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Original Contribution

Sonoanatomic indices of lumbar facet joints in patients with facetogenic back pain in comparison to healthy subjects☆

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ABSTRACT

Background: Nowadays, ultrasound is increasingly used with a great accuracy in performing nerve blocks for facet joint disease.
Objectives: To measure sonoanatomic characteristics for the facet joints of lumbar vertebras in patients with facetogenic pain and healthy volunteers.
Study design: Cross-sectional, observational study.
Setting: University-affiliated Specialty Clinic for Pain Management.
Patients: Twenty patients with facet joint disease (FJD) and 40 healthy volunteers (HVGs) were matched for age and sex, height, and weight. Patients with FJD were referred with complaints of pain in the left lumbar facet joints that twice responded favorably to ultrasound guided medial branch blocks.
Intervention: Medial branch blocks.
Measurement: The interfacet joint distance (IFJD) between the third, the fourth, and the fifth lumbar vertebras and their depth from the level of skin (DFS) were measured bilaterally, using a high-resolution ultrasound in both groups.
Results: Thirty-one men and 29 women with average age of 41.5 ± 9.5 years were enrolled. The IFJD for L3-L4 was 31.5 ± 4.0 mm on the left side and 31.8 ± 4.0 mm on the right side. The IFJD for L4-L5 was 31.3 ± 4.4 mm on the left side and 31.5 ± 4.0 mm on the right side. The IFJD was uniformly 2.2 mm shorter in the FJD group than those in the HVG group ($P = .021$). The measurements of DFS increased in lower vertebras (L3 < L4 < L5), bilaterally. With an exception of the left facet joints of L4 ($P = .016$), DFS measurements were similar in FJD and HVG groups.
Limitations: The diagnosis of facet joint disease was merely clinical and the total number of the patients was relatively small.
Conclusion: Interfacet distances of the lumbar vertebras are smaller in patients suffering from degenerative FJD compared with HVGs. Degenerative changes of intervertebral discs and partial reduction of space between 2 adjacent vertebras may contribute to this observation.

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1. Introduction

Low back pain (LBP) is the most common complaints of the patients referred to a pain clinic. The LBP has multiple etiologies and according to the International Organization Pain, pain caused by lumbar facet joint is responsible for 15%-45% of all reported cases. The terminology of facet syndrome was first used in 1933 by Ghormley, which has separated this condition from the other causes of LBP [1,2]. Among other major etiologies of lumbar pain, intervertebral disc herniation and inflammation of the sacroiliac (SI) joint can be noted [3]. Pain associated with lumbar

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facet joint is generally localized over the involved joint; however, it may be referred to back and thigh. Due to this latter pattern of spread, it is not uncommon for the facet joint pain to be falsely perceived as radicular pain (pseudoradiculopathy).

Diagnosis of facet joint disease (FJD) is generally made using 4 physical examination components of Revel criteria (standing flexion, returning from standing flexion, standing extension, and the extension rotation test), which describe the pain relief with rest [4]. Dependence on the lack of pain exacerbation by coughing or bending forward has yielded conflicting results [5]. Although both the computerized tomographic (CT) scanning and the magnetic resonance imaging (MRI) provide valuable information on the presence of degenerative joint disease, they lack the ability to make a final diagnosis of FJD. In another study, positron emission tomography scanning was used for diagnosis with a high sensitivity. However, low specificity (lower true-positive rates) and excessive cost of the unit have been limiting factor for its widespread use [6].

Injections of corticosteroids and local anesthetics into the joint or around the medial branch nerves have been used both for treatment and diagnosis of FJD. The use of these blocks to diagnose FJD carries significant rates of false negative due to variation in the anatomical path of the medial branch nerves and false positive due to the block of the other branches of the intervertebral nerves [7]. Performing multiple blocks while increasing its sensitivity and specificity in diagnosis of FJD is both money and time consuming. The use of ultrasound technology has lately become popular among the physicians practicing interventional pain management worldwide. In addition, the ultrasound technology has enabled us to define new sonoanatomic landmarks, which not only can be used in the success of the guided blocks as they may also be applied in diagnosis FJD in patients with LBP.

