



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 10, October 2022

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.118

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com



Image Processing of MRI Scan Human Lumbar Spine Image Using Finite Element Analysis and Catia Software

C.Sivaprakasam¹, V.K.Buvanesvari², P.Suresh³, U.Saravanakumar⁴, E.Punarselvam⁵, T.Aravind⁶

¹Associate Professor, Department of MCA, Muthayammal Engineering College (Autonomous), Namakkal, Tamilnadu, India

²Assistant Professor, Department of MCA, Muthayammal Engineering College (Autonomous), Namakkal, Tamilnadu, India

³Professor, Department of Mechanical Engineering, Muthayammal Engineering College (Autonomous), Namakkal, Tamilnadu, India

⁴Professor, Department of ECE, Muthayammal Engineering College (Autonomous), Namakkal, Tamilnadu, India

⁵Professor, Department of IT, Muthayammal Engineering College (Autonomous), Namakkal, Tamilnadu, India

⁶Assistant Professor, Department of CSE, Muthayammal Engineering College (Autonomous), Namakkal, Tamilnadu, India.

ABSTRACT: The Central Nervous System (CNS) is the region of the nervous system comprising of the brain and spinal cord. Spinal cord is the most vital and continuous complex structure that starts from the brain through the base of the skull and down the spinal column. It acts as the control system for the entire human body and also safeguards the medulla spinalis. Ergonomics means discovering a new principles or tools to reduce operator fatigue. This approach employed with the Manual Material Handling (MMH) mechanism to perform the certain tasks namely lifting, pushing, and pulling and so on. MMH mechanism are commonly used with the industrial ergonomists. Generally the lifting task is considered as the important cause for Human back- pains and other joint impairments. For this reason, an industrial ergonomists considered it as topmost task and gives extra importance to provide the optimistic postures for safe lifting. Many mechanisms are there to provide the postures for lifting but, most of them are risky and time consuming while testing in a practical implementation. In this paper, we introduce one of the most popular mechanical-oriented software called CATIA that is used in designing phase and also simulation software called ANSYS that is used in the analysis phase for processing the two dimensional (2D) Lumbar Spine model. During the lifting the loads, three dimensional model (3D) of the spine is compared with two dimensional (2D) image which is attained from Magnetic Resonance Imaging (MRI) scan. This model generates an extremely accurate and precise information about the spine. This proposed study may be used in various applications like monitoring the spine performance, predicting the biomechanical characteristics of spine, testing the spine bone remains stable or not and also to accomplish spine operations. To analyze human spine behavior, the importance is given to the Lumbar vertebrae (L1- L5) of spine. During this study we have a tendency to focus essentially on the particular body part of spine that is L1-L5 vertebrae regions. Using the proposed Manual Material Handling (MMH) mechanism, the stress strain relationship has computed in lumbar vertebrae spine bone under which they are treated with different weighting states. The entire mechanism is designed and developed using two software namely CATIA and ANSYS.

KEYWORDS: Spine Disc image, Finite Element Method, Functional Spinal Unit, Magnetic Resonance Imaging (MRI) scan, Anthropometry, CATIA, ANSYS.

I. INTRODUCTION

The spinal cord relays as a connecting, functional nervous structure in between the brain and sensory organs. The spinal cord departs through a large hole in the base of the skull and is bounded by the protective vertebral



column. Pairs of nerves known as spinal nerves arise from the spaces between the bony arches of the vertebrae. These spinal nerves are termed based on which section of the vertebral column they originated from. These regions of are:

- The Cervical region
- The Thoracic region
- The Lumbar region
- The Sacral region
- The Coccyx region

Fig 1 shows the clear picture of spine vertebral column. One exciting information about the spinal cord is that it only takes up about 2/3 of the vertebral channel in which it is accommodated. This is because the vertebral column grows faster than the spinal cord, when person grows, the cord takes up minimal space. By the time when a person reach adulthood, the spinal cord alone prolongs to the first lumbar vertebrae.

