ORIGINAL ARTICLE Anatomy Journal of Africa. 2023. Vol 12 (3): 2472-2480

VERTEBRAL CHANGES IN THE LUMBAR SPINE OF ADULTS PRESENTING WITH CHRONIC LOW BACK PAIN AT A REFERRAL HOSPITAL IN WESTERN KENYA

Papa Imade Stellah[1], Adero Sulman Walter[1], Domnic Marera[1], Otieno Washington[2] and Masoni Isaac[3].
[1]Department of Human Anatomy, School of Medicine, Maseno University, Kisumu, Kenya.
[2]Department of Radiology, School of Medicine, Maseno University, Kisumu, Kenya
[3]Oasis Multi-Specialty Hospital, Kakamega, Kenya
Corresponding Author: Dr. Papa Imade Stellah. **Email:** Stellahpapa2018@gmail.com
ORCID ID: https://orcid.org/0009-0003-6227-8593

ABSTRACT

Background: Chronic low back pain is a common musculoskeletal symptom affecting the lower part of the spine. It is described as pain and discomfort around the lumbar region lasting for more than twelve weeks. The symptoms of chronic low back pain might range from a dull ache to a stubbing or shooting sensation. This nature of pain may be localized around the axial region or radiate to the lower limbs affecting the patients' daily activities. The aim of this study, therefore, was to evaluate vertebral changes in the lumbar spine of adults presenting with chronic low back pain at Kakamega County General and Referral Hospital. **Methods:** This was a cross-sectional quantitative descriptive study whereby; patients' data was collected during patients' presentation at orthopedic outpatient clinic and MRI department. Purposive sampling of lumbar spine Magnetic resonance imaging scans was used to obtain data. A total of 144 patients were selected using the Yamane Taro formula. Anatomical vertebral changes of the lumbar spine were assessed from the selected MRIs to evaluate the structural causes of chronic low back pain. Descriptive statistics such as frequency and percentage were used in analyzing the data. **Results**: It was noted that osteophytes were the most pathological changes causing chronic low back pain while fractures were the least common. Osteophytic changes in the vertebra and desiccation of the intervertebral discs can predispose one to chronic lower back pain. **Conclusion**: The study recommends early screening and treatment of lower back pain to avert its sequelae.

Keywords: Chronic low back pain, lumbar spine, intervertebral disc
DOI: https://dx.doi.org/10.4314/aja.v12i3.3

INTRODUCTION

Lower back also referred to as the lumbar region or spine is described as the area of the spine located inferior to the twelfth thoracic vertebrae (T12) ending at the superior part of the first sacral vertebrae (S1) (Munsif, 2016). There are several structures that make up the lumbar spine namely the soft tissue, five movable vertebrae (L1- L5), intervertebral discs, zygapophyseal joint and neurovascular structures (Gray, 2000). The lumbar vertebrae (L1 –L5) are usually stacked together to form part of the spinal canal. The spinal canal acts as a tunnel housing the spinal cord and its respective nerves therefore preventing it from injury. The lumbar vertebra provides strong structural support to the upper part of the spine and is also connected to the pelvis (Netter, 2018). It bears most of the body's weight, stresses of lifting and carrying items.

Chronic low back pain (CLBP) is one of the common musculoskeletal symptoms that affect the lower part of the spine (El-Tallawy et al., 2021). It is described as pain and discomfort around the lumbar region lasting for more than twelve weeks (Traeger et al., 2019). The global burden

of disease studies (GBDS) defines chronic low back pain as "Pain in the area around the posterior aspect of the body from the lower margin of the twelfth rib to the lower gluteal folds with or without pain referred to one or both lower limbs that lasts for a period more than twelve weeks". Generally pain in the lower back can be associated with skin covering the lower back, muscles, lumbar vertebrae, intervertebral discs, spinal cord, neurovascular structures as well as internal organs of the pelvis and abdomen (Nelson et al., 2014).