The main objective of this study was to identify sonoanatomic characteristics that are associated with FJD of the 3 lower lumbar vertebras (L3-L5). By the use of ultrasound, we measured interfacet joint distance (IFJD) as the primary end point and the distance of the facet joints from the skin (DFS) as the secondary end point in patients with established diagnosis of FJD and compared with healthy population. We hypothesized that both IFJD and DFS are decreased in patients with FJD.

2. Methods

The scientific merit, study design and protocol, ethical conduct, and the forms used for obtaining informed consents were reviewed and approved by the institutional review board of Rasul-e-Akram hospital an affiliate of Iran University of Medical Sciences. Although the study was determined to be noninterventional and observational in nature, special care was taken to assure that the privacy of the participants.

The following are the inclusion and exclusion criteria and definitions: patients between ages of 18 to 60 years old with established diagnosis of FJD, who were referred to the pain clinic with LBP, were screened. Demographic and anthropometric data and past medical history were gathered and recorded in the prepared sheets. To confirm a diagnosis of FJD, the patients must have previously received medial branch block on 2 occasions with more than 80% decrease in the severity of LBP after each block for at least 2 weeks [8]. After obtaining an informed consent, 20 patients with FJD and 40 healthy volunteers (HVG) were enrolled in this study (Fig. 1). The HVG were enrolled in a ratio of 2:1 after they were matched for sex, age, body habitus, and the anthropometric variables (eg, height and weight). Patients with known diagnoses of SI joint pathology, spinal stenosis, spondylolysis and spondylolisthesis herniated discs, failed back syndrome, history prior back surgery, and those with diabetic neuropathy were excluded. The patients with past medical history of chronic use of oral corticosteroids, chronic kidney diseases, those with hyperparathyroidism, vitamin D deficiency, and alcohol abuse were also excluded.

The following are the primary and secondary end points: patients were placed on Wilson table in prone position to eliminate lumbar lordosis. All measurements were obtained using MicroMaxx (SonoSite, Bothell, WA) and a curved C-60 2-6 MHz probe. For measurements of sonoanatomic indices, we used a 3-step sonographic scanning method that was described by Loizides et al [9]. In brief, by using the iliac crest index as the anatomic landmark, the vertebral level was determined in midline sagittal view of the spine. By moving the probe in parasagittal view, transverse processes of each vertebra, superior articular pillars, and facet joints were identified on both sides. The distance between the facet joints (IFJD) of L3-L4 vertebras and L4-L5 was measured on

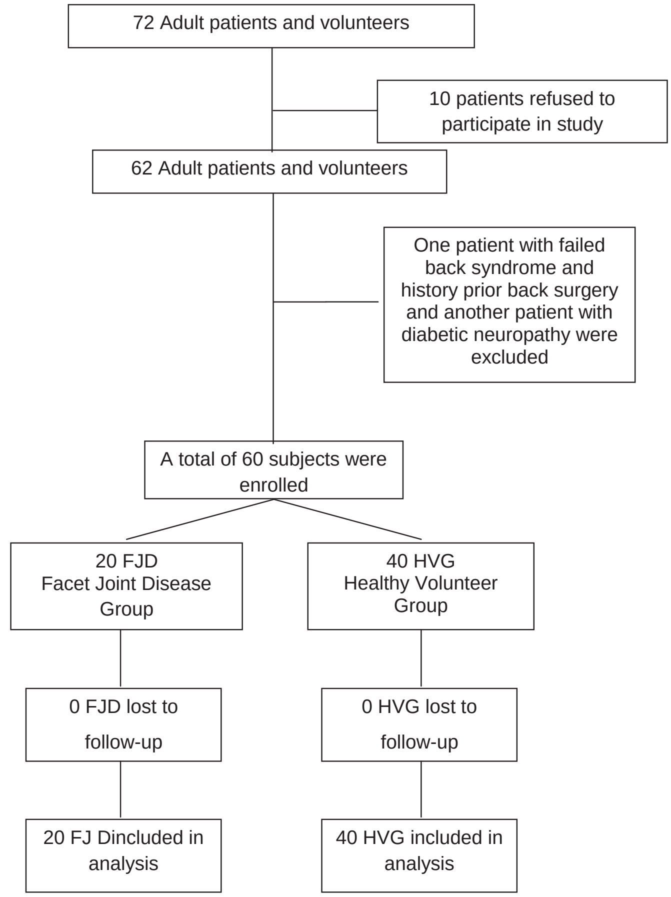

Fig. 1. Study flow diagram.

