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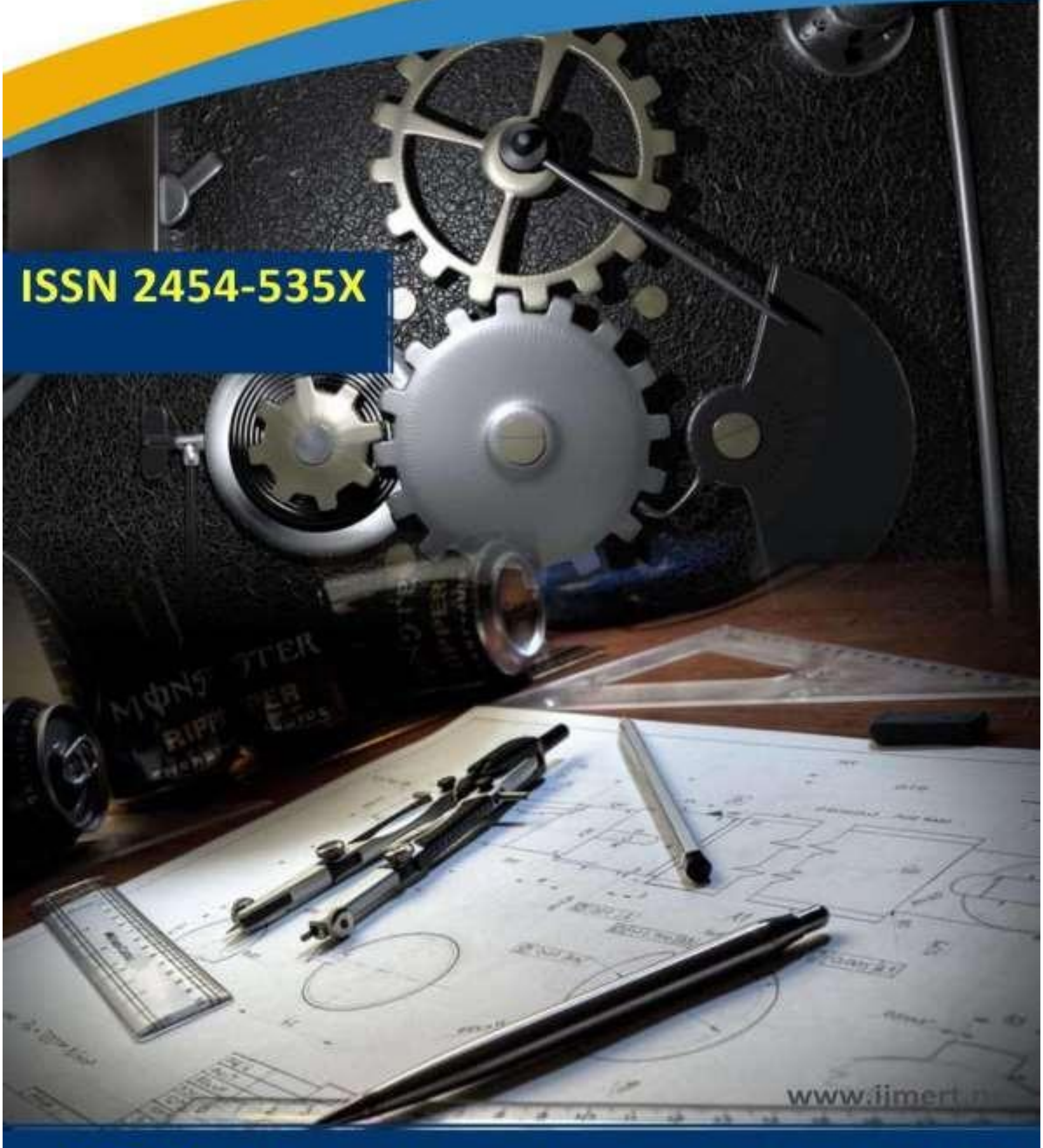

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Comparing the range of motion in the lumbar segment between boys and females at different intervertebral levels

