m^2)	25.09 ± 2.45	24.53 – 25.66
Canal Diameter (L_1-L_2)	15.85 ± 3.14	15.13 – 16.58
Canal Diameter (L_2-L_3)	14.45 ± 3.37	13.68 – 15.23
Canal Diameter (L_3-L_4)	13.68 ± 3.41	12.89 – 14.46
Canal Diameter (L_4-L_5)	11.28 ± 2.87	10.62 – 11.94
Canal Diameter (L_5-S_1)	10.50 ± 2.31	9.97 – 11.03
Walking Distance (m)	159.60 ± 49.61	148.18 – 171.02

Source: The authors (2022).

Table 2. Correlation of Walking Distance with demographics and canal diameter at different lumbar levels

Variables		Walking Distance	
		r	p-value
Age (yrs.)		-0.14	0.23
Height (m)		0.17	0.13
Weight (kg)		0.12	0.27
BMI (kg/m^2)		0.01	0.97
Canal Diameter (mm)	L_1-L_2	0.10	0.40
	L_2-L_3	0.08	0.50
	L_3-L_4	0.18	0.11
	L_4-L_5	0.22	0.06
	L_5-S_1	0.29	0.01

*r= Pearson correlation coefficient
p-value≤0.05 defines significant results
Source: The authors (2022).

Table 3. Linear regression analysis between Canal diameter and Walking Distance

Dependent Variable		Walking Distance		
		R squared	Adjusted R squared	p-value
Canal Diameter (mm)	**L_1-L_2**	0.10	-0.04	0.40
	L_2-L_3	0.07	-0.08	0.51
	L_3-L_4	0.34	0.02	0.12
	L_4-L_5	.047	0.03	0.06
	L_5-S_1	0.08	0.07	0.01

*R-squared defines level of correlation
p-value≤0.05 defines significant results
Source: The authors (2022).

Prediction Equation

The formula for the prediction equation, Y= a + bX, was used to predict the value of canal diameter if the walking distance is known and vice versa. In the equation, Y is the dependent variable (walking distance), X is the independent variable (canal diameter), a is the constant, and b is the regression coefficient. The prediction equations for different lumbar spine levels are mentioned in table 4.

Table 4. Prediction equation for different lumbar levels

Spinal levels	Walking Distance
L_1-L_2	134 + 1.55 (CD)
L_2-L_3	143 +1.14 (CD)
L_3-L_4	123 + 2.67 (CD)
L_4-L_5	117 + 3.73 (CD)
L_5-S_1	93.5 + 6.28 (CD)

*CD= Canal diameter
Source: the authors (2022).

Discussion

Walking ability is the major outcome that could be used to correlate to the reduced canal diameters of the lumbar spine.[14] Many articles have been written for the interventions or preparing a treatment protocol for patients with LSS, but least literature is present on the association of clinical and radiological findings.[15] To the best of our knowledge, this is the first study to determine the correlation between the reduced spinal canal diameter in patients with lumbar spinal stenosis at different stenotic levels. This study has revealed a prediction equation of walking distance with reduced spinal canal diameter at different levels, i.e., L1-L2, L2-L3, L3-L4, L4-L5, L5-S1. In the present study, 75 patients (51 males and 24 females) with lumbar canal stenosis were recruited, and the result shows a fair positive correlation ($\rho = 0.29$) between canal diameter and walking distance, suggesting that reduced canal diameter at this level may lead to a reduction in walking distance of the patient.

No linear correlation was found between clinical and the radiological assessment in the study. The results of the present study are supported by a study conducted in 2014 in which a subject with severe stenosis was having greater walking distance as compared to a subject with moderate canal stenosis, also it was seen that leg pain was higher in subject with moderate lumbar canal stenosis when compared with those having severe lumbar canal stenosis.[16] The reason would be that the patients in the present study were having a mean age of 38.27 years; thus, there would not be degenerative changes as compared to the previous study with a mean age of 63 years.