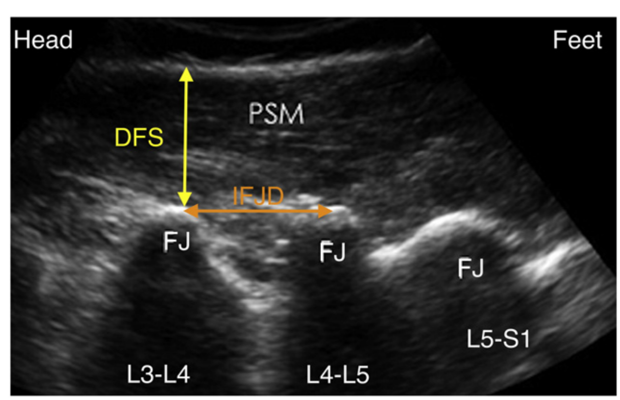

Fig. 2. Left parasagittal view of the lower 3 lumbar vertebras is shown in this figure. The left of the image is cranial and the right of the image is caudal. Posterior spinal muscle is shown on top. Three facet joints of L3-L4, L4-L5, and L5-S1 are shown in order form left to right. The depths of the facet joint (yellow line) and interfacet joint distance (orange line) are depicted. The measurements were done bilaterally and expressed in millimeters.

both sides (Fig. 2). This distance was used as the primary end points. The DFS was also measured on both sides for L3, L4, and L5 vertebras in parasagittal and transverse planes (Fig. 1). This measurement was the secondary end point of this study.

The following are the sample size determination and statistical analyses: the sample size was calculated using the online calculator provided online by the University of British Columbia (www.ubc.edu/stats). For an average IFJD of 34 mm, SD of 4 mm, and an effect size of −4 mm; a total of 16 patients were required in each group to provide a power of 80% and α error of .05. By including 20 patients and 40 controls, the power of the study was 89%. SPSS ver. 22.0 (IBM, Chicago, IL) was used to perform all statistical analyses. The categorical data were analyzed using χ^2 test and the results were presented as the frequency with percentages. Kolmogorov-Smirnov analysis was used to test the normality of the numerical variables. All numerical variables were analyzed by independent 2-tailed t test if the normality could not be rejected. For the data with normal distribution, the data were presented with mean ± SD. If the normality was rejected, then Mann-Whitney U test was used and the data were presented with median (interquartile range). Null hypotheses were rejected where α was less than .05.

3. Results

Ten female and 10 male patients with FJD and 40 (19 female and 21 male) HVG were enrolled in this study. The average age of the patients was 44.2 ± 10.2 years old in the FJD, which was similar to the average age of 40.5 ± 9.3 years old in the HVG ($P = .190$). Both groups were also similar from the anthropometric variables point of view. The average height and weight was both similar between the FJD and HVG groups. The body mass index was 25.4 ± 2.9 kg/m^2 in FJD patients that was similar to 24.7 ± 3.5 kg/m^2 in the HVG group ($P = .405$).

The IFJD was similar in both left and right sides both in FJD and HVG. In average the IFJD for any given level of vertebra was 2 mm smaller in female patients compared with those measured in men; however, this difference was not statistically significant in any of the 4 measurements (Fig. 3). At the level of L3-L4, the IFJD was 31.5 ± 4.0 mm on the left side and it measured 31.8 ± 4.0 mm on the right side ($P = .898$). At the level of L4-L5, the IFJD measured 31.3 ± 4.4 mm on the left side, which was similar to 31.5 ± 4.0 mm measured on the right side ($P = .786$). Interestingly, at any given level and on either side, IFJD in average measured 2.4 mm (range, 2.2-2.6 mm) shorter in FJD than those of HVG (Table 1). The average of the bilateral measurements was used as the dependent variables in general linear regression models. Sex and the presence of FJD were used as fixed predictors and age, height, and weight were used as the covariates predictors in linear regression models (Fig. 4).