Because of different activities of spine, it tends to dislocate the vascular and neural structure of spine away from their anatomical and functional ranges. The main cause for neurological damage is usage of loading combination. A spinal cord injury will affects the spinal cord badly and causes serious alteration in its function, either temporarily or permanently. These alteration in spinal cord leads to serious disorders like loss of muscle function, loss of sensation and total collapse in spinal cord's autonomic function. Spinal cord injury can happens in any region of spinal cord. A damage is classified based on the injured region of the spine. If person suffers from a total loss of sensation and muscle function, then it means that the damage is on nervous region because nervous signals are able to travel past the injured area of the cord. Depending on the location and severity of damage, the spinal cord injury can be accurately diagnosed. The discovery of those parameters leads to fix the neurological deficit and also make a wider way to understand and prevent all these spinal oriented occurrences. After validating medical data observation reports, it clarifies that the functional modifications of soft tissues leads to reduce the space for neural structures. By using this mechanism we can predict vertebrae slip as a result of the weakness of vertebral facets, ligament classification, vertebral joint fusion and osteoporosis. For finding all those parameters ought to emphasis in the region which links vertebral rudiments and the spinal cord rudiments. Mostly, the lumbar spine is located in the lower posterior area after the cervical and thoracic sections of the spine. It consists of five vertebrae columns namely L1, L2, L3, L4 and L5. These lumbar vertebrae columns comprise of spinal cord tissue and nerves which govern communication between the brain and the legs. Any Injure to the lumbar spinal cord consequently affects the hips and groin area, and cause serious impact on the lower abdominal muscles and thigh flexion.

Biomechanics deals with the estimation of various mechanical stresses acting on the body while a person manually handles an object. Maurel (Maurel et al, 1996) biomechanical model proves a successful results for the estimation of stresses forced on the body musculoskeletal. National Institute for Occupational Safety and Health (NIOSH) documented and recognized the problem of work related back injuries and published the Work Practices Guide (WPG) for manual lifting. Computed values of applied trunk moments and forces are required to validate the actual biomechanical analysis of lifting pressures. Accurate measures of the trunk kinetic data are difficult to accomplish from dynamic exertions without significant approximation, cost, or motion constraints.

Lumbar Spine injury may distress either single or both sides of the human body. This lumbar spine injury leads to severe damages to human body. The exact symptoms can't be predicted as in cases of other spine injury cases. To say the precise symptoms it is essential to know about the anatomical lumbar vertebrae. The lumbar vertebrae has unique variations in which it elongates only to certain extend. The bottom level of vertebra is L2, till this level nerves are been extended. After this point, the nerves continues to next level of lumbar regions. While body is in motion or rest conditions, the Neutrogena claudicating causes sphincter malady o spine. This malady sometimes not found when a body is in rest condition. The toughest task for medical experts is spinal component displacements that emerges lots of serious disorders after successful completion of spine operations.

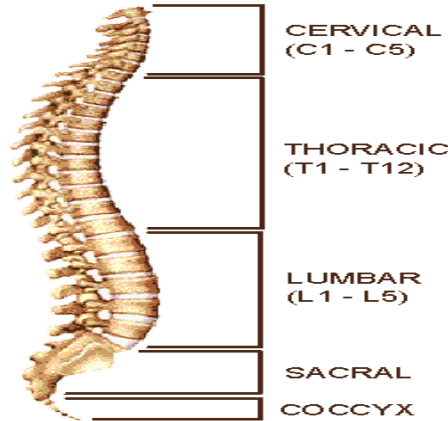


Fig 1: Diagrammatic representation of Spine Vertebral Column

Based on the clinical observational study made by the experts clarifies that the spinal cord generates the transverse crack when they are treated tested with various loading compression conditions. After this experts concluded that it is crucial to link obtained biomechanical observations with different physiological observations. Then many authors documented the biomechanical analysis research to find the relationship between spinal columns under different loading pressures. None of the researches has not gave picture about behavioral of lumbar spine.