Several anatomical structures are associated with chronic low back pain, thus the pain can either be nociceptive, nosiplastic, neuropathic or non-specific pain (Knezevic et al., 2017). Each of these pains can occur solely or overlap with each other based on the severity of pain or illness. The symptoms of chronic low back pain might range from dull ache to a stubbing or shooting sensation. This nature of pain may be localized around the axial region or radiate to the lower limbs affecting the patients' daily activities (Seminowicz et al., 2011). The effects of chronic low back pain can be very devastating in severity resulting into physical disability (Geurts et al., 2018). Severe low back pain after injury may be felt during coughing or micturition and can also be associated with loss of bowel or bladder control, weakness of the lower limbs and even fever (Dutmer et al., 2019). The severity of pain is dependent on the anatomical structure of the low back affected or injured (Cedraschi et al., 2016). Due to the severity and chronicity of pain, it has led to persistent absence from work and the commonest reason for seeking medical treatment in primary health care settings (A. Wu et al., 2020). The combination of these effects has resulted into social, psychological and economic problems in the society globally.

CLBP the commonest musculoskeletal symptom that affects the lumbar spine (El-Tallawy et al., 2021). It is the most common reason for outpatient musculoskeletal visits (Z. Wu et al., 2020) The point prevalence rate of CLBP by the International Association for the study of pain (IASP) in 2017 was estimated to be about 7.5 % of the global population. In Africa , the mean prevalence rate of CLBP is approximated to be 33% in a adolescents and 50% in adults (Mwangi et al., 2019) However, in Kenya there is sparse information regarding common spinal anatomical changes implicated in chronic low back pain. Lumbar spinal anatomical changes can predispose a patient to chronic low back pain (Hartvigsen et al., 2018). The effect may result into social, psychological and economic problems (Maher & Ferreira, 2022). Proper diagnosis and management can drastically improve patients quality of life, families and society (Gilligan et al., 2021). This study, therefore, sought to examine the lumbar spinal vertebral anatomical changes associated with CLBP. The knowledge obtained from this study will also be disseminated to the medical training institutions and all health care providers. The ministry of health will also benefit from the study since the study may help in the formulation of policies in regards to prevention, care and management of chronic low back pain.

MATERIALS AND METHODS

This was a cross sectional quantitative descriptive study where 144 study participants were purposively selected during their visit at orthopedic outpatient clinic and MRI department at Kakamega County Teaching and Referral Hospital, Western Kenya. The study included 99 women and 45 male patients who presented with history of chronic low back pain more than 12 weeks, referred to

radiology department for lumbar spine MRI scan and consented to the study. Autonomy and confidentiality were ensured after an Informed consent was obtained from study participants.

Sociodemographic characteristics of study participants were recorded in data collecting tool thereafter, lumbar spine MRI scan was done using Magsense 360, Mindray brand with 0.5 Tesla strength as per hospital's SOP. Axial, sagittal and coronal T1, T2 and T2 STIR weighted MRI scans of the lumbar spine were reviewed by the principal investigator to identify and document changes within the vertebra and intervertebral discs. The findings were corroborated by two board certified consultant radiologist. In cases where the two consultant radiologists differed, a third radiologist's opinion was sought as a tiebreaker. An observational descriptive statistic was used to evaluate vertebral changes associated with CLBP while a chi square test was used to find out the relationship between anatomical vertebral and intervertebral disc changes with CLBP. Research license was obtained from National Commission for Science, Technology & Innovation (NACOSTI) license No: NACOSTI/P/23/2.Authorization to collect data was granted by Kakamega county General Hospital Ethics Review committee under license No. ERC/196-04/2023.

RESULTS

Lumbar spine anatomical structures associated with chronic low back pain

Of the total respondents, 43.8% had abnormal vertebral changes. The most common pathology observed was presence of osteophytes at 31.3% whilst the least common was fractures at 4.2% (Table 1). Concerning the intervertebral discs, the most common abnormality was desiccation observed in 27.1% (n=39) of participants and the least common abnormality was present in only 2.1% (n=3) of participants (Table 2).

Anatomical vertebral changes of the lumbar spine may predispose one to chronic low back pain. These vertebral changes may present as a fracture of the vertebral end plate, osteophytes or modic changes (Figure 1a and b). A broken vertebral bone may predispose one to obvious deformity of the spine, severe pain and disability. Osteophytic changes of the vertebrae are usually smooth bone spurs that form between two adjacent bones. They have severe effects to tendons therefore resulting into joint damage. Modic changes are end plate sclerotic changes that result into ischemia of the vertebrae.