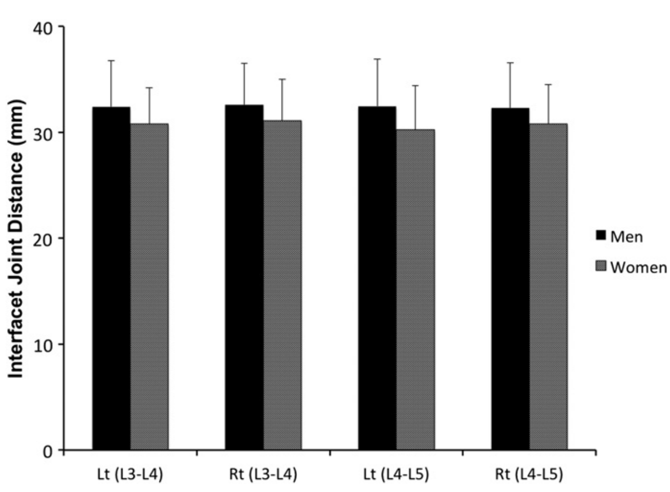

Fig. 3. The interfacet joint distance is shown in millimeters for L3-L4 and L4-L5, bilaterally. Solid bars depict the IFJD for men and the shaded bars are for women.

Table 1
Sonographic measurement of the interfacet joint distance over the L3-L5 levels in patients with facet joint disease and healthy volunteers. The values are presented in millimeters

Vertebral level and side		FJD (N = 20)	HVG (N = 40)	P
L3-L4 joints	Left	30.1 ± 3.2	32.3 ± 4.1	.029
	Right	30.2 ± 2.9	32.6 ± 4.2	.010
L4-L5 joints	Left	29.7 ± 3.9	32.1 ± 4.5	.037
	Right	29.8 ± 2.4	32.4 ± 4.4	.004

FJD = facet joint disease; HVG = healthy volunteers.

Age, height, and weight neither affected on IFJD of L3-L4 joints nor they influenced IFJD of L4-L5 levels. The presence of FJD was the only independent factor that negatively affected the IFJD at both L3-L4 and L4-L5 levels ($P_{L3\text{-}L4} = .013$ and $P_{L4\text{-}L5} = .014$).

The depth of left side facet joints at the levels of L3, L4, and L5 vertebras was also similar to the depth of these joints on the contralateral side (Table 2). The DFS increased in craniocaudal direction in both groups. The DFS was the smallest at the level of L3 (31.4 ± 5.8 mm in FJD group vs 29.5 ± 5.7 mm in HVG; $P = .231$), followed by DFS at the level of L4 (34.2 ± 4.5 mm in FJD group vs 31.3 ± 5.9 mm in HVG; $P = .050$), and it was the greatest at the level of L5 (34.4 ± 5.4 mm in FJD group vs 32.7 ± 6.0 mm in HVG group; $P = .303$). The presence of FJD did not affect the depth of facet joint in any of the 3 vertebral levels. The average values of DFS were greater for the left side (34.7 ± 5.1 mm) than those for the right side (31.9 ± 5.0 mm; $P = .003$) in patients with FJD, whereas they were similar for both sides in HVGs (30.8 ± 4.9 vs 31.4 ± 5.0; $P = .349$). The facet joints of L3 and L4 on the left side were significantly deeper in FJD group than those on the left side of HVG (Table 2). Fig. 5 depicts the interaction between sex and the presence of FJD on the average DFS. Except L4, the change in the depth of facet joints that is related to the presence of FJD is incremental among female patients whereas it is decreasing among male subjects.

