Comparing Range of Motion Between Females and Males Within Intervertebral Levels of Lumbar Segment

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ABSTRACT: The biomechanical characteristics of the healthy human spine for both of female and male are critical to be understood thoroughly so that the treatment of spinal pathology can be advanced. However, the rotational ranges of motion (ROM) are not the same for each sex. Hence, our goal is to; investigate the motion of the lumbar spine segment, as measured by range of motion ROM for the models of both sexes. A process works when by a CT scan of a lumbar spine is transformed into a simulation model. The study examines human lumbar segments; (L1-S1) responding to a pure-moment loading in: flexion extension (FE); lateral bending (LB) and also axial torsion (AT). The greater FE ROM is found at the lower lumbar levels alongside the significantly greater ROM for female segments compared with males. On that subject, there is greater flexibility in the female segments compared to males, and its influence on ROM has been discovered. These differences may be justified by higher incidence of LBP in females including the time when they are pregnant, and this causes the disc and facet degeneration deference rate in female more than male. The simulate models also could provide a critical input for: implant design; biomechanical study design; and interpretation, not to mention to the development of diagnostic criteria.

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

INTRODUCTION

Low back pain (LBP) has become prevalent as a common reason for primary care visits after the common cold. It is reported that the majority of adults will have been suffering from this condition at some point in their lives [1, 2]. The Sacroiliac joint and lumbar spine constitute the largest axial joints in the body, as well as the spine articulation with the pelvis that allows loads being transferred to pelvis and lower extremities [3, 4]. Sexual dimorphism exists in pelvis it is different between the male and female sacrum. The female sacrum tends to be wider, not even, less curved, and that it tilts backward more. Additionally, males tend to have a relatively long and narrow pelvis, with a longer and more conical pelvic cavity than those of females [5].

We need to really comprehend the bio mechanical features for the healthy human spinal column for both of female and male because the treatment of spinal pathology has to be taken up a notch. As there is a problem of scarce vivo, and in-vitro studies, the state is a challenge toward quantify definite biomechanical parameters. The finite element analysis which could be utilized by understands of the biomechanics of the spine is very advantageous. The rotational ranges of motion (ROM) differ from one gender to another. The range of difference appears in the main loading modes, as flexion extension case (FE); also lateral bending (LB) in addition to axial torsion (AT), whereas they make common variables as well as they make the ultimate popular metrics that concerns with the biomechanics activity of the vertebral column.

Descriptive statistics ROM in healthy vertebrae and their relations with the demographical variables, can well contribute to: the implantation design with biomechanical investigating design; interpretation; Moreover, diagnostic criteria development; as well as design of bio mechanical spine models. Most of in-vitro studies for biomechanical of the vertebral column weigh in osseoligamentous creations unchanged.

Despite the varying methods to measure the Sacroiliac and lumbar segment motion [6-9] it is important to look closely into the biomechanical differences between male and female with regard to ROM. Cadaver studies demand a very technical procedure, as the motions at segments are very low. Furthermore, quantifying stresses across the joint is not feasible. With that, experimentally validated finite element analysis approach would be the best approach where the ROM, stresses, and strains across the joint can be evaluated.

We are going in the direction of consider the motion at the lumbar spinal column segment for both of male and female models as per measured by range of motion ability ROM, then study the dependences proceeding sex difference at

intervertebral 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.

Female- Male 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 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 cortical layer. 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.

