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A Review on "Measurement of Deviation in an Asymmetric Human Spine using Optimization Technique"

Ankita Sharma[1], Nathi Ram Chauhan[2] and Saurabh Kumar Yadav[3]

[1]M.Tech Student, MAE Deptt., IGDTUW, Kashmere Gate, Delhi
[2]MAE Deptt. IGDTUW, Kashmere Gate, Delhi
[3]ME Deptt. Graphic Era University, Dehradun
E-mail: [1]ankita3700@gmail.com, [2]nramchauhan@gmail.com, [3]saurabhkumaryadav.iitr@gmail.com

Abstract—*Symmetry is one of the basic features which is possessed by the human beings, and is characterized by the presence of at least one axis or plane of symmetry. Minor asymmetry can be treated as normal. However, a higher degree of asymmetry of the human body is typical. This paper presents the various techniques which were introduced to understand the functional asymmetry of the human spine, with the help of 3D geometric model of the human spine.*

Keywords*: Symmetry, geometric modelling, spine curvature, spinal deformities.*

1. INTRODUCTION

The human spine structure consists of bones, muscles and tissues that forms the back of the body from neck region to pelvic region. There are total 33 vertebrae present in the spine that are stacked on top of each other- 24 Individual vertebrae which includes cervical, thoracic and lumbar and nine fused vertebrae on the sacrum and coccyx.

In addition, the human body can be divided according to the planes- transverse plane, coronal plane and sagittal plane. Sagittal plane corresponds to the bilateral symmetry which means that the body can be divided into two equal halves: right and left, which are their mirror images. Any deviation from this sagittal axis plane leads to the functional asymmetry.

The factors which can cause the functional asymmetry of human spine with respect to the sagittal plane of the human body includes injuries like scoliosis, kyphosis etc. and bad standing and sitting postures due to today's sedentary life style. The progression of spinal deformity is thought to be primarily biomechanical. However, the asymmetric loading is also one of the reasons to promote asymmetric growth of spine and progression of deformity. Proper back support and good posture are important since poor posture can lead to muscle strain and also spine stress. Over time, the stress of poor posture can change the anatomical features of the spine, which leads to pressure on blood vessels and nerves, and rapid degeneration of muscles, discs and joints.

Therefore, Quantitative analysis of human spine curvature is important for understanding the features and functioning of normal and deformed spine anatomical structure.

2. RECENT STUDIES AND EXPERIMENTATION:

In order to study the geometric structure of the human spine, biomechanical models had been generated and studied. There are four types of biomechanical models available: physical, in-vitro, in-vivo and computer models. Mostly used are computer models because they provide the information that other models cannot provide, such as stress-strain relationship, etc. Multi body and finite element models, or the combination of two are the most extensively used simulation tools that can be used to study and analyze the biomechanical features of the human spine.

From a biomechanical point of view, Finite Element Analysis is the approach that accurately represents the 3D geometry of the bones and heterogeneous distribution of the material properties of the bones [6]. Bone finite element modelling techniques have been developed using the Quantitative Computed Tomography (QCT) scans to describe the geometry.

Rapid Prototyping(RP) also, along with the medical image based modelling techniques has proved to be an effective tool in generating the complex 3D models of the anatomical structure of the human body, with the help of the information retrieved from MRI, CT or Laser scanning methods.

In recent years, the geometric model of the spine is created mainly by the use of reverse engineering models methods [4]. The basic steps of reverse engineering process includes: data measuring; data preprocessing; data partitioning and surface reconstruction; CAD modelling. There are two methods of reverse engineering modelling: (1) Point-Line-Surface and (2) Point-Surface. The latter method has low accuracy as compared to the former one, but it is more suitable for complex modelling.

2.1 BTS Smart Unit:

The objective of this experiment was to study the relationship between functional asymmetry of the spine and the position of the body. For this, the degree of the thoracic and lumbar regions of the spine were measured in transverse and frontal planes and served as dependent variables. The position of the subject was repeatedly measured and taken into consideration. The sequence of testing positions and the plane of movement were administered in a constant order.

In order to measure the range of motion, the BTS Smart Unit was used. It emits infrared beams that are reflected by the markers mounted on the surface of the body back to the capturing cameras. The accuracy of linear and angular measurements can be verified using mechanical models. The measuring tool (basic software) contains three integrated computer programs: Smart capture, Smart Tracker and Smart analyzer.

To describe the degree of the functional asymmetry of the spine mainly in thoracic and lumbar regions due to the bad sitting positions, the mean ranges are recorded. Both for the lateral and rotational flexions the Functional Asymmetry Ratio (FAR) is used in the form: FAR= [|R-L|/(R+L)]*100 where R- range of right rotation/lateral flexion and L- range of left rotation/lateral flexion. This way FARs for rotation and lateral flexion in the region of thoracic and lumbar spine area in both sitting and standing positions can be calculated.