Rani, latha& Swapna

ABSTRACT: To improve the treatment of spinal disease, it is essential to fully comprehend the biomechanical properties of the healthy human spine in both genders. But for each sex, the rotational ranges of motion (ROM) differ. Therefore, our objective is to examine, for the models of both sexes, the motion of the lumbar spine segment as **Comparing the range of motion in the lumbar segment between boys and females at different intervertebral levels**

measured by range of motion (ROM). A lumbar spine CT image is converted into a simulation model to initiate the process. The investigation looks at how the human lumbar segments (L1-S1) react to a pure-moment loading in terms of axial torsion (AT), lateral bending (LB), and flexion extension (FE). The lower lumbar levels contain the greater FE ROM next to

KEYWORDS: Range of motion; flexion extension; lateral bending; axial torsion

INTRODUCTION

Following the common cold, low back pain (LBP) has become a common reason for primary care visits. Most individuals will have experienced this disease at some point throughout their lives, according to reports [1, 2]. The largest axial joints in the body are the lumbar spine and the sacroiliac joint. The spine's articulation with the pelvis also permits loads to be transferred to the pelvic and lower extremities [3, 4]. The pelvis exhibits sexual dimorphism, with the sacrums of the male and female being distinct. The female sacrum tilts backward more and has a tendency to be wider, not even, and less curved. Males also often have a somewhat narrow and lengthy pelvis, with a longer and moreintervertebra l spine level at the lumbar segment using female and male specific finite element models.. It is hoped that in terms of their mobility and the possible pain sites, relevant parties can better understand the biomechanical differences in lumbar spine between female and male.

MATERIALS AND METHODS

CT scans developed a validated finite element models in lumbar spine for both of female and male. The models helped to simulate spine physiological motions. A comparison between male and female models was made, with regard to the range of motion ROM across the left and right lumbar segment.

The study focuses on human spine segments (from L1 to S1). As well as, response to: a pure-moment; loading in flexion and extension case (FE); (LB) lateral bending; in addition to axial torsion (AT). The analyses were done so that the differences between the female and male in each mode of loading can be detected at intervertebral levels. Table 2 includes the Material properties for the models of both genders.

Fema le- Ma le Finite Element Lumbar Spine Model

Computer tomography (CT) images of a 57 years old female's and male's spine without any abnormalities, degeneration helped to reconstruct the female and male lumbar spine model. MIMICS software (Materialise, Leuven, Belgium) was utilized to create a 3D geometry of the bones and then intervertebral discs were made by having the space between each two vertebrae of the CT images filled in. Next, smoothing and meshing were

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carried out with the help of the Geomagic Studio software (Raindrop Geomagic Inc., USA) and the Hypermesh software (Altair Engineering, Inc., USA). Table 1 illustrates the male and female spine FE models. The finite element lumbar spine model [10, 11] previously developed and validated was used with the current models. Lumbar spine bones were modeled as trabecular cores surrounded by a cortica l la yer. The linear hexahedral element type was used for cortical and cancellous bones of vertebrae and intervertebral discs. The truss elements were used for ligamentous tissues. 118,417 elements were generated for the male model, while female model as a whole contained 437,792 elements.

Materia l PropertiesThe material properties used in the FE models were extracted from previous studies [10, 13] and summarized in table 2.

Table 1. FE models parts of spine, (a) FE model of female lumbar spine -femur (b) FE model of male lumbar spine – femur

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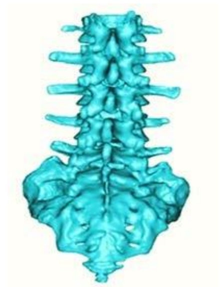
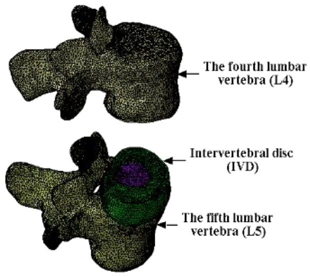
<td></td>
<td>