Material Properties

The 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
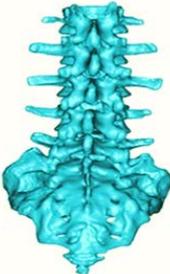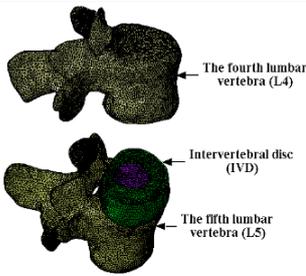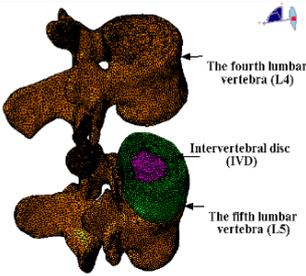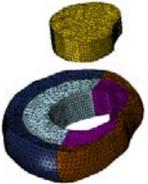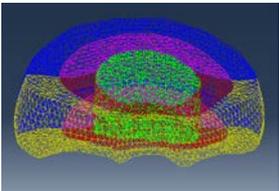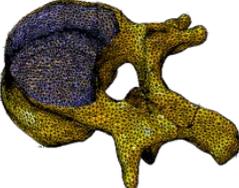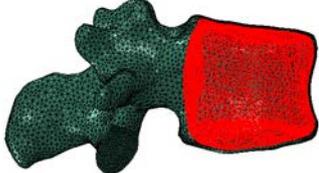

| (NP) and (AF) | End plate | Intervertebral Disc |
| Cancellous Bone | Cortical bone | Vertebrae |

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, elastic	8 Nodes brick element (C3D8)	Lindsey et al. [10]
Vertebral cancellous bone	E = 100 GPa v = 0.2	Isotropic, elastic	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, elastic	8 Nodes brick element (C3D8)	Lindsey et al. [10]
Ligaments	Nonlinear stress–strain curves	Hypoelastic	Tension-only, truss elements (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 assigned 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 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.
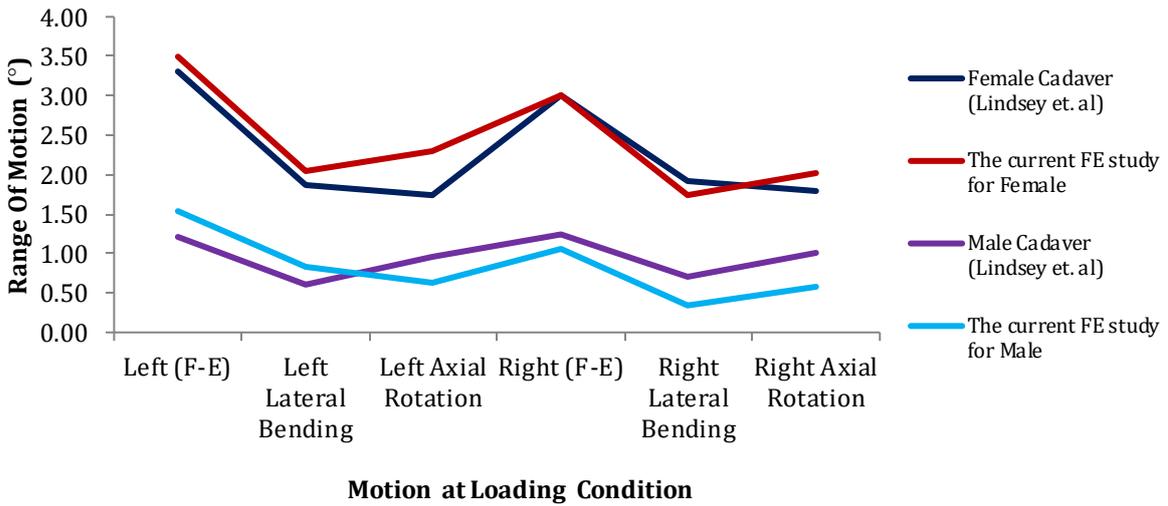
Figure 1. Validation results for the intact female and male lumbar segment-sacrum (right and left sides) at 7.5 N.m moment under loading condition. Experimental data was taken from Lindsey et al. [14].

