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Research article

Low-field Magnetic Resonance Imaging Assessment of Relationship between Facet Joint Tropism and Lumbar Disc Herniation in a Cohort of Black Africans with Low Back Pain

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ABSTRACT

Facet tropism is the difference in orientations between the right and left facet joints and has been argued to play a causative role in disc herniation. This study aimed to determine the association between facet tropism and lumbar disc herniation among black Africans. This was a comparative study of 136 patients with low back pain, comprising 91 cases with disc herniation and 45 controls showing normal discs. Axial and sagittal T2-weighted images obtained from a 0.36-Tesla MRI scanner were used for evaluation. Facet angles were measured using the method described by Noren *et al* and a substantial facet tropism was defined as a difference of mean + 1SD (Standard Deviation) between the bilateral facet joint angles obtained in the controls. A disc herniation was defined as a focal prolapse of disc material beyond the posterior vertebral margin within 90 degrees of disc circumference. Of the 91 images evaluated, herniated disc was noted at the L1/L2 level in 8 cases; L2/L3 in 31; L3/L4 in 62; L4/L5 in 88, and at L5/S1 in 58, with many cases showing multilevel disc prolapse. Adjusting for the effects of age and gender, multiple logistic regression was performed to determine the difference in mean facet tropism between the cases and the controls. Greater degree of facet tropism was noted among the cases compared to controls at all lumbar motion segments ($p<0.05$).
Facet tropism among black Africans is associated with lumbar disc herniation at all the lumbosacral motion segments.

Keywords: *Facet joint, Tropism, Disc herniation, Lumbosacral, Spine*

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INTRODUCTION

Low back pain (LBP) is one of the most common clinical presenting complaints as well as for occupational absenteeism. With a global life-time prevalence as high as 84%, it is associated with a 12% disability rate (Sundell, Bergström and Larsén, 2019) Disc degeneration, particularly herniated nucleus pulposus (HNP), and its resultant LBP are thus a major health care problem sometimes with devastating effects and negative impacts on the quality of life for millions of people, leading to heavy health-care cost burden and work loss (Gruber *et al*., 2014).

Whether or not there is a relationship between substantial facet joint tropism and lumbar disc prolapse has been a subject of raging debates; with some studies corroborating (Chadha *et al*., 2013; Chotiyarnwong and Pichaisak, 2014; Degulmadi *et al*., 2019) and others refuting (Ko and Park, 1997; Kunakornsawat *et al*., 2007; Zhou *et al*., 2018) it. Apart from the high-field MR systems, low-field-strength MRI can reliably be used to evaluate the facet joints and measure joint anthropometric characteristics.(Kong *et al*., 2009; Do *et al*., 2011; Gulek *et al*., 2013) Facet tropism is defined as the difference between the angles of orientation of the right and left vertebral facet joints at each disc level.(Do *et al*., 2011) Thus, one of the joints may be more coronally oriented than the other. Farfan and Sullivan (1967) were the first to suggest a correlation between facet tropism and lumbar disc herniation by showing the tendency of disc herniation to occur on the side of the more coronally-facing facet joint. Thus facet joint asymmetry is a potential risk factor for LBP as it predisposes the individual to degenerative spine disease (Do *et al*., 2011) by increasing the effect of anterior shear forces on the spine (Kim *et al*., 2013)

However, there is paucity of data in sub-Saharan Africa on the relationship between facet joint tropism and lumbar disc herniation. Therefore, our aim was to determine the association between facet joint tropism and lumbar disc herniation in patients with low back pain. The study also aimed to define the cut-off values for substantial facet tropism from values obtained in the controls as well as to determine the association between the direction of facet joint tropism and the side of lumbar disc herniation at each motion segment).

MATERIALS AND METHODS

Study area: This was a prospective comparative study carried out in Ibadan, Nigeria between March and November 2016.