In this study, with the help of three dimensional (3D) nonlinear finite element analysis (FEM) mechanism, the mechanical behavior of the L2-L3 disc-vertebrae is analyzed under various complex loads.

II. FINITE ELEMENT METHOD

A model of L1-L5 lumbar vertebrae is analyzed and modelled using three dimensional (3D) finite element model FEM principle with the help of Magnetic Resonance Imaging (MRI) scan. This model helps to analyze the mechanical properties of spine. The spine composed of ligaments, articular and capsular parts, 5 vertebrae, 4 intervertebral discs and the spinal cord.

The finite element methods (FEM) modelling technique is used to analyze anatomical structure of spine and it does not mechanical properties of spine. The analysis requires certain parameters namely geometrical specification of testing model, values of stress concentrated on that model and other elastic characteristics of that model. The validated geometrical specification of model is segregated into sub regions or elements. To direct the distortion of solids the divided regions is treated with the concept of differential equations. Based on the various applied loads corresponding the stress on spine, calculated local deformation quality of a bone.

There are three steps to achieve this module. They are as follows:

- 1) Grouping the geometry column in a constitutive quantities.
- 2) Applying various load and stress factors on the lumbar spinal unit;
- 3) Calculation of the model by accomplishment of numerical computational methods.

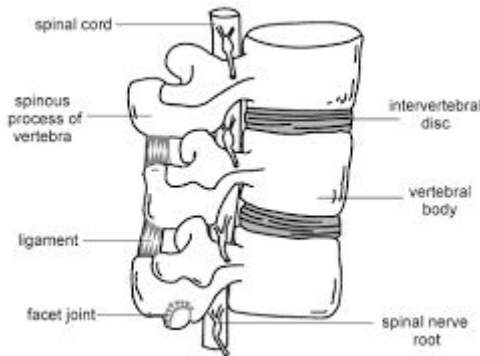


Fig 2: Diagrammatic illustration of Lumbar Spine

Strategy finite element model is a numerical approach applied for discovering a predictable arrangements of halfway differential conditions besides boundary conditions. So the Strategy finite element model (FEM) is also known as limited component investigation. The FEM method can be carried out in two ways. First way is to spread out the light entirely using differential constrains. Second way is to render the Partial Differential Equation (PDE) into an approximating arrangement. Then the resultant value is included with standard techniques. Limited Element Modeling remains most effective and broadly used to examine the flaws oriented issues whereas, in other models it is difficult to observe. In this scenario of light accessible hypothesis, the examination of thick-walled barrels is computed by observational values of some default results using limited component displaying methodology. The Limited FEM is based on numerical approach in which the components are converted into smaller discrete components which contains interrelating hubs. This test gives the clear picture about each components individually. The obtained outcomes are been combined in accordance with the individual components to predicts the bearing capacity of entire model. The precise arrangement has developed as a result of components of interrelating hubs formed in top down fashion. FEM examines each components to a larger number of times in lesser time to provide a precise result. The testing is based on the size of the components. The models precise level enlarge due to complementary elements. However processing time depends on size of the component. The entire FEM analysis is accomplished with the help of either 2D or 3D models. Specifically, 3D models are preferred to provide a better outcomes because it make use of real world three dimensional viewing approach. Lots of hubs are present in 3D model. So that arrangement time increases to order them sequentially. In the other hand, if we use 2D model approach, then the arrangement time decreased drastically compared to 3D model. But it does not measure the third axis of the image. So the result would be appeared either in a planar or axisymmetric geometry.

III. CATIA AND ANSYS

3.1 CATIA:

Computer Aided Three-dimensional Interactive Application is an acronym of CATIA. It is used to design, analyze, simulate, sharpening, visualization to create/ modify, modifying, styling, surfacing workflow and validate complex innovative shapes from industrial design to Class-A surfacing using the ICEM surfacing technologies. It supports multiple stages of product design, either from scratch or 2D sketches.