Although previous studies have suggested that there is a high prevalence of LSS in males as compared to females, recent reports have suggested that LSS is 3-5 times more prevalent in women.[17] However, in our study, more men were involved as compared to females. This could be due to less reporting of females to clinical settings. As suggested by previous literature, there is a high prevalence of lumbar spinal stenosis at multiple levels in comparison to single level. Out of all patients recruited, the maximum number of patients were found to have minimum canal diameter at the level of L5-S1, which is highly associated with previous literature, showing a high prevalence of lumbar stenosis at the level of L4-L5 and L5-S1.[18] As vertebrae are anatomically more angulated at the level of L5-S1, there is a higher prevalence of degeneration due to hypermobility.[19]

The findings of the present study are similar to the previous study, suggesting that the increased BMI is one of the factors related to the decreased canal level— a correlation between the BMI and lumbar canal stenosis was established in a previous study.[20] It suggested that the individuals with kyphotic posture and having higher BMI are more likely to have LSS; it may be due to increased loading of the disc, there is increased degeneration leading to biomechanical changes.[21] Lumbar spinal stenosis is a syndrome that needs to be correlated both with the radiological as well as clinical features.[22] Therefore, the prediction equation established in the present study may help in predicting the walking distance using canal diameter and vice versa and could be used in clinical settings.

Clinical implication

The study might be helpful clinically in the prognosis of the condition and in estimating pain-free walking distance according to the diameter of the lumbar canal. The conservative treatment may be planned to keep the walking distance into consideration to avoid exertion beyond the proposed distance in designing a home protocol for the patients or combining it with a period of rest after specific exertion.

Limitations

- Single-centered study
- Less sample size

Conclusion

The relationship between the walking distance and the canal diameter has been established in previous studies. The findings of our present study suggest a fair positive correlation between the walking distance and canal diameter; also, to the best of our knowledge, this is the first study that may predict the approximate canal diameter by estimating the walking distance of the patient with symptoms of LSS or vice versa.

Authors' contributions

Singh G participated in the conceptualization, methodology, writing, data collection, and original draft preparation. Chahal A participated in the design of the study and provided research materials. Singh M participated in the writing, reviewing and editing.

Conflicts of interest

No financial, legal or political conflicts involving third parties (government, companies and private foundations, etc.) were declared for any aspect of the submitted work (including, but not limited to grants and funding, participation in an advisory board, study design, preparation manuscript, statistical analysis, etc.).

Acknowledgement

The authors are thankful to Prof. (Dr) Asir John Samuel and Dr. Saumya Kothiyal for their immense help in the statistical work and editing of the manuscript.

Indexers

The Journal of Physiotherapy Research is indexed by EBSCO, DOAJ, LILACS and Scopus.

References

1. Wei W, Xu C, Yang XJ, Lu CB, Lei W, Zhang Y. Analysis of Dynamic Plantar Pressure before and after the Occurrence of Neurogenic Intermittent Claudication in Patients with Lumbar Spinal Stenosis: An Observational Study. Biomed Res Int. 2020;2020:5043583. https://doi.org/10.1155/2020/5043583

2. Grelat M, Gouteron A, Casillas JM, Orliac B, Beaurain J, Fournel I, et al. Walking Speed as an Alternative Measure of Functional Status in Patients with Lumbar Spinal Stenosis. World Neurosurg. 2019;122:591-97. https://doi.org/10.1016/j.wneu.2018.10.109

3. Anasuya DG, Jayashree A, Moorthy NLN, Madan S. Anatomical study of lumbar spinal canal diameter on MRI to assess spinal canal stenosis. Int J Anat Res. 2015;3(3):1441-44. http://www.ijmhr.org/ijar.3.3/IJAR.2015.261.html

4. Dutta S, Bhave A, Patil S. Correlation of 1.5 Tesla magnetic resonance imaging with clinical and intraoperative findings for lumbar disc herniation. Asian Spine J. 2016;10(6):1115-21. https://doi.org/10.4184%2Fasj.2016.10.6.1115

5. Elhassan YAM, Ahmed AO, Ali QM, Handady SOM. Clinical Presentation of Lumbosacral Spinal Canal Stenosis Among Sudanese Patients. Glob J Orthop Res. 2019;1(3). http://dx.doi.org/10.33552/GJOR.2019.01.000512

6. Bumann H, Nüesch C, Loske S, Byrnes SK, Kovacs B, Janssen R, et al. Severity of degenerative lumbar spinal stenosis affects pelvic rigidity during walking. Spine J. 2020;20(1):112-20. https://doi.org/10.1016/j.spinee.2019.08.016

7. Comer CM, Redmond AC, Bird HA, Conaghan PG. Assessment and management of neurogenic claudication associated with lumbar spinal stenosis in a UK primary care musculoskeletal service: A survey of current practice among physiotherapists. BMC Musculoskelet Disord. 2009;10:121. https://doi.org/10.1186/1471-2474-10-121