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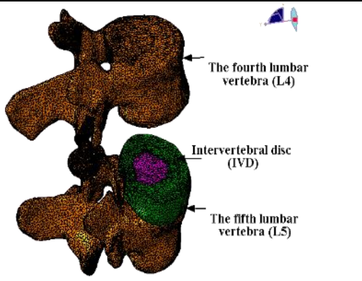
<td>

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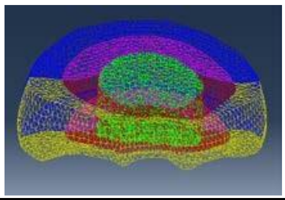
<td></td>
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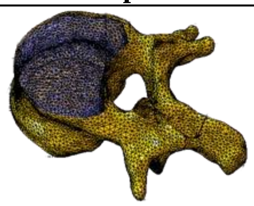
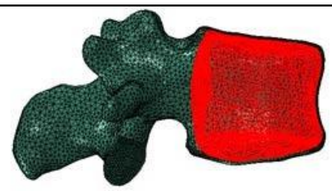
<td></td>
<td></td>
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<td>Cancellous Bone</td>
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Table 2. Material properties of male and female models

Component	Material Properties	Constitutive relation	Element Type	Reference
Vertebral cortical bone	E= 12000 GPa v = 0.3	Isotropic, ela stic	8 Nodes brick element (C3D8)	Lindsey et al. [10]
Vertebral cancellous bone	E = 100 GPa v = 0.2	Isotropic, ela stic	8 Nodes brick element (C3D8)	Lindsey et al. [10]
Annulus fibrosis (Male model)	C10 = 0.3448 D1 = 0.3	Hyperelastic, neo-Hookean	Rebar	Lindsey et al. [10]
Annulus fibrosis (Female model)	C10 = 0.035 K1 = 0.296 K2 = 65	Hyperelastic anisotropic (HGO)	8 Nodes brick element (C3D8)	Shahraki et al. [13]
Nucleus Pulposus	E = 1 GPa v = 0.499	Isotropic, ela stic	8 Nodes brick element (C3D8)	Lindsey et al. [10]
Ligaments	Nonlinear stress – strain curves	Hypoelastic	Tension-only, truss element s (T3D2)	Lindsey et al. [10]

*** E: Is Young's elasticity modulus; v: Poisson's ratio; C1 and C2: Material constant characterizing the deviatoric deformation of material.**

The Mesh Convergence Analysis

The mesh convergence analysis was carried out on the segregated L1-L5 motion segment of the female model. An initial seed size was a ssigned and the model was subjected to 7.5N.m bending moment to simulate motions in all planes, prior to the measurement of ROM. The final element size was used to mesh the other segments of the model. ABAQUS 6.14 software (Materialise, Leuven, Belgium) was used for the simulation.

Loading and Boundary Conditions

In all models, a 400 N compressive follower load was applied through wire elements right after the curvature of the lumbar segment. This is to simulate the effect of muscle forces and weight of the upper trunk. To simulate the physiological flexion, extension, lateral bending, and axial rotation, a 10 N.m bending moment was then applied at the superior surface of the L1 vertebrae. For constraining the models, femurs were set in all degrees of freedom as to avoid relative displacement [10, 11].

RESULTS

Model Validations

The data predicted for all physiological loadings fell within one standard deviation of the experimental data, with the exception of the right lateral bending and right axial rotation for the male data, Figure 1. The intact male model L1-S ROM was validated before under the same loading and with the same posture conditions. For consistency, the validation under loading condition was done for both models. For intact validation, the loading conditions of the cadaver study analysed by Lindsey et al. [14] had to undergo a simulation. This experiment was carried out for intact L4 to pelvis for both gender specimens under

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loading condition. A 7.5 Nm pure moment load was applied to the top endplate of L4 in order for various spinal motions to be simulated. The motion at the segment was then calculated for both right and left joints.