Pathological Intervertebral disc changes may predispose one to chronic lower back pain and may present as a disc bulge which is protrusion of inner part of the intervertebral disc into the spinal canal causing narrowing of the spinal canal and compression of the spinal nerves. (Figure 2a). Desiccation of the disc (Figure 2b) is basically dehydration of the disc which leads to rigidity and shortening of the disc space causing to chronic low back pain. Diffuse disc bulge is generalized protrusion of the disc which causes compression of bilateral foramina and their respective nerves thus resulting into pain (Figure 2c). Right and left paracentral disc bulge is protrusion of the disc on either side causing bilateral neural foramina narrowing and subsequent compression of the nerve roots (Figure 2d)

Table 1: lumbar vertebral changes of patients with CLBP

Lumbar spine anatomical structures		N	%
Vertebrae changes	Osteophytes	45	31.3%
	Fracture	6	4.2%
	Modic changes 1	12	8.3%
	Modic changes 2	0	0.0%
	Modic changes 3	0	0.0%
	Normal	81	56.2%

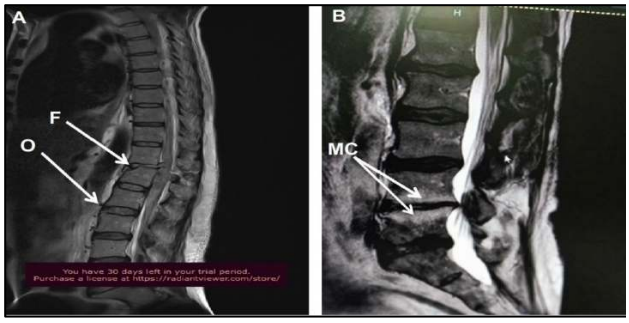

Figure 1: MRI sagittal view of the lumbar spine illustrating fracture at L1, Osteophytes at L2 and modic changes at end plates of L4 and L5. F- fracture, O- Osteophytes, MRI- Magnetic resonance imaging, MC-Modic changes L3-Lumbar vertebra three, L2-Lumbar vertebra two.

Table 2: Intervertebral discs of patients with CLBP

Intervertebral discs	Desiccation	39	27.1%
	Diffuse	30	20.8%
	Right paracentral discs bulge/prolapse	21	14.6%
	Left paracentral discs bulge/prolapse	3	2.1%
	Normal	51	35.4%

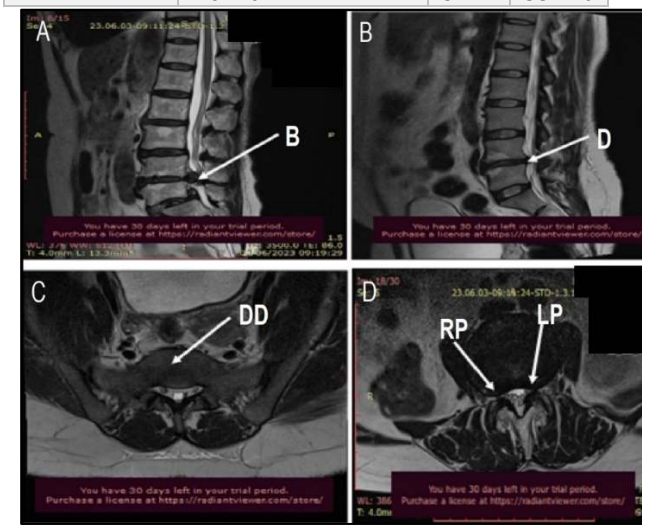

Figure 2: MRI sagittal view of the lumbar spine showing disc desiccation, bulge/prolapse, diffuse disc bulge, right and left paracentral disc bulges. D- Disc desiccation, B- Bulge, DD– Diffuse disc, RP-Right paracentral, LP-Left paracentral Changes and MRI - Magnetic resonance imaging.

Association between sociodemographic and severity of chronic low back pain

The analysis was conducted using the Chi-square test, and results were interpreted based on the p-value, with a level of significance set at $p<0.05$. In terms of the vertebrae changes, the Chi-square test revealed no significant association between gender and osteophytes ($\chi2=2.525$, $p=0.471$), with 22.9% (n=33) of females and 8.3% (n=12) of males presenting this condition. There was an equal distribution of fracture and Modic changes type 1 between both genders. A significant association was found between gender and disc desiccation ($\chi2=20.37$, $p<0.00042$*), with this condition more prevalent among females (20.8%, n=30) than males (6.3%, n=9). Diffuse disc changes were also more prevalent in females (18.8%, n=27) than males (2.1%, n=3). There was no significant difference in the prevalence of right paracentral disc bulge/ prolapse between females (8.3%, n=12) and males (6.3%, n=9). However, left paracentral disc bulge/prolapse was only observed in males.