8. Ahmad T, Goel P, Babu CSR. A study of lumbar canal by M.R.I. in clinically symptomatic and asymptomatic subjects. J Anat Soc India. 2011;60(2):184–7. https://doi.org/10.1016/S0003-2778(11)80022-5

9. Ammendolia C, Chow N. Clinical outcomes for neurogenic claudication using a multimodal program for lumbar spinal stenosis: A retrospective study. J Manipulative Physiol Ther [Internet]. 2015;38(3):188–94. http://dx.doi.org/10.1016/j.jmpt.2014.12.006

10. Jain N, Acharya S, Adsul NM, Haritwal MK, Kumar M, Chahal RS, et al. Lumbar canal stenosis: A prospective clinicoradiologic analysis. J Neurol Surgery, Part A Cent Eur Neurosurg. 2020;81(5):387–91. https://doi.org/10.1055/s-0039-1698393

11. Tomkins CC, Battié MC, Rogers T, Jiang H, Petersen S. A criterion measure of walking capacity in lumbar spinal stenosis and its comparison with a treadmill protocol. Spine (Phila Pa 1976). 2009;34(22):2444–9. https://doi.org/10.1097/brs.0b013e3181b03fc8

12. World Medical Association. Declaration of Helsinki, ethical principles for scientific requirements and research protocols. Bull World Health Organ. 2001;79(4):373-74. Cited: PMID: 11357217

13. Portney LG, Watkins MP. Foundations of clinical Research applications to practice. 3a ed. C.A.Davis; 2015.

14. Fors M, Enthoven P, Abbott A, Öberg B. Effects of pre-surgery physiotherapy on walking ability and lower extremity strength in patients with degenerative lumbar spine disorder: Secondary outcomes of the PREPARE randomised controlled trial. BMC Musculoskelet Disord. 2019;20:468. https://doi.org/10.1186/s12891-019-2850-3

15. Gaur P, Goyal M, Singh G. Manual therapy and canal enlargement exercises versus conventional physiotherapy in lumbar stenosis – a study protocol. Rev Pesqui Fisioter. 2021;11(3):549-60. https://doi.org/10.17267/2238-2704rpf.v11i3.3864

16. Kuittinen P, Sipola P, Saari T, Aalto TJ, Sinikallio S, Savolainen S, et al. Visually assessed se verity of lumbar spinal canal stenosis is paradoxically associated with leg pain and objective walking ability. BMC Musculoskelet Disord. 2014;15:348. https://doi.org/10.1186/1471-2474-15-348

17. Lee BH, Moon SH, Suk KS, Kim HS, Yang JH, Lee HM. Lumbar Spinal Stenosis: Pathophysiology and Treatment Principle: A Narrative Review. Asian Spine J. 2020;14(5):682–93. https://doi.org/10.31616%2Fasj.2020.0472

18. Lai MKL, Cheung PWH, Samartzis D, Cheung JPY. Prevalence and Definition of Multilevel Lumbar Developmental Spinal Stenosis. Glob Spine J. 2022;12(6):1084-90. https://doi.org/10.1177%2F2192568220975384

19. Mahato NK. Disc spaces, vertebral dimensions, and angle values at the lumbar region: a radioanatomical perspective in spines with L5-S1 transitions. J Neurosurg Spine. 2011;15(4):371-79. https://doi.org/10.3171/2011.6.spine11113

20. Hirano K, Imagama S, Hasegawa Y, Muramoto A, Ishiguro N. Impact of spinal imbalance and BMI on lumbar spinal canal stenosis determined by a diagnostic support tool: cohort study in community-living people. Arch Orthop Trauma Surg. 2013;133(11):1477-82. https://doi.org/10.1007/s00402-013-1832-4

21. Samartzis D, Karppinen J, Chan D, Luk KDK, Cheung KMC. The association of lumbar intervertebral disc degeneration on magnetic resonance imaging with body mass index in overweight and obese adults: a population-based study. Arthritis Rheum. 2012;64(5):1488-96. https://doi.org/10.1002/art.33462

22. Andrasinova T, Adamova B, Buskova J, Kerkovsky M, Jarkovsky J, Bednarik J. Is there a correlation between degree of radiologic lumbar spinal stenosis and its clinical manifestation? Clin Spine Surg. 2018;31(8):403-08. https://doi.org/10.1097/bsd.0000000000000681