3.2 ANSYS:

ANSYS is a kind of real time simulation software tool that is used to compute the stress and strain parameters for the lumbar region of spine. This computation is done after a successful completion of design phase using CATIA software.



IV. DESIGN AND ANALYSIS OF FUNCTIONAL SPINAL UNIT (FSU)

Low back pain and some spinal injuries is primarily caused by lifting process. Even if, the epidemiological studies have recommended possible causes of lumbar spine is injured during loading process that leads to low back pain, but it does not provide the necessary information of the affected lumbar region of spine, which remains unknown. So it is complicated to estimate an lifting reaction of spines bones when they are subjected to various loading conditions in vivo and in vitro study and also reveals that none of the model had come forward to investigate the actual behavior of spinal unit in past. In vitro and in vivo studies we came know that the analysis of Function Spine Unit (FSU) were considered as risky task and also time consuming process. In this paper, an attempt has been made to analyze Function Spine Unit (FSU) using appropriate finite element modelling (FEM) for sagittal plane lifting activity.

Spinal unit which is also known vertebral column consists. It consists of 24 distinct bony vertebrae composed with 5 fused vertebrae, that form the sacrum, and usually 4 fused vertebrae, which form the coccyx. 24 distinct bony vertebrae of spine are interlocked with inter-vertebral discs. Typically, vertebral column appears symmetrical in the posterior plane and poses a characteristic curvatures in the sagittal plane. Curvatures afford a natural shock absorbency and flexibility to the spine bone that shown in Fig 1.

Three primary functions of vertebral column are;

- To help the human in the standing position
- To permit moment and locomotion
- To safe guard the spinal cord.

4.1 ANTHROPOMETRY OF FSU

Anthropometry is the approach to determine the human body in order to calculate an average dimensions of human form at different ages and in different conditions. Functional Spinal Unit (FSU) comprises of Lumbar and sacrum region. Lumbar vertebral column consists of five vertebrae and the intervertebral discs. It has a distinctive curvature called lumbar Lordosis. In upright posture, the sacrum is slanted in forward direction. So that it's upper surface is inclined towards forward and downward directions that forms an angle between the top of the sacrum and the horizontal, which ranges between 50° to 53°

4.2 FACTORS CONTRIBUTING TO THE NORMAL SHAPE OF THE LUMBAR LORDOSIS

The main factors that affects the normal shape of the lumbar lordosis are discussed below;

- Normally, L5 vertebral body has a wedge shaped structure. The anterior body wall is 3 mm thicker than the posterior body wall. This brings the upper surface of the L5 body closer to the horizontal plane.
- Also the L5/S1 disc has a wedge shaped structure. The anterior vertical height is 6~7 mm greater than its posterior height. As a result of the wedge shaped arrangement of the disc , the lower surface of the vertebral bone is not similar to the upper surface of the sacrum, so that the angle formed between two surfaces ranges between 6° ~ 29° and has an average size of 16° .
- Each vertebra above is inclined slightly backwards in relation to the vertebrae below.

4.3 MODELLING AND ANALYSIS OF FSU

Magnetic Resonance Imaging (MRI) Scanning technique is used to diagnose the internal organs and bones with high resolution and accuracy. MRI is based on non-invasive imaging approach. Using this MRI scan, a cross sectional size of L1 lumbar were measured from an adult.



The measurements are found to be 40mm major and 32 mm minor. Using the anthropometric proportions, other dimensions were evolved. Many 3D modelling software are available, but in this paper we used CATIA software due its effortlessness and unified integration analysis phenomenon.

Complete Function Spine Unit model has demonstrated and assembled using ANSYS simulation software according to the alignment depicted in Fig 2. Assembled model was relocated to CATIA/Mechanical environment.