Table 4 below presents the association between lumbar spine anatomical changes causing chronic low back pain with different age groups. For the vertebral changes, there was a statistically significant association with age (Chi-square=34.878, $p<0.0001$). Osteophytes were most prevalent in the 55-64 age group (14.6%). Fractures and Modic changes 1 seemed to be unrelated to age, as they occurred sporadically across the age groups. Desiccation and diffuse changes seemed to peak in the 55-64 age group (10.4% and 8.3%), respectively. Table 5 provides an overview of the association between lumbar spine anatomical causing chronic low back pain and weight categories. The vertebral changes showed a statistically significant association with weight (Chi-square=30.151, $p=0.00265$). Osteophytes were most prevalent in the 79-88 weight category (10.4%), whereas fractures and Modic changes 1 were observed mainly in higher weight categories (69-78 and above). For intervertebral discs, the association with weight was borderline significant (Chi-square=33.636, $p=0.006$).

Desiccation were most common in the 79-88 weight category (10.4%), while diffuse changes were relatively evenly distributed across all weight categories. The instances of right paracentral disc bulge/prolapse increased with weight, peaking in the above 88 weight category (6.3%).

Table 3. Association between lumbar spine anatomical changes causing chronic low back pain with gender

Lumbar spine anatomical structures		**Gender**				**Chi-square & p value**
		Female		Male		
		n	%	n	%	
Vertebrae changes	Osteophytes	33	22.9	12	8.3	Chi =2.525 df=3 p= 0.471
	Fracture	3	2.1	3	2.1	
	Modic changes 1	9	6.3	3	2.1	
	Modic changes 2	0	0.0	0	0.0	
	Modic changes 3	0	0.0	0	0.0	
	Normal	51	35.4	30	20.8	
Intervertebral discs	Desiccation	30	20.8	9	6.3	Chi=20.37 df=4 P=.00042*
	Diffuse	27	18.8	3	2.1	
	Right paracentral discs bulge/prolapse	12	8.3	9	6.3	
	Left paracentral discs bulge/prolapse	0	0.0	3	2.1	
	Normal	27	18.8	24	16.7	

Table 4. Association between lumbar spine anatomical changes causing chronic low back pain with age group.

Lumbar spine anatomical structures		**Age group**						**Chi-square & p value**
		34-44	**45-54**	**55-64**	**65-74**	**75-84**	**85>**	
		%	%	%	%	%	%	
Vertebrae changes	Osteophytes	4.2	8.3	14.6	2.1	2.1	0.0	Chi = 34.878 df=12 P=0.0001*
	Fracture	0.0	2.1	0.0	0.0	2.1	0.0	
	Modic changes 1	2.1	2.1	0.0	2.1	2.1	0.0	
	Modic changes 2	0.0	0.0	0.0	0.0	0.0	0.0	
	Modic changes 3	0.0	0.0	0.0	0.0	0.0	0.0	
	Normal	10.4	18.8	16.7	8.3	2.1	0.0	
Intervertebral discs	Desiccation	2.1	8.3	10.4	4.2	2.1	0.0	Chi = 25.736 Df=16 p=0.058
	Diffuse	2.1	6.3	8.3	2.1	2.1	0.0	
	Right paracentral discs bulge/prolapse	2.1	4.2	2.1	4.2	2.1	0.0	
	Left paracentral discs bulge/prolapse	0.0	2.1	0.0	0.0	0.0	0.0	
	Normal	10.4	10.4	10.4	2.1	2.1	0.0	

Table 5. Association between lumbar spine anatomical changes causing chronic low back pain with weight categories

		Weight categories					
Lumbar spine anatomical structures		48-58	59-68	69-78	79-88	88>	Chi square
		%	%	%	%	%	
Vertebrae changes	Osteophytes	6.3	2.1	6.3	10.4	6.3	Chi= 30.151 Df=12 p=0.00265*
	Fracture	0.0	0.0	2.1	0.0	2.1	
	Modic changes 1	0.0	0.0	4.2	2.1	2.1	
	Modic changes 2	0.0	0.0	0.0	0.0	0.0	
	Modic changes 3	0.0	0.0	0.0	0.0	0.0	
	Normal	4.2	10.4	6.3	14.6	20.8	
Intervertebral discs	Desiccation	2.1	2.1	4.2	10.4	8.3	Chi= 33.636 Df=16 p=0.006*
	Diffuse	4.2	6.3	2.1	2.1	6.3	
	Right paracentral discs bulge/prolapse	2.1	0.0	4.2	2.1	6.3	
	Left paracentral discs bulge/prolapse	0.0	0.0	0.0	2.1	0.0	
	Normal	2.1	4.2	8.3	10.4	10.4	