Sampling: The sample *size was* calculated using the formula for estimating two means by Kirkwood and Sterne: $N=2(Z_\alpha + Z_\beta)^2\sigma^2/(\mu_1 - \mu_2)^2$

Where

Z_α = Standard normal deviate corresponding to a 2-sided level of significance of 5% = 1.96

Z_β= Standard normal deviate corresponding to a power of 80% = 0.84

σ = Standard deviation of facet joint tropism (at L5/S1 in adult controls) = 4.06 (Koet al)

$\mu 1 - \mu 2$ = Difference in mean facet tropisms between herniated (μ_1=5.86) and control (μ_2=7.77) = 1.91

We obtained a minimum number of 80 patients with lumbar disc herniation. Adjusting with a 10% non-response rate and using a 2:1 ratio for controls (i.e. 40 patients with normal discs). However, a total of 136 participants, consisting of 91 cases and 45 controls were actually recruited and completed the study.

A total of 136 adult patients with low back pain presenting for lumbosacral MRI were selected after satisfying the study eligibility criteria. Patients with single- or multi-level disc herniation served as the cases while patients who had lumbar spine MRI for other indications including low back pain but show normal discs served as controls. Patients with previous spinal surgery, previous history of spinal trauma, spondylolisthesis, severe facet joint degenerative disease precluding adequate joint assessment and those with severe scoliosis were excluded from the study.

Ethical consideration: Informed consent was obtained from all participants and institutional ethical approval was obtained from the UI/UCH institutional review board.

Methodology

MRI technique: The lumbar spine MRI was performed using a 0.36T MRI scanner (Magsense 360, Mindray). Axial images were obtained parallel to the vertebral endplate using a 4mm slice thickness. Axial and sagittal T2-weghted fast spin echo images (TR=2420.00–6509.60ms, TE=96.00–108.00ms) were acquired and assessed on a Clear Canvas Workstation v.2.0 SP1(ClearCanvas Inc., Toronto, Canada).

Determination of imaging parameters: Using method described by Noren *et al*.(Noren *et al.*, 1991) the degree of facet joint tropism was determined from the axial T2-weighted image for each lumbar motion segment from L1/L2 to L5/S1. This was done for each spinal unit at the disc level. Here, the axial image that clearly showed both facet joints was analysed, using the Clear Canvas image review workstation, for the measurement of facet angles, (Fig. 1). A reference sagittal line was drawn to pass through the center of the disc and the base of the spinous process. Facet line was then drawn passing through the anteromedial and the posterolateral margins of the superior articular facet to intersect the sagittal line bilaterally. The facet angle (a or b) is the angle between the facet line and the reference sagittal line. The difference of the right and left facet angles (a-b) gives the magnitude of the facet joint tropism. The mean of 2 sets of facet angle measurements obtained at different times was recorded by the same radiologist before facet tropism determination was done, in order to minimise intra-observer bias. A senior radiologist (GO) independently obtained facet angle measurements in 25% of the study sample and the level of inter-rater reliability was determined for reproducibility. The inter-ratter reliability as determined by intraclass correlation coefficient was 0.681(CI: 0.40, 0.83 p<0.001). Mean +1SD of the facet tropism value at each lumbar motion segment in the controls was used as the cut-off value of substantial facet tropism for the equivalent disc level in the cases. When the more coronally-oriented facet angle is on the right, direction of facet joint asymmetry is regarded as positive and negative when the more coronally-oriented facet angle is on the left. Measurements from patients with disc herniation (cases) (Plate 2) were then compared with those of equivalent disc levels in patients with normal discs (controls) (Plate 1).

A disc herniation was considered only as a focal prolapse of the disc material beyond the posterior vertebral margin over < 90 degrees of the disc circumference, which was determined from both the axial and sagittal T2-weighted images (fig.3). The determination of disc herniation was however done prior to and independent of facet tropism assessment to minimise bias in facet angle measurement.