2.2 Detection and Modelling of Human spine.

This approach emphasis on finding the point of best symmetry, that is, the point of minimum symmetry using the concept of Principal Curvatures [9]. In this method, a human body is attached to a particular coordinate system. The reference points of this coordinate system are taken into consideration and for the reference point's localization, the detection of the symmetry line along the back was done. The digital image processing method was employed for locating the anatomical points. Another approach used in this technique was the use of an active shape model based on the statistical scheme trained with a set of samples. This method looked for a set of curves that represent the shortest path between the point matching vertebrae C7 and point matching vertebrae L5.

The approach presented by the proposed model proceeds by locating the horizontal profiles placed on the back surface with the help of computation of minimum asymmetry point. Each of these points is an estimation of the position of the spine, so that we can obtain the model of the spine by means of this set of minimum asymmetry points. A local shape descriptor was also used to find the directions of the principal curvature. The modified NVV Algorithm was used to estimate the principal curvature. The projection of the mesh vertices was performed on a closest profile, and in order to obtain points all along each profile, clustering was done. The best symmetry point was found according to the concave-convex changes bounded in each profile. Having one best symmetry point in each profile, the fitness of a three degree polynomial curve was found with the help of least square method .

2.3 Geometric structure of 3D Spinal curve:

Spinal curves show generally three regions with opposite curvatures: thoracic, lumbar and cervical. Angles of regional curvatures are measured and calculated from the sagittal curve equation. [1]. The mathematical representation of the sagittal spinal curve is represented by the B-spline curve.

The technique used for defining the sagittal projections is the radiographic images which have been shot independently. The radiographic technique is coupled with photogrammetric reconstruction of points from their two images. Spinal curves are defined from series of isolated points. Plane regions are detected along the rough spinal curve. This detection requires two successive steps, the first one locates its position, and the second one eliminates aberrant points and restricts the regional extent so that two criteria would be satisfied. The first one check that linear distances between points of the spinal curve and facing plane are lower than a maximum value. The second criteria verify that planes passing through three adjacent points along the curve are much closed to the regional plane. The regional normal vector to the regional plane is calculated. The rough spinal curve facing each regional plane is projected on this plane. The regional plane projection of the 3D rough curve is uniquely flexed. The flexion angle bending this region is then obtained. The goal of this study is to obtain the geometric structure of spinal curves defined from a series of points reconstructed from photogrammetric techniques. Study demonstrated that scoliotic spines show highest curvatures when shot under specific radiographic incidences. A plane of maximum curvatures of scoliotic spines has been determined from points of spinal curve. This technique was based on the determination of one plane located so that linear distances between 3D spinal curve and plane would be minimum. The maximum distance value governs the relevance of the geometric model representing the spinal curve as a unique plane. If the maximum distance value is too high (up to 10mm) the unique plane model is maladapted. But this modelling technique may be adapted to any imaging system giving the accurate representation of spinal curves.

2.4 Measurement of Spinal Curvature by Manual Methods

In order to correct the deformities caused due to the deviation in spine angle , assessment of spinal curvature from radiograph images is necessary[10]. The two methods to measure the curvature angle in human spine are the traditional Protractor method (Cobb Method) and the Goniometer method. The most popular technique is the traditional Cobb method in which angle of curvature is measured manually by using a protractor. This method is relatively elaborate. But this technique is not universally available and cost ineffective.

Another method, that is, goniometer method is employed as an alternative to the protractor method in order to calculate the curvature angle. This method demonstrated that for the assessment of the spinal curvature, having spinal angle deformity, goniometer method is the most preferable method.

2.5 Quantitative analysis of Spinal Curvature.

For understanding the anatomical characteristics of the human spine , it is necessary to perform quantitative analysis. Most methods prove inefficient in defining the anatomical characteristics of the normal and deformed human spine. The small deformation in the vertebra may result in miscalculation of the curvature.

For the assessment of spine, process is described as follows: (1) Extraction of the spinal canal using the method of two step segmentation of spinal canal. (2) Extraction of the curve based on the segmentation of the spinal canal and the spine curve is found using minimal path algorithm. (3) Modelling of the curve based on extraction of the healthy individual's spine curve. (4) Analysis of the spine curvature is done through evaluation of the curve and assessing the deviations present. This method clarifies that there is a relation between the curvature deformation and low back pain.

3. CONCLUSION:

From the above studies it is concluded that human spine model is a very complex structure, however many methods are implemented to create an accurate 3D human spine model and also the studies explain how the bad sitting postures or injuries like scoliosis, kyphosis etc. are responsible for the deformation in the human spine and causes functional asymmetry according to the sagittal plane of the body. These models and their quantitative analysis can provide a great help to the clinical procedures and also to the yoga instructors and physiotherapist so that they can improve the problem of low back pain.

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