DISCUSSION

During Radiological examination of the lumbar spine, several anatomical changes can be seen in the vertebral bone, intervertebral discs, facet joints, spinal canal and ligamentum flavum. These anatomical changes can predispose one to CLBP. In the lumbar vertebral bone, anatomical changes such as osteophytes, fractures and sclerotic end plate changes are likely to occur in patients with CLBP as observed in radiological studies.

In the current study, osteophytes were the most common pathological change observed at 31.3% whilst the fractures were less prevalent at 4.2 % (Table 1). Osteophytes are growths that usually occur on joints of the lumbar vertebral region due to degenerative changes of the spine. It is mostly caused by poor postures, nutritional deficiencies and structural anomalies, this can cause disc breakdown thus causing increased movements of the spine and potentially cause pain due to injuries to the nerves, ligamental strains and sprains. The findings of this study correlate with (Goode et al., 2013) in which individuals who had radiographic vertebral osteophytic changes were likely to present with low back pain due to nerve injury, intervertebral disc anomaly , muscle dystrophy and ligament strains. However; another study (Wong et al., 2016) reported that although osteophytic changes of vertebral column were observed in 60% of women and 80% men above 50 years, it was not sufficient enough to correlate with low back pain.

With regards to intervertebral discs, anatomical changes such as desiccation, prolapse or disc bulge may predispose one to CLBP. The intervertebral discs are made up of spongy pads that act as shock absorbers between the two lumbar vertebrae. When dehydration occurs, it causes degenerated disc or desiccation resulting into loss of its normal height thus reducing the disc space. This results into compression of the surrounding spinal nerves causing pain. Desiccation of intervertebral disc is mostly caused by genetic factors affecting shape of the disc hence causing bulging due to reduced disc signal intensity. In this study, desiccation of the disc was the most common abnormality at 27.1%. Diffuse disc bulge was observed at 20.8% while left paracentral disc prolapse was the least at 2.1% in Table 4.3. These changes are more critical in helping radiologists achieve a high diagnostic power and indexes affecting the spinal column. The findings of this study are in tandem with (Lambrechts et al., 2021; Sundarsingh & Kesavan, 2020; Videman et al., 2009) in which patients who have intervertebral disc desiccation were more predisposed to CLBP which might be associated with muscle dystrophy and ligamental strains. In the current study, disc prolapse was also attributed to causing CLBP. Disc prolapse is a biomechanics contributor to CLBP (Adams, 2004). These findings are similar to (Van Der Windt et al., 2010) in which disc herniation causes radiculopathy and lumbar low back pain, as it was linked to sciatica.

Lumbar spine anatomical changes are the major factors causing chronic low back pain among most respondents in reference to age groups. In the current study, it was observed that vertebral changes; osteophytes, fractures and modic changes were the major contributing factors to CLBP. Osteophytes were the leading cause of CLBP within the ages between 45-64 years. These findings are similar to (Goode et al., 2013) when describing the osteophytic changes on vertebral column. Osteophytes are degenerative changes that progress with age, its severity worsening within the ages between 40-70 years. Modic changes also largely contributed to CLBP by causing spinal narrowing, facet changes among other components. Modic changes are sclerotic end plate changes that generally interfere with the alignment of the lumbar spine. A study in India (Ahdhi et al.,

2016; Farin et al., 2013) deduced that there was high association of chronic low back pain and sociodemographic factors where by most women with CLBP had anatomical changes of vertebral column as seen on radiographical images.

In the current study, desiccation and diffuse changes were common in the age group 55-64 years (10.4% and 8.3%) respectively. These anatomical changes mostly worsen with age and are more common in the said age group. (Raja'S et al., 2009) found out that most intervertebral desiccation were seen in elderly patients on radiological examination.(Videman et al., 2009) in an Indian based study used men of age group35-70 years to evaluate the intervertebral disc desiccation, herniation and prolapse. Advanced age had these features on radiological examinations. Therefore, this study postulates that with advancing age spinal biomechanics do occur and this can be a leading cause to CLBP. The present study noted that right paracentral disc bulge/prolapse increased with weight and was peak at 88kg (6.3%). These findings are similar to (Wahby & Edward, 2013; Wang et al., 2014) in which patient with weight within the normal ranges were less likely to have a disc prolapse. The study postulates that disc prolapse might have been more common among patients weighing more than 75kg because the heavier the trunk the more weight the lumbar vertebral body has to bear as all this weight is usually projected to the lumbar segment. This might cause obvious degeneration, reduced movement, muscle dystrophy and hypertrophy so as to sustain this level of weight. This might also cause anatomical anomalies on the spine.