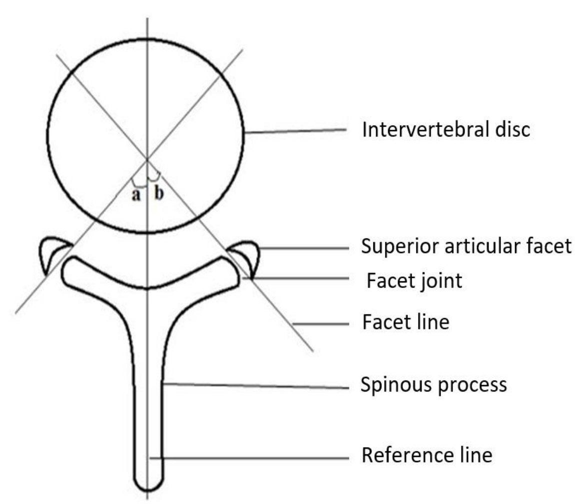

Figure 1
Schematic Diagram of the technique used for measuring the Facet Joint Tropism. (Degree of facet joint tropism = a-b)

Statistical analysis: The statistical package for social sciences (SPSS inc. Chicago, IL, USA.) version 20 was used for analysis. Mean and standard deviation were used to summarise quantitative variables such as the age of the patients and the degree of facet joint tropism for each lumbar motion segment while the chi-square test was used to assess the association between the direction of facet asymmetry and the side of lateral disc herniation. Odds ratios were calculated to assess the strengths of associations. Multiple logistic regression was applied to determine the relationship between facet tropism and the occurrence of lumbar disc herniation, while adjusting for possible confounders such as age and gender. A P-value <0.05 was considered as significant for this study.

RESULTS

Demographic characteristics of the study population: There were 91 participants with disc herniation, many of them with multi-level disc herniation, at various levels of the lumbosacral spine. Thus, evidence of HNP was noted in 8 cases at L1/L2; 31 at L2/L3; 62 at L3/L4; 88 at L4/L5 and 58 at L5/S1 disc levels. There were 45 controls without evidence of disc herniation. The cases consisted of 61 males (67%), while the control group had 26 males (57.8%) with male to female ratios of 2.03:1 and 1.37:1 respectively (P=0.344). The mean age for the cases was 58.78±12.04 years compared with 41.31±12.60 years in the control group (p<0.05).

Facet tropism cut-off: The distribution of facet tropism among the control group had a mean+1SD of 10.29° at L1/L2, 7.97° at L2/L3, 8.67° at L3/L4, 9.07° at L4/L5 and 9.77° at L5/S1. These were the cut-off values for substantial facet tropisms at the corresponding levels for both cases and controls.

Association between facet tropism and disc herniation: Multiple logistic regression was performed to model the relationship between facet joint tropism and lumbar disc herniation, while adjusting for the effect of age and gender. The result indicate that the mean degree of facet joint tropism, adjusted for age and gender, is greater among cases compared to controls at all the lumbar motion segments (OR>1)(p<0.05) (Table 1).

Table1:
Association between facet joint tropism and lumbar disc herniation at each motion segment

Facet Tropism	Exp(β)	P -value	95% Confidence Interval	
			Lower	**Upper**
L1/L2	1.31	0.018	1.05	1.64
L2/L3	1.84	0.006	1.19	2.82
L3/L4	1.75	<0.001	1.33	2.32
L4/L5	1.75	<0.001	1.40	2.19
L5/S1	2.15	<0.001	1.49	3.09

Exp(β)= odds ratio

Association between the direction of facet tropism and the side of postero-lateral disc herniation: Regarding the relationship between the direction of facet joint asymmetry and the side of lumbar disc herniation, there was no statistically significant difference in the proportion of positive or negative tropism between the right-sided and the left-sided herniated lumbar discs (Table 2).

Table 2:
Difference in the proportion of positive or negative tropism between the right-sided and the left-sided herniated lumbar discs

Lumbar Motion Segments	Side of Herniation	Facet Tropism Asymmetry		
		Negative	**Positive**	**P-value**
L1/L2	Right	0(0.0%)	1 (100%)	
	Left	0(0.0%)	0(0.0%)	
L2/L3	Right	0(0.0%)	3(37.5%)	0.157
	Left	4(100%)	5(62.5%)	
L3/L4	Right	8(66.7%)	5(41.7%)	0.219
	Left	4(33.3%)	7(58.3%)	
L4/L5	Right	6(54.5%)	6(40.0%)	0.462
	Left	5(45.5%)	9(60.0%)	
L5/S1	Right	5(50.0%)	4(44.4%)	0.809
	Left	5(50.0%)	5(55.6%)	