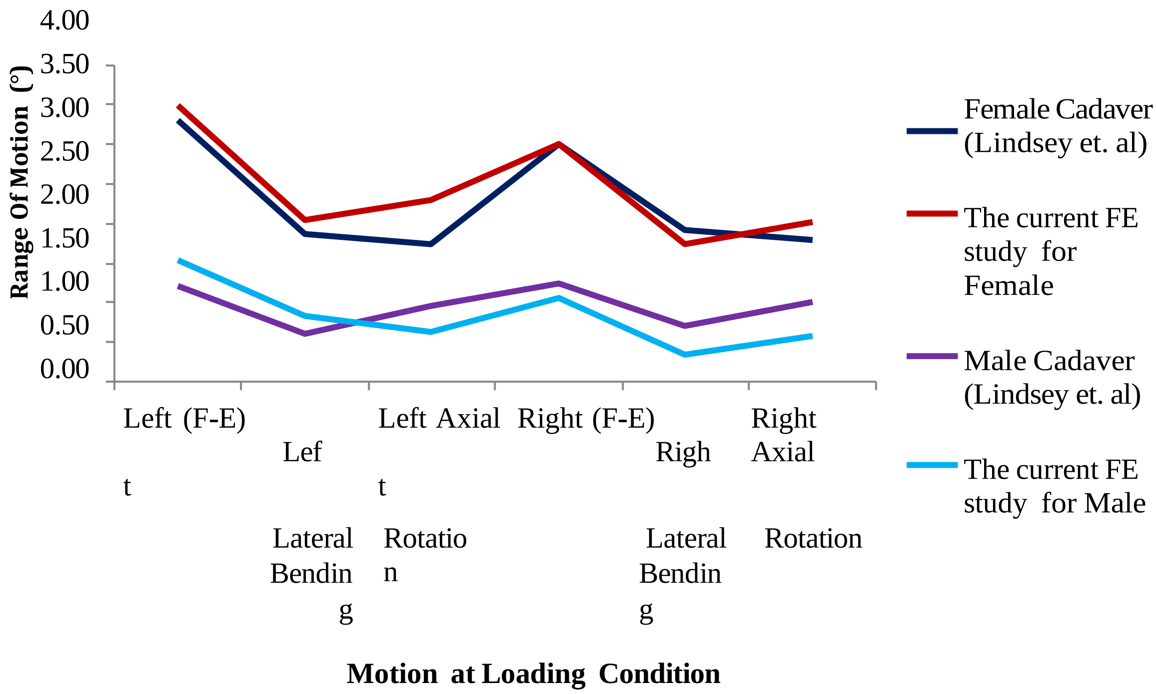
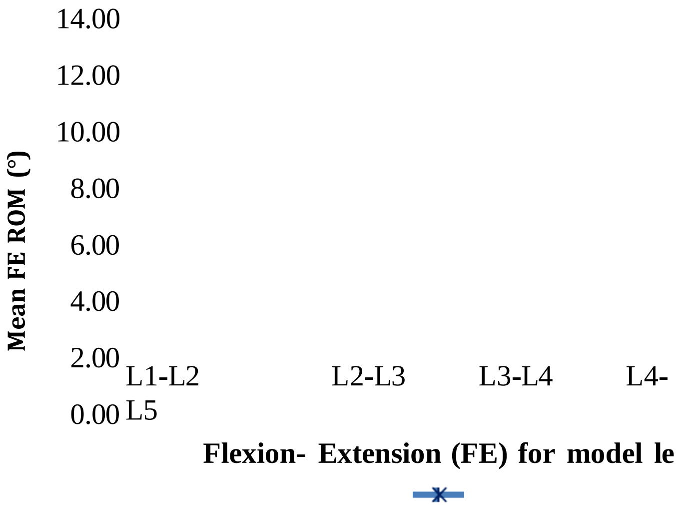


Figure 1. Validation results for the intact female and male lumbar segment-sacrum (right and left sides) at 7.5 N.m moment under loading condition. Experimental data was taken from Lindsey et al. [14].