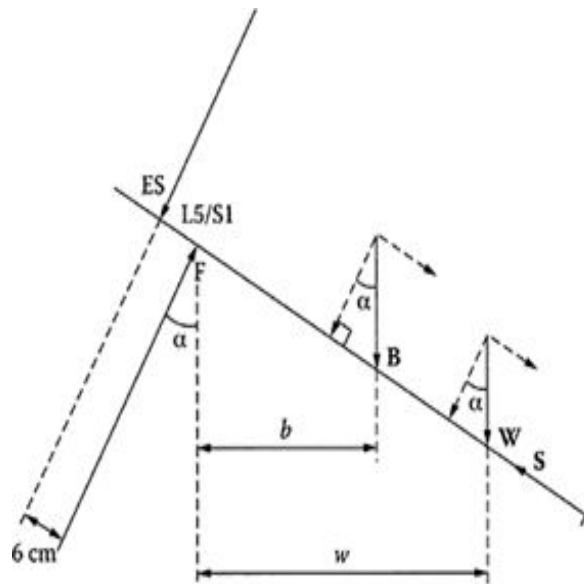


Fig 3: Diagrammatic illustration of Mathematical analysis of lumbar spine

4.2.1 BOUNDARY CONDITIONS

The boundary conditions are

1. Fix the Lower vertebral disc (L5/S1) of the L5 vertebral body.
2. All other vertebral bodies and discs are indorsed with all degrees of freedom.
3. Only 11% of axial load acts on lumbar vertebrae L1 and rest of loads were acts on muscles. This thing has to take in to consideration while loading the FE model.

Normally the human spinal bone has a capability to bear a weight of 50 kilogram and a weight of 490N stressed on vertical region of Cervical vertebrae. By this average weighting values, we can come to conclusion that the stomach weight increase to 0.5 MP which leads to stack in the Lumbar Vertebrae. Generally, Sacrum region and Coccyx territory region are compactly adhered with spine bone. And also acts a natural mounting in the spine bone. The boundary conditions are applied on the spine in accordance with their prescribe weighting procedures will create a settled base for the lumbar region. To find the pressure parameters, the subjected load is fixed to greater extent to word the homogeneity of the associated loading weight. The loading weight is taken into account by removing each loads positioned on the lumbar vertebrate L1. The axial force due to body weight is calculated (at L5/S1) as follows:

From the forces along spine directions are;

$$F - ES - B \cos \theta - W \cos \theta = 0$$

Moment:

$$ES \times l = Bb + Ww$$



Where,

ES denotes Erector spinae muscle force

F denotes Disc compressive force

B denotes Force from upper body weight

W denotes Force from lifted weight

l denotes Length of moment arm from ES

b denotes Length of moment arm from centre of gravity of the body weight

w denotes Length of moment arm from lifted weight

θ denotes Angle made by the force of body weight with erector spinae muscle force.

$$B = 0.65 \times M \times g$$

Where,

M denotes the body mass of the individual

g denotes Acceleration due to gravity

From literature, for a grown up normal adult

$l = 6 \text{ cm}$, $b = 18 \text{ cm}$
 $w = 35 \text{ cm}$, $\theta = 53^\circ$
 (Helander et al 1984).

$$F - ES - B \cos \theta - W \cos \theta = 0$$

Moment:

$$ES \times l = Bb + Ww$$

$$ES \times 0.06 = (400 \times 0.18) + (98 \times 0.35)$$

$$\frac{72 + 34.3}{0.06}$$

$$ES = \frac{106.3}{0.06} = 1771.5 = 1772$$

Replacing the ES value in equation

$$F - 1772 - 400 \cos 53^\circ - 98 \cos 53^\circ = 0$$

$$F - 1772 - 299 = 0$$

$$F = 2071 \text{ N}$$



Where $\theta = 53^{\circ}$

Hence, axial force on L1 is found to be 227 N @ 11% Maximum von misses stresses are experienced at L5/S1 and L4/L5 and its magnitude is found to be 3.45 Mpa.