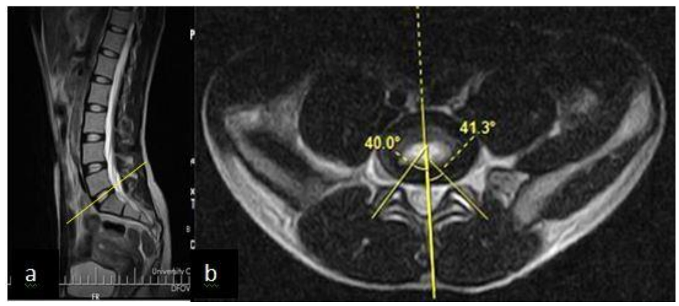

Plate 1
(a) Sagittal and (b) axial (L5/S1) T2-weighted lumbar spine MRI of a 30-year-old female patient with low back pain showing non-herniating normal intervertebral disc but some L5/S1 facet joint tropism (41.3° 40.0° = 1.3°). This was, however, within normal limits.

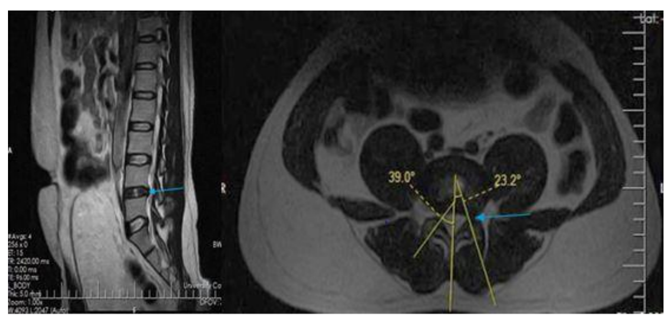

Plate 2
(a) Sagittal and (b) axial (L4/L5) T2-weighted lumbar spine MRI of a 38-year-old male patient with low back pain showing a left posterolateral L4/L5 disc herniation (arrow) and associated significant facet joint tropism (39.0° 23.2° = 15.8°).

DISCUSSION

Low back pain has remained a major problem of public health importance, with rising global, African and Nigerian prevalence rates; these, as high as 84%(Sundell, Bergström and Larsén, 2019), 64.07%(Kasa *et al*., 2020) and 46.8%(Ogunbode, Adebusoye and Alonge, 2013) respectively. Disc herniation has been demonstrated to show a causal relationship with LBP in many reports.(Lee *et al*., 2013; Topcu, 2017; Shin *et al*., 2019) Facet tropism is measurable as the difference between the angles of orientation of the right and the left facet joints and was first proposed as a possible cause of disc herniation by Farfan *et al*.(Farfan and Sullivan, 1967)Hence, facet joint asymmetry has been implicated in the pathogenesis of LBP.(Yang *et al*., 2020) Low-field MRI as low as 0.2T has reliably been used to evaluate facet joint anthropometric characteristics and intervertebral disc changes(Solgaard Sorensen *et al*., 2006; Kong *et al*., 2009; Do *et al*., 2011; Gulek *et al*., 2013)

Although facet joint tropism has been defined as the difference in the orientation between the right and the left facet joints, different threshold values have been arbitrarily assigned to what determines ‘substantial’ facet joint tropism by different studies. This study defined the cut-off value for substantial facet asymmetry at each lumbar motion segment as the mean + 1 SD of the facet tropism at that segment, using values obtained from the control group. Other studies (Ko and Park, 1997; Kong *et al*., 2009; Do *et al*., 2011) have similarly defined substantial facet joint tropism at each motion segment as asymmetry greater than the mean + 1SD of the bilateral angle difference at that segment. This quantitative definition was used in order to eliminate the possible confounding effect of racial and geographical variations of facet tropism which may explain the varying threshold values obtained ranging from 7° in the study done by Kong *et al*(Kong *et al*., 2009) to as high as 15° in the study conducted by Ko *et al*.(Ko and Park, 1997) However, Lee *et al* and Noren *et al*, pegged substantial tropism cut-off values at 10° and 5° respectively.