4. Discussion

In this study, the distance between lumbar facet joints and the skin and the other facet joints has been measured in both healthy and facetogenic back pain patients. We describe that the interfacet distance is smaller in patients with FJD compared with HVGs as measured by ultrasonic methods. Although there is no difference in the depth of the facet joints between the patients with the FJD and normal subjects, these joints are significantly deeper on the side of inflammation (left) than the intact side (right) only among the patients with FJD. Such a difference is not observed in HVGs. The deeper facet joints of L3 and L4 on the left side in FJD group is maybe due to concomitant left lateral wedging of lumbar vertebrae secondary to the greater axial height of right side compared with the left side. This lateral wedging is more common among women [10]; however the number of subject in the current study was too few to perform a subgroup analysis according to the sex.

Differentiation of the causes of LBP has always posed a challenge for practitioners in the field of pain management. Various studies propose methods to help in identifying the etiology of LBP. Chen and colleagues have reported a prevalence ranging from 15%-40% for FJD [11]. These investigators have described the presence of a localized LBP that is aggravated by hyperextension whereas it is not affected with flexion. The same authors also point out that in some cases, pain may radiate to the side of the ipsilateral leg and mimic lumbar radiculopathy (pseudoradiculopathy). Kalichman et al [12] fail to support their initial hypothesis on osteoarthritis as the contributing factor for FJD and facetogenic causes of LBP.

Due to the lack of accurate diagnostic modalities such as MRI or CT scanning, some studies propose using single-photon emission computed tomography in diagnosis of facet joint syndrome [13]. Combining single-photon emission computed tomography with CT scan improves both the sensitivity and the specificity of either technique when it is

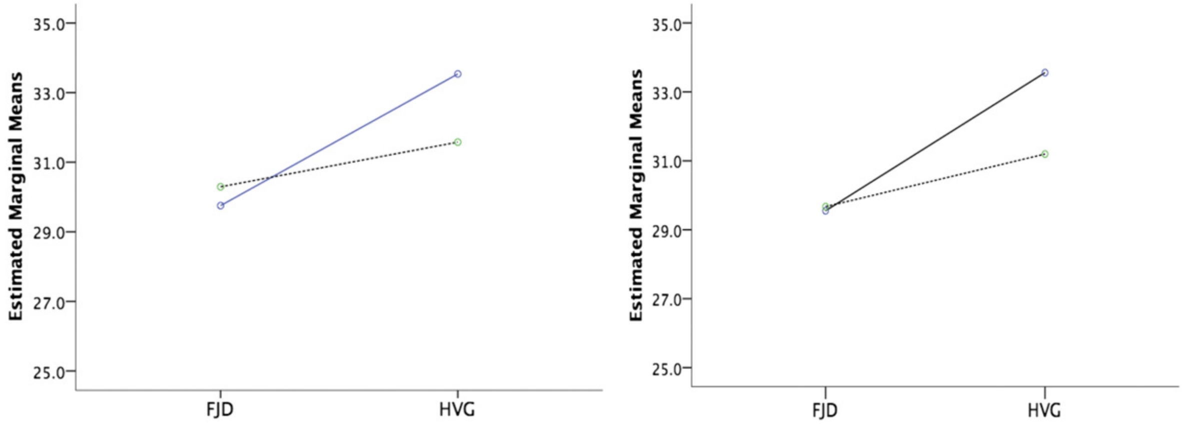

Fig. 4. The interaction between the sex and the presence of FJD is shown for the average of interfacet joint distance (mm) at the level of L3-L4 (left panel) and at the level of L4-L5 (right panel). Covariates appearing in the model are evaluated at the following values: height = 1.67, weight = 69.3, and age = 41.7. Male sex is shown with solid lines and the female sex is shown with dashed lines.

used alone. Despite higher sensitivity, most methods have significantly low specificity, which makes them a better screening tool with lower rates of false negatives. As a general rule, a screening test should be available at a lower cost and therefore the use of high expensive diagnostic methods is cost-prohibitive [4,13].