Comparing between the female and male range of motion ROM

At vertebral levels, comparing between males and females, ROM was greater for females in a greater way ra ther than ma les at: FE; LB; a lso AT. ROM at LB is wont to be grea ter towa rd a central part of segment per L2 and 3, L3 and 4; moreover L4-5 hence ROM being considerably la rger than both of L1-2; L5-S1. These comparisons can be referred to in Figure 2, Figure 3 and Figure 4.



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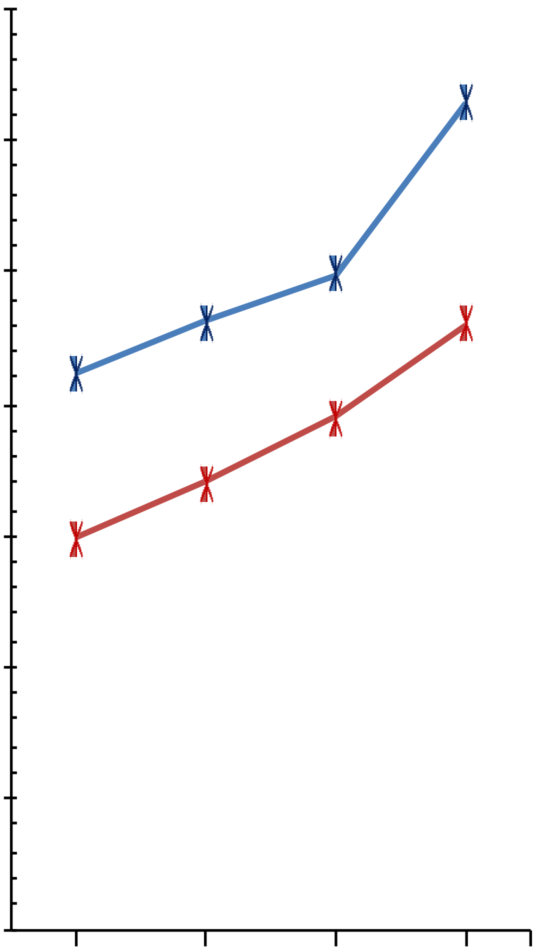

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Figure 2. Comparisons Range of Motion at Flexion- Extension (FE) within Intervertebral Level between females and males

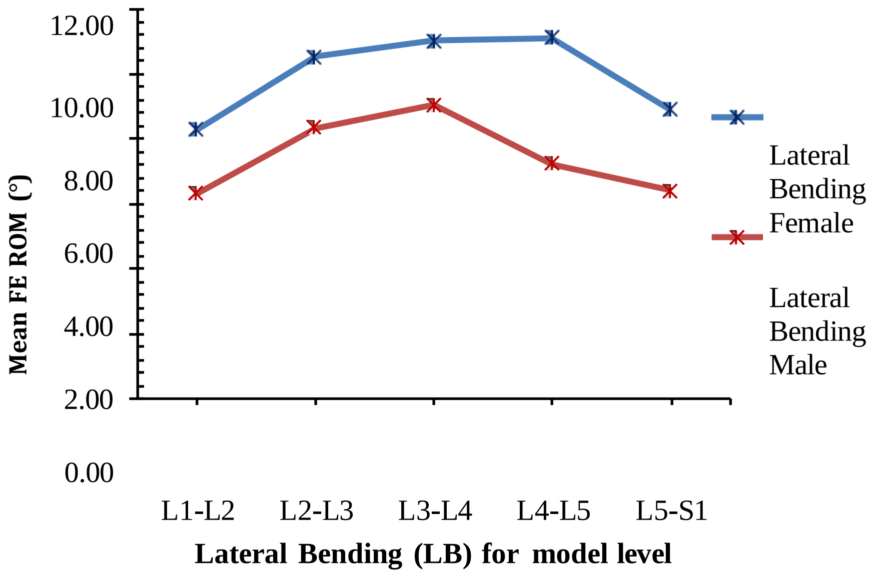

Figure 3. Comparisons Range of Motion at Lateral Bending LB within Intervertebral Level between females and males