Several studies (Noren *et al*., 1991; Do *et al*., 2011; Chadha *et al*., 2013; Wang and Zhou, 2016; Degulmadi *et al*., 2019) have shown a significant positive association between substantial facet tropism and lumbar disc herniation. This is consistent with the finding in this study which demonstrated a statistically significant higher odd ratio of substantial facet asymmetry among the cases when compared to controls, at all lumbar motion segments. This is supported by separate biomechanical studies by Weng *et al* (2022) and Masharawi *et al* (2005), who reported an increased risk of intervertebral disc injury due to facet joint axial rotation caused by the joint asymmetry. In contrast, some other studies (Ko and Park, 1997; Kunakornsawat *et al*., 2007; Liu *et al*., 2017; Zhou *et al*., 2018) have refuted this hypothesis. These conflicting findings have been attributed to the different methodologies and definitions of significant facet tropism used in these studies (Ko and Park, 1997)

Despite the significant association between facet joint asymmetry and lumbar disc herniation, the current study showed that there was no significant relationship between the direction of tropism and the side of posterolateral herniation. This is corroborated by Chadha *et al* (Chadha *et al*., 2013) and Cassidy *et al* (Cassidy *et al*., 1992), who in separate studies, showed no significant difference in the distribution of the more obliquely-oriented facet joint in relation to the side of lateral disc herniation. However, this is in contrast with the findings by Ghandhari *et al* (Ghandhari *et al*., 2018) and Ke *et al* (Ke *et al*., 2023) who independently found a significant association between the side of disc herniation and the more sagittally-facing facet joints. The contrary finding in the current study might be due to the relatively small sample size (varying from 12 at L2/L3 to 26 at L4/L5 motion segments) of the cases of lateral disc herniation compared with Ghandhari *et al* and Ke *et al* who studied 129 and 529 patients respectively.

The methodology used for the current study was based on a case-control study design. However, most of the studies (Cassidy *et al*., 1992; Lee, Ahn and Lee, 2006; Kunakornsawat *et al*., 2007; Chadha *et al*., 2013) on facet joint asymmetry were cross-sectional, and used values from an adjacent normal intervertebral disc as the control for a herniated disc. This was noted as a significant limitation to their study findings. (Do *et al*., 2011; Chadha *et al*., 2013)This is because the degree of facet asymmetry at the normal disc level may be distorted by the same factors determining facet asymmetry at the adjacent herniated disc and hence may bias the study findings. Thus, this study enrolled subjects with normal intervertebral discs as controls, as previously performed in some other studies (Ghandhari *et al*., 2018; Zhou *et al*., 2018), as this is expected to improve the validity of the study outcomes.

There were few limitations encountered in the current study. The use of symptomatic patients, even with normal discs on MRI, might not have been ideal for use as controls. Recruiting asymptomatic controls was difficult due to the high cost of MRI investigation, limiting its use to mostly symptomatic patients who could afford the fee-for-service health system. The use of retrospective images for control may not been ideal. However, due to the few and limited number of patients with lumbosacral MRI images that show normal discs, it was difficult to obtain an equal number of controls as cases within the study period. In order to reduce bias, controls were recruited, as much as possible, from prospective images and then added to retrospective ones to achieve required number of controls. The use of a relatively small sample size for the controls as well as detection of only few cases of lateral herniation among the cases might have limited the power of the study to detect little difference in some of the variables between the cases and the controls. Exact age and gender matching was not achieved. However, gender difference does not appear in the literature to make a significant difference in the presence and severity of facet joint tropism in the lumbosacral spine. Nevertheless, regression analysis helped control the differences.

In conclusion, a positive imaging correlation exists between substantial facet joint tropism and lumbar disc herniation at all lumbar motion segments in Nigerian adults with low back pain. However, the direction of facet joint tropism is not associated with the side of lateral disc herniation. These findings indicate that substantial facet joint asymmetry may represent a contributory risk factor for lumbar disc herniation and subsequent low back pain in Nigerian patients. Further investigative studies into the possible effects of tropism may explore more in-depth relationships in disc disease and degeneration in people of black ancestry.

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