Study on Structural Behaviour of Human Vertebral Column Using Staad.Pro

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ABSTRACT
During accidents, one of the vulnerable parts getting injured is the vertebral column. It is a well-known fact that at the time of accidents, the vertebral column is subjected to axial loads; horizontal loads, bending moments and combination of the above. This paper deals with the study about the deflections and forces in vertebrae produced in the vertebral column (spine) during the course of accidents, using the software STAAD.Pro.

Keywords: vertebral column, Euler column, back pain, STAAD.Pro

1 Introduction
The paper is about cause of back pain, which most people, including doctors, don't understand. The back pain is not a disease like cancer or arthritis or an injury such as falling off a ladder. This back pain is caused by incorrect use of voluntary muscles. Voluntary muscles are muscles, which can be controlled. Lifting the arm is a best example for using the voluntary muscles. It can be painful