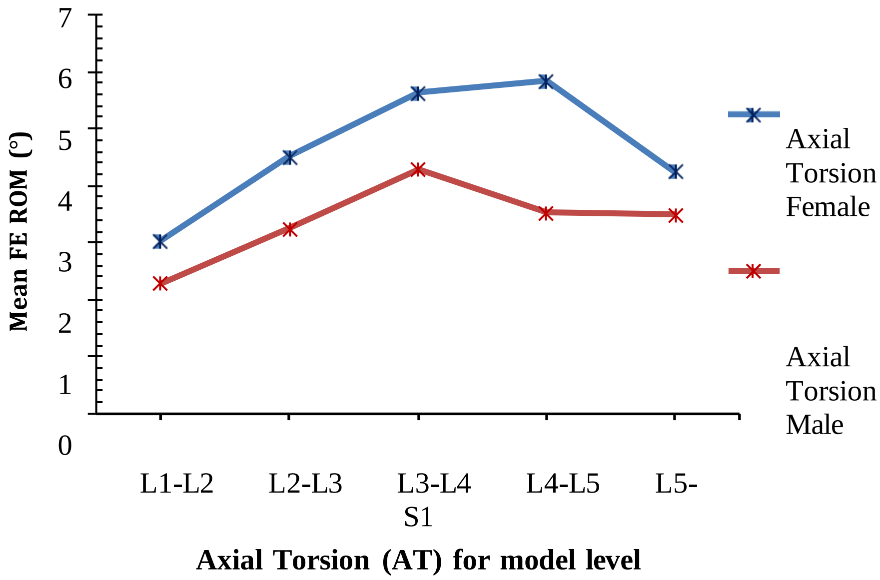

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Figure 4. Comparisons Range of Motion at Axial torsion AT within Intervertebral Level between females and males

ROM wa s considerably higher for females ra ther than for their counterparts of FE When comparing, fema les demonstrated significa ntly higher ROM in each level of FE. These comparisons can be seen in Figure 2. In FE, ROM of Female lumbar spine model ranged had a greater ROM than Male lumbar spine model at L1-L2 and L3-L4, respectively. In flexion, the ROM of Female was again la rger at L (3-4), a lso in L (4-5). The biggest comparative differences were noticed at state of extension, in which segments of a Female had highlighted a la rger ra te of ROM at L5-S1 which is greater at L4-L5. The ROM is wont to growth downwa rd the vertebral column in FE; L3 with L4 FE ROM a re recorded to be significantly more than L1 and 2, so for L4 and 5, with L5 to S1 FE ROM were considerably grea ter from every other level. Flexion ROM lean towards to be greater in the direction of the center of the segment with L2 and L3, L3- 4 and L4-L5 ROM being significantly greater than both L1-L2 and L5-S1. A simila rly in trending wa s establish with extension. Nevertheless, just L1-L2 wa s a lesser amount in a striking way than all other levels. In LB, ROM of Female specimens were greater than that of males at L3-4 and L4-5, respectively (as shown in figure 3). The higher comparative variances is evident at (AT), in which is the Female segments had shown a la rger mean value of ROM at L5-S1 and at L4-5 (as shown in fig 4). The LB of ROM lean towards to be grea ter in the direction of the center of segment within L2 and 3, a lso L3 and 4 until L4 and 5. A simila rly trend founded at AT case. However, only for L1 and 2 were noted to be lesser from whole other levels.

It is a fact that many studies have been conducted to define the effects of disc degeneration, then facet osteoarthritis happened on lumbar spine flexibility, and subsequently there are different forms of the effect of disc furthermore facet degeneration taking place on ROM amongfemales and ma les. A number of factors may be the reasons for the variability for ROM values. It can be stated that the height, weight and age may contribute to the differences in ROM values.

The current study has analysed the difference between lumbar segment ROM of female and male in different motions. The presented data helped to address the many critical questions about the male and female lumbar segment’s anatomical variation. The indication is that men would have a greater lever arm than women, as the former has stronger sacroilia c joints [15, 18]. This characteristic may explain why males are known to be less mobile.