It was observed that, there was a significant correlation between vertebral changes and weight of the respondents($p=0.00265$). Among the changes, the presence of osteophytes was the most common change among patients weighing 79 to 88kg. This findings are similar to (Wolfe et al., 2002) in which patients with weight above 74kg had osteophytes as examined on MRI. Osteophytic changes have multiple effect on the vertebral column and thus would more likely cause pain. Therefore, the study accords that overweight and obesity could probably interfere with anatomical structure of the vertebral column, causing disc prolapses, herniation, muscle dystrophy and hypertrophy thus leading to CLBP.

CONCLUSION

Based on this study it can be concluded that, osteophytic changes within the vertebra and desiccations of intervertebral discs were the most common lumbar spine anatomical changes that may predispose one to chronic low back pain.

Conflict of interest

No conflict of interest

REFERENCES

1. Adams, M. A. (2004). Biomechanics of back pain. *Acupuncture in medicine*, *22*(4), 178-188.
2. Ahdhi, G. S., Subramanian, R., Saya, G. K., & Yamuna, T. V. (2016). Prevalence of low back pain and its relation to quality of life and disability among women in rural area of Puducherry, India. *Indian Journal of Pain*, *30*(2), 111.
3. Cedraschi, C., Luthy, C., Allaz, A.-F., Herrmann, F., & Ludwig, C. (2016). Low back pain and health-related quality of life in community-dwelling older adults. *European Spine Journal*, *25*, 2822-2832.
4. Dutmer, A. L., Preuper, H. R. S., Soer, R., Brouwer, S., Bültmann, U., Dijkstra, P. U., Coppes, M. H., Stegeman, P., Buskens, E., & van Asselt, A. D. (2019). Personal and societal impact of low back pain: the Groningen spine cohort. *Spine*, *44*(24), E1443-E1451.