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 rather than males at: FE; LB; also AT. ROM at LB is wont to be greater toward a central part of segment per L2 and 3, L3 and 4; moreover L4-5 hence ROM being considerably larger than both of L1-2; L5-S1. These comparisons can be referred to in Figure 2, Figure 3 and Figure 4.
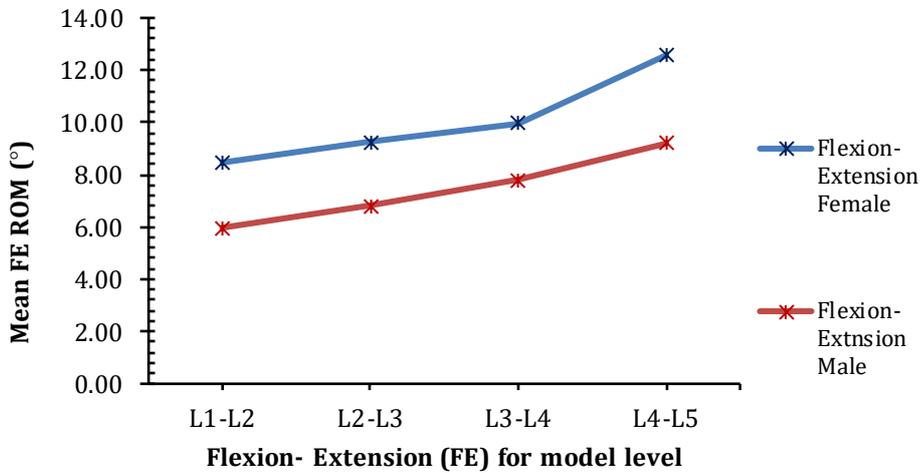

Figure 2. Comparisons Range of Motion at Flexion- Extension (FE) within Intervertebral Level between females and males
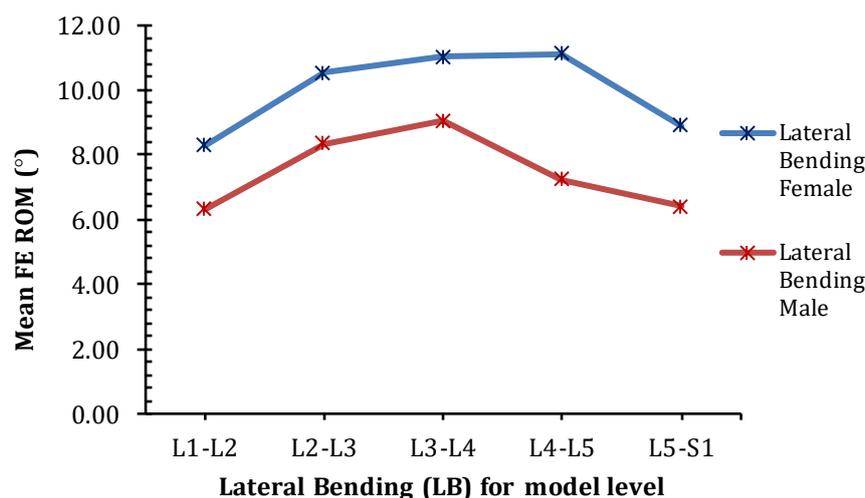
Figure 3. Comparisons Range of Motion at Lateral Bending LB within Intervertebral Level between females and males
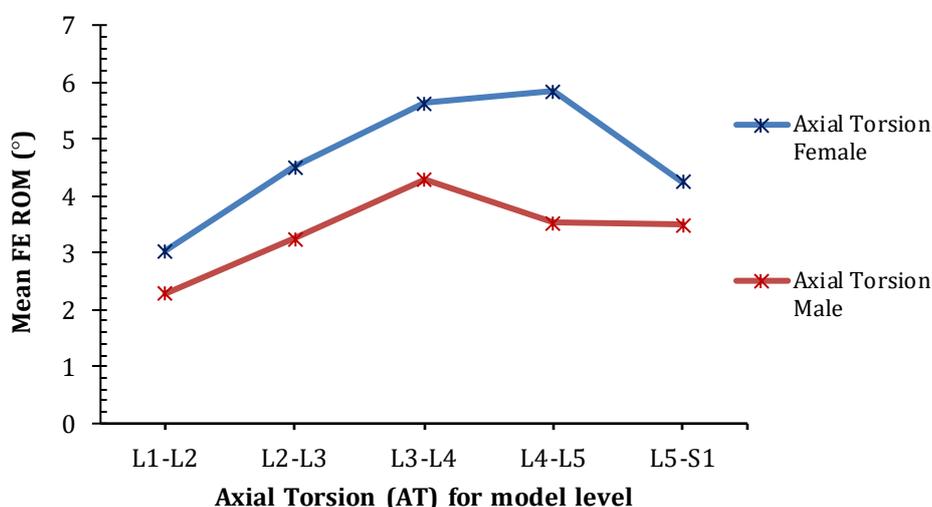