In a systematic review, Hancock et al [3] have concluded that physical examination alone is as useful as other high-cost diagnostic tools in diagnosing LBP secondary to discopathies and SI joint. Diagnostic nerve blocks are still considered the gold standard of the diagnosis of FJDs [14]. Controlled comparative local anesthetic blocks of facet joints or dorsal ramus of the intervertebral nerves (medial branch blocks) offer superior diagnostic advantages. A pain relief of 80% or greater which lasts longer than 2 weeks after a diagnostic block is generally accepted as the criteria for diagnosis of FJD. Cohen et al [1,15] conclude that despite improvement in imaging technology, a dual medial branch block with injection of a local anesthetic or placebo without any sedation has a higher diagnostic accuracy in facetogenic pain. The use of ultrasound for needle guidance improves the accuracy of these blocks thereby increasing the predictive value of these blocks in diagnosis of FJD.

Anatomical variations in lumbar facet joints have been reported in 444 cadaveric lumbar spines [16]. These researchers have examined interfacet spread, the distance between the facet joints at each vertebra, from L4-S1 levels by digital calipers. In relatively younger adults (<50 years old), as the interfacet spread increases, there has been lesser evidence for degenerative changes of the intervertebral discs and osteoarthritic changes of the facet joints. Interfacet spread of the lumbar vertebras increases in a caudal direction, which contributes to a pyramidal shape of the lumbar spine. This pyramidal shape is necessary for more stable and even distributions of the weight on the lower lumbar spine and related intervertebral discs. However, we did not find an increase in IFJD in our study.

Although we do not report on this measure, our measurement of the facet joint space width in vertical direction shows an opposite relation with the presence of FJD. We have noticed that the vertical distance between each pair of opposing surfaces decreases in patients with facetogenic pain. One study which was done by using CT scan showed that overall facet joint space width at L5-S1 was narrower than that in L3-L4 and L4-L5 [17], whereas decreasing interfacet distance (vertical plane) at the level of L4-L5 by using CT scan images and standard digital calipers have been associated with spondylolysis [18,19]. By using lateral x-rays, due to uniform height of vertebral body for each person and vertebral level, the facet joint parameters may individually be specified [20]. Although the interfacet spread plays a critical role in development and progress facet joint arthrosis, the association between the interfacet distance (current work) and decreasing distance by coexisting degenerative changes of the intervertebral discs has been investigated by different tools. In a comprehensive biomechanical study of the facet joints, the direction and the amount of the forces over the spine play critical roles in the pathogenesis of FJDs [21]. In fact, the degenerative changes of intervertebral discs may result in partial reduction in space between 2 adjacent vertebrae and decreases in the IFJDs. Subsequently, noninvasive imaging techniques that examine the geometric kinetics of spine in living individuals are extremely superior to those obtained from cadaveric spine or static images from the living patients.

We have additionally shown that the depths of facet joints especially over the lower lumber region (L4 and L5) are more in patients with FJD compared with HVGs. However, this relation was mostly true for the female sex; in men, there was no difference in the depth of facet joints in patients with FJD and HVGs. Moreover, the depth of the facet joints on the affected side is significantly larger than the nonaffected site in both sexes among the patients with FJD. Our results agree with a previous report by Greher et al in that both describe an increasing trend in the depth of facet joints and articular process from upper to lower lumbar vertebras but among HVGs [22].

Real-time imaging is valuable accessory used by the practitioners in guiding the placement of the needle in performing nerve blocks, joint injections, and other neuromodualtion techniques. Exposure to the ionizing radiation has been a concern to both patients and the physicians performing these procedures under fluoroscopic or CT guidance. Ultrasound technology, although it provides the accuracy needed in making diagnosis and aiding in treatment, it is less invasive in nature. Being readily available, ultrasound is safer technology, saves time at a lower cost, and has greater accuracy than the anatomic standard injection technique [23]. The accuracy and the level of agreement of sonographic method in measuring the indices of lumbar facet joints have been comparable to spiral CT scan (1-mm slicer) in terms of depth and distance measures [24]. Ultrasonographic guidance of the needle is routinely recommended for the guidance of the needle and real-time measurement of sonoanatomic characteristics of the lumber vertebras and the spinal nerves with comparable results with both CT scan and fluoroscopic

Table 2
Sonographic measurement of the depth of facet joints defined as the distance from the skin to the facet joints of the lumbar vertebras L3-L5 in patients with facet joint disease and healthy volunteers. The values are presented in millimeters