5. El-Tallawy, S. N., Nalamasu, R., Salem, G. I., LeQuang, J. A. K., Pergolizzi, J. V., & Christo, P. J. (2021). Management of musculoskeletal pain: an update with emphasis on chronic musculoskeletal pain. *Pain and therapy*, *10*, 181-209.
6. Farin, E., Gramm, L., & Schmidt, E. (2013). The patient–physician relationship in patients with chronic low back pain as a predictor of outcomes after rehabilitation. *Journal of behavioral medicine*, *36*, 246-258.
7. Geurts, J. W., Willems, P. C., Kallewaard, J.-W., van Kleef, M., & Dirksen, C. (2018). The impact of chronic discogenic low back pain: costs and patients' burden. *Pain research & management*, *2018*.
8. Gilligan, C. J., Cohen, S. P., Fischetti, V. A., Hirsch, J. A., & Czaplewski, L. G. (2021). Chronic low back pain, bacterial infection and treatment with antibiotics. *The Spine Journal*, *21*(6), 903-914.
9. Goode, A. P., Carey, T. S., & Jordan, J. M. (2013). Low back pain and lumbar spine osteoarthritis: how are they related? *Current rheumatology reports*, *15*, 1-8.
10. Hartvigsen, J., Hancock, M. J., Kongsted, A., Louw, Q., Ferreira, M. L., Genevay, S., Hoy, D., Karppinen, J., Pransky, G., & Sieper, J. (2018). What low back pain is and why we need to pay attention. *The Lancet*, *391*(10137), 2356-2367.
11. Knezevic, N. N., Mandalia, S., Raasch, J., Knezevic, I., & Candido, K. D. (2017). Treatment of chronic low back pain–new approaches on the horizon. *Journal of pain research*, 1111-1123.
12. Lambrechts, M. J., Pitchford, C., Hogan, D., Li, J., Fogarty, C., Rawat, S., Leary, E. V., Cook, J. L., & Choma, T. J. (2021). Lumbar spine intervertebral disc desiccation is associated with medical comorbidities linked to systemic inflammation. *Archives of Orthopaedic and Trauma Surgery*, 1-11.
13. Maher, C., & Ferreira, G. (2022). Time to reconsider what Global Burden of Disease studies really tell us about low back pain. *Annals of the Rheumatic Diseases*, *81*(3), 306-308.
14. Mwangi, A., Downing, R., & Elias, H. E. (2019). Low back pain among primary school teachers in Rural Kenya: Prevalence and contributing factors. *African Journal of Primary Health care and family medicine*, *11*(1), 1-7.
15. Nelson, A. E., Allen, K. D., Golightly, Y. M., Goode, A. P., & Jordan, J. M. (2014). A systematic review of recommendations and guidelines for the management of osteoarthritis: the chronic osteoarthritis management initiative of the US bone and joint initiative. Seminars in arthritis and rheumatism,
16. Netter, F. H. (2018). *Atlas of Human Anatomy: Latin Terminology E-Book: English and Latin Edition*. Elsevier Health Sciences.
17. Raja'S, A., Corso, J. J., Chaudhary, V., & Dhillon, G. (2009). Desiccation diagnosis in lumbar discs from clinical MRI with a probabilistic model. 2009 IEEE International Symposium on Biomedical Imaging: From Nano to Macro,
18. Seminowicz, D. A., Wideman, T. H., Naso, L., Hatami-Khoroushahi, Z., Fallatah, S., Ware, M. A., Jarzem, P., Bushnell, M. C., Shir, Y., & Ouellet, J. A. (2011). Effective treatment of chronic low back pain in humans reverses abnormal brain anatomy and function. *Journal of Neuroscience*, *31*(20), 7540-7550.
19. Sundarsingh, S., & Kesavan, R. (2020). Diagnosis of disc bulge and disc desiccation in lumbar MRI using concatenated shape and texture features with random forest classifier. *International Journal of Imaging Systems and Technology*, *30*(2), 340-347.
20. Traeger, A. C., Buchbinder, R., Elshaug, A. G., Croft, P. R., & Maher, C. G. (2019). Care for low back pain: can health systems deliver? *Bulletin of the World Health Organization*, *97*(6), 423.

21. Van Der Windt, D. A., Simons, E., Riphagen, I. I., Ammendolia, C., Verhagen, A. P., Laslett, M., Devillé, W., Deyo, R. A., Bouter, L. M., & de Vet, H. C. (2010). Physical examination for lumbar radiculopathy due to disc herniation in patients with low-back pain. *Cochrane database of systematic reviews*(2).
22. Videman, T., Saarela, J., Kaprio, J., Näkki, A., Levälahti, E., Gill, K., Peltonen, L., & Battié, M. C. (2009). Associations of 25 structural, degradative, and inflammatory candidate genes with lumbar disc desiccation, bulging, and height narrowing. *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology*, *60*(2), 470-481.
23. Wahby, D. M. A.-A., & Edward, S.-C. (2013). *Evaluation of lumber lordotic angle in patients with inter vertebral disc prolapse using Cobb's method* sudan university of science and technology].
24. Wang, S., Park, W. M., Kim, Y. H., Cha, T., Wood, K., & Li, G. (2014). In vivo loads in the lumbar L3–4 disc during a weight lifting extension. *Clinical Biomechanics*, *29*(2), 155-160.
25. Wolfe, F., Lane, N. E., & Buckland-Wright, C. (2002). Radiographic methods in knee osteoarthritis: a further comparison of semiflexed (MTP), schuss-tunnel, and weight-bearing anteroposterior views for joint space narrowing and osteophytes. *The Journal of Rheumatology*, *29*(12), 2597-2601.
26. Wong, S. H. J., Chiu, K. Y., & Yan, C. H. (2016). osteophytes. *Journal of orthopaedic surgery*, *24*(3), 403-410.
27. Wu, A., March, L., Zheng, X., Huang, J., Wang, X., Zhao, J., Blyth, F. M., Smith, E., Buchbinder, R., & Hoy, D. (2020). Global low back pain prevalence and years lived with disability from 1990 to 2017: estimates from the Global Burden of Disease Study 2017. *Annals of translational medicine*, *8*(6).
28. Wu, Z., Zhu, Y., Xu, W., Liang, J., Guan, Y., & Xu, X. (2020). Analysis of biomechanical properties of the lumbar extensor myofascia in elderly patients with chronic low back pain and that in healthy people. *BioMed Research International*, *2020*.