V. RESULT AND DISCUSSION

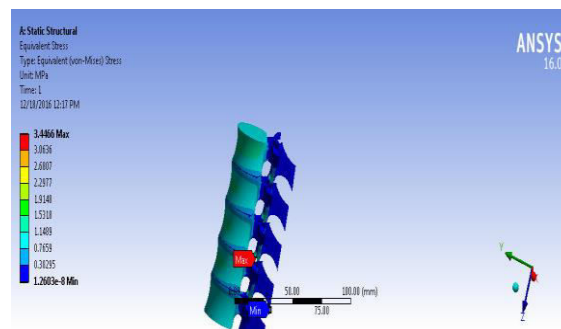


Fig 4: Graphical Representation of Stress Distribution

The 3D model of the lumbar vertebra was created using CATIA using the MRI scanned data. Then the 3D model was analyzed using FEA analysis that diminish the amount of triangles to an optimal value. The various stress strain distribution for vertebrae L1-L5 was obtained and recorded. This recorded information gave a clear view of the regions that are with maximum and minimum stress strain distribution. Further analysis of this stress and strain distribution helps to resolve various spine disorders such as osteoporosis, spondylolysis, and disc degeneration.

Complete rigidity and strength of human spine model has been analyzed using finite element analysis (FEA) approach. Additionally FEA approach gave the complete analysis report on mechanical behavior of spine. By this obtained results that discussed in this paper provides a greater scope to diagnose the spine injury in detail using available digital computational techniques. Moreover, this paper provides the clear forecasting suggestions to be followed in complicated operations like vertebroplasty operations. With the help of advanced image processing technique, the clear boundary level conditions and characteristics of bone tissue can also be forecasted. Still some bone related problems like “failure load” and “bone strength” are unresolved and might be resolved in future discoveries of advanced techniques.

Fig 4 depicts the Mathematical analysis of stress distribution of the lumbar vertebra. This analysis is accomplished under different loading pressures that acts positioned on the lumbar vertebrae. The stress level are estimated in terms of contours. Based on the pictorial graph, it clearly shows that the higher stress concentration acts on the lower posterior vertebrae region with Von Misses stress value of 3.45 MPa. Due to this high stress problems, spinal injuries are occurred to human beings. As a result, the mechanical integrity of bone is reduced and also results in severe damage to bone. In an entire spine, the vertebral region plays an important and sensitive role that acts as center point to hold the weight on facet joints. So that in this paper, a special care is taken to analyze the lumbar vertebrae.

VI. CONCLUSION

The entire Function Spine Unit (FSU) model has demonstrated and assembled using ANSYS simulation software according to the alignment shown in Fig 2. Assembled model was relocated to CATIA/Mechanical environment. As it was discussed earlier, the model was initially analyzed in upright posture with various loading conditions. The obtained result of the FSU was matched to the reality. The segments from L1 through L5 were modeled for a normal adult. Fig 4 depicts the Mathematical analysis of stress distribution of the lumbar vertebra when they subjected to various compression loading conditions. The model is tested under the load of 50 kilogram boundary constraints. After a mathematical calculation of stress distribution, the maximum von misses stress was found at L5/S1 and its magnitude



value is found to be 3.45 Mpa. Some important biomechanical researches and conclusions are drained from these results. First and foremost thing is to estimate the stress within the numerous regions of the body part vertebrae (cortical bone, cancellous bone, and pedicle). Secondly, from a biomechanical viewpoint, fix the compressive load to 490N that is perfect for internal fixation of body part vertebrae L1. Our results are limited by expectations regarding the properties of materials and by the basic models employed in finite component analysis. Since clinical studies are needed to validate with obtained results. After validating the analysis results, specifically lumbar L4 region has a major role to diagnose the problem related to spine.

VII. FUTURE WORK

In forthcoming generations some advanced versions could make the suggested analysis smarter in future. Few advanced methodologies that would make the proposed method more effective. They are Usage of multi optimization tools for the selection of pedicle screw size, improved screw thread design to decrease the stresses and also increase stability. Practice number of 3D modelling techniques to analyze the structural behavior of lumbar spine that could embed into proposed method to provide better outcomes. Moreover using this proposed method, we can fix any kind of spine injuries with available digital computation and image processing techniques. By discovering some advanced techniques we can even estimate the fluid properties of bone with cross sectional views.