Figure 4. Comparisons Range of Motion at Axial torsion AT within Intervertebral Level between females and males

ROM was considerably higher for females rather than for their counterparts of FE When comparing, females demonstrated significantly 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 larger at L (3-4), also in L (4-5). The biggest comparative differences were noticed at state of extension, in which segments of a Female had highlighted a larger rate of ROM at L5-S1 which is greater at L4-L5. The ROM is wont to growth downward the vertebral column in FE; L3 with L4 FE ROM are recorded to be significantly more than L1 and 2, so for L4 and 5, with L5 to S1 FE ROM were considerably greater 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 similarly in trending was establish with extension. Nevertheless, just L1-L2 was 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 larger mean value of ROM at L5-S1 and at L4-5 (as shown in fig 4). The LB of ROM lean towards to be greater in the direction of the center of segment within L2 and 3, also L3 and 4 until L4 and 5. A similarly 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 among females and males. 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 sacroiliac 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 increasing in FE of ROM in the lower levels at L4 -L5 also 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 females segment as compared to a males. Hence, a varying in pattern was influencing of intervertebral 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].
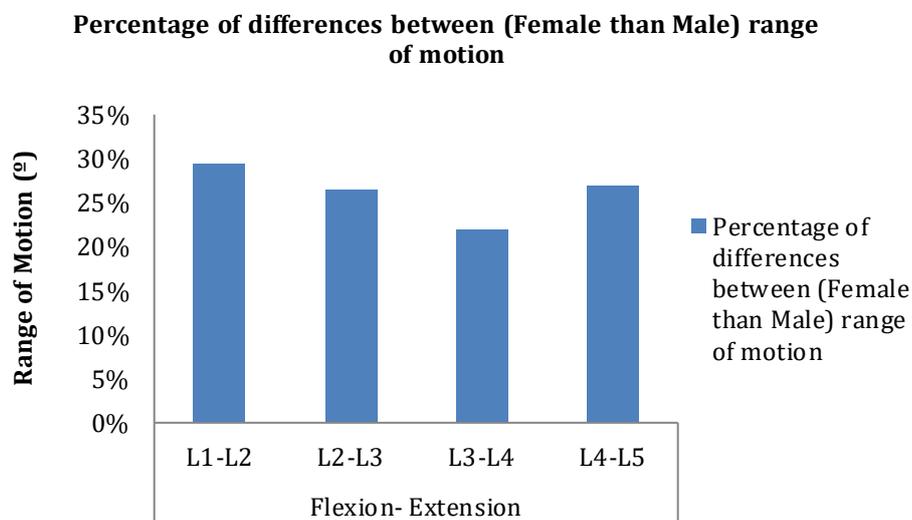
Percentage of differences between (Female than Male) range of motion

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 male spinal column segments, and between the intervertebral levels in study design; to avoid biases in outcomes. a female spinal column have been known to have higher flexibility or mobility; stresses; pelvis ligament strains and loads, as a compared with a male. Furthermore, it is causing higher rate of stress through the joint, principally at the sacrum in a similar loading conditions. Hence, a well explanation about: why there is larger incidence of sacroiliac ache with pelvic stress fracture in body of females. The implications within the conclusions or outcomes could strictly be critical 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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