DISCUSSION

In the current study we have seen that the female segment is appeared to be further flexible than males, and there is evidence of their influence on ROM. There were high increa sing in FE of ROM in the lower levels at L4 -L5 a lso L5 until S1. Furthermore, the maximum LB ROM was at L (2-3). The greater FE ROM found at the lower lumbar levels additional to significantly higher ROM at fema les segment as compared to a ma les. Hence, a

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varying in pattern was influencing of intervertebra l disc, and facet degeneration on ROM among males and females which have been observed. The results seem likely that geometrical differences between intervertebral levels in additions to between males and females offer a significant contribution to the differences in this study as pointed in Fig 5 [19-22].

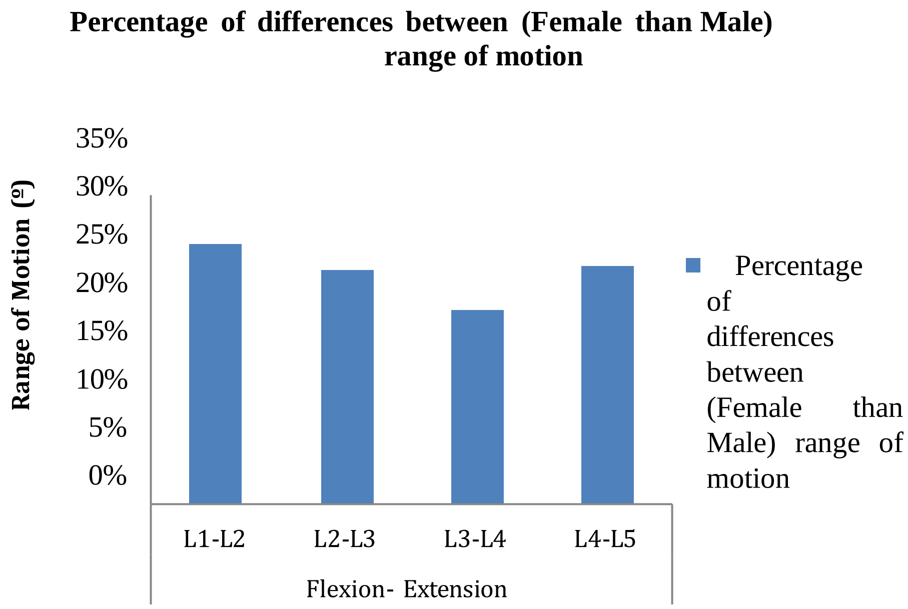

Figure 5. Percentage of differences between (Female than Male) range of motion

The influence of FSU dimensions on the ROM response has somehow altered the percentage of difference for the results between both sexes. The difference can to be justified by the greater dimension size of male segments and lack of correspondence evident in properties of noted material. Last but not least, there are some significant correlations between height, weight, gender and ROM. Despite their weakness, they can still explain the differences of the current result.

CONCLUSION

In conclusion, higher range of motion has been found in the female lumbar segment compared to the male model at both sides of the lumbar joint. Also, the act of stabilizing the lumbar segment was performed by one of the strongest ligaments in the body, the sacroiliac. These differences may lead to higher incidence of LBP in females, even though they are carrying a baby. We must consider the important variances in lumbar ROM between female and ma le spinal column segments, and between the intervertebral levels in study design; to avoid biases in outcomes. a fema le spinal column have been known to have higher flexibility or mobility; stresses; pelvis ligament strains and loads, as a compared with a ma le. Furthermore, it is causing higher ra te of stress through the joint, principa lly at the sacrum in a similar loading conditions. Hence, a well expla nation about: why there is la rger incidence of sacroiliac ache with pelvic stress fracture in body of fema les. The implica tions within the conclusions or outcomes could strictly be critica l in the design of spinal implants, particularly those concentrating on maintaining or else restoring for a healthy ability for motion. The major correlations concerning weight; ROM and height, however which is not clear sense, so may still be able to explain the differences of the current result, also through the intra gender differences.

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