REFERENCES

- [1] M.A. Tyndyk and V. Barron 'Generation of a finite element model of the thoracolumbar spine', Act of Bioengineering and Biomechanics Vol. 9, No. 1, 2007
- [2] Zhenhe Ye¹, Xin Li² and Ying Li², The Virtual Prototyping Design and Evaluation of Ergonomic Gymnastic Based on CATIA, International Journal of Hybrid Information Technology Vol.6, No.5 (2013),pp.67-78 <http://dx.doi.org/10.14257/ijhit.2013.6.5.07>
- [3] Sean Smith, Computationally Efficient Finite Element Models of the Lumbar Spine for the Evaluation of Spine Mechanics and Device Performance, University of Denver, March 2012,PP(1-85)
- [4] P. J. Evans, W. Sun 'Finite element analysis and computer aide tissue engineering design for the replacement lumbar intervertebral disc', 0- 7803-9564-6/06/©2006 IEEE (2006)
- [5] Zhan, G. and Gibson, I'A finite element simulator for spine orthopaedics with haptic interface', Virtual and Physical Prototyping, 3: 3, 141 — 149 .(2008)
- [6] Razeen Ridhwan U ,Aasish C , Bharathraj S , Mohammed Azarudeen Jaffurullah, Cyril Anthony A , Non Gps Navigation Using Simultaneous Localization And Mapping In Uav, Volume 4, Issue 1, January 2015 ISSN 2319 – 4847
- [7] Yabo Guan, Frank A. Pintar 'Biomechanics of the prodisc artificial disc using finite element analysis'.Synthes spine, L.P (2007)
- [8] Rashmi Shahu , The NIOSH Lifting Equation for Manual Lifting and Its Applications, Shahu, J Ergonomics 2016, :2<http://dx.doi.org/10.4172/2165-7556.1000159>
- [9] Antonious Rohlmann, Jorge Callisse and George Bergmann (1999), 'Estimation of trunk muscle forces using the finite element method and in vivo loads measured by telemeterised internal spinal fixation devices', Journal of Biomechanics, vol. 32, pp. 727 – 731
- [10] Konrawee Keawcharoen and Nimit Thongpulsawasdi, Influence of Different Angulations of Force in Stress Distribution in Implant Retained Finger Prosthesis: World Journal of Medical Sciences 10 (2): 217-221, 2014 ISSN 1817-3055 © IDOSI Publications, 2014 DOI: 10.5829/idosi.wjms.
- [11] Morandi, X., Riffaud, L., Houedakor, J., Amlashi, S.F.A, Brassier, G. and Gallien, Ph., (2004) Caudal spinal cord ischemia after lumbar vertebral manipulation. Joint Bone Spine, 71, 344-337. doi:10.1016/S1297-319X(03)00154-4
- [12] Wang, J.L., Parnianpour, M., Shirazi-Adl, A., Engin, E., Li, S. and Patwardhan, A. (1997) Development and validation of a viscoelastic finite element model of an L2/L3 motion segment. Theoretical and Applied Fracture Mechanics, 28, 81-93. doi:10.1016/S0167-8442(97)00032-3
- [13] Shirazi-Adl A., Ahmed A.M. and Shrivastava S.C. (1986), 'A Finite Element Study of the Lumbar Motion Segement subjected to pure sagittal plane moments', Journal of Biomechanics, Vol. 19, No. 4, pp. 347.
- [14] Williams J.R., Natarajan R.N., Andersson G.B.J. (2002), 'Biomechanical Response of a Lumbar Motion Segment Under Repetitive Loading conditions - A Finite Element study', Tenth Annual Symposium on Computational Methods in Orthopaedic Biomechanics, university of Texas southwestern Medical Center, Dallas.



INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor: 8.118



ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

9940 572 462 6381 907 438 ijirset@gmail.com



www.ijirset.com

Scan to save the contact details