Vertebral level and side		FJD (N = 20)	HVG (N = 40)	P
L3 facets	Left	32.7 ± 5.8	29.2 ± 5.7	.027
	Right	30.0 ± 5.9	29.8 ± 6.0	.883
L4 facets	Left	35.9 ± 3.9	30.7 ± 6.2	.001
	Right	32.4 ± 5.2	31.8 ± 5.9	.714
L5 facets	Left	35.6 ± 5.4	32.6 ± 6.0	.054
	Right	33.2 ± 6.6	32.8 ± 6.3	.791

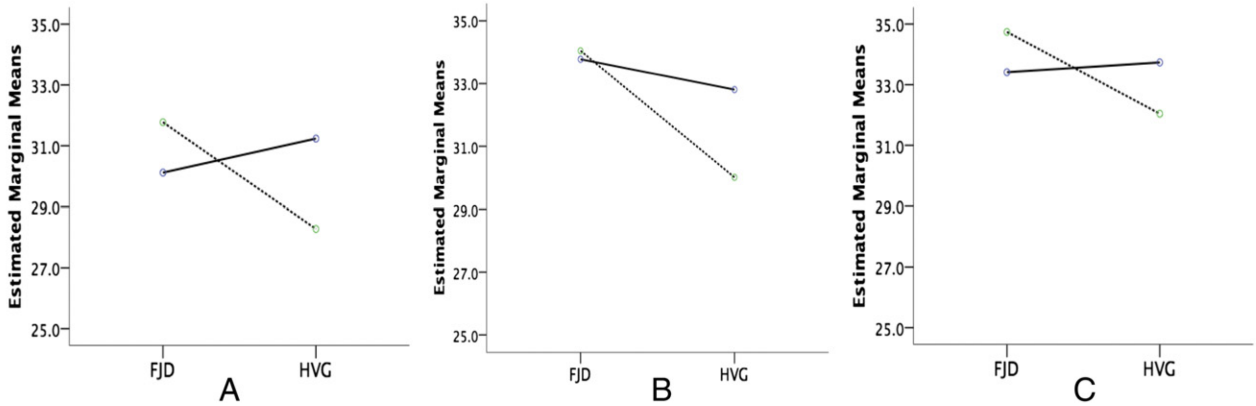

Fig. 5. The interaction between the sex and the presence of FJD is shown for the average of facet joint depth (mm) at the level of L3 (A), L4 (B), and at the level of L5 (C). Covariates appearing in the model are evaluated at the following values: height = 1.67, weight = 69.3, and age = 41.7. Male sex is shown with solid lines and the female sex is shown with dashed lines.

guidance plus the fact that the procedure time is shorter with ultrasound [25-28].

In conclusion, use of ultrasound technology showed us morphometric indices of lumbar facet joints that may be helpful in establishing a diagnosis in patients with FJDs. As the resolution of the sonographic images improves and the use of 3-dimensional ultrasound becomes widespread, more and more physicians will reach to the top of their learning curve and feel comfortable with the use of ultrasound technology in their daily practice. This method will continue to offer a lower cost and a higher safety profile compared with other x-ray imaging systems.

5. Limitations

One of the major pitfalls of this study is the fact that the diagnosis of facet-mediated pain has been made solely by clinical examination, not confirmed by any imaging such as MRI or x-rays. There are some concerns about the diagnostic value of medial branch block in FDJ. Comparing sonometric measurements with those of MRI would have added information regarding the bias and precision of this imaging modality for each one of the measurements. However, there is enough evidence in the literature that indicates that this method has an acceptable validity for the measurements examined in this study. We also understand that the examination is operator dependent. The measurements carry a lower interrater variability and more accuracy when the operator has significant experience in obtaining the views. A minimal deviation in either longitudinal or perpendicular plane would have inevitably resulted in artificial differences in measurements. Moreover, the facet joint measurements are made using Tuffier line, which has a questionable reliability in determining the anatomic lumbar spine level. Hence, the validity of our level determination may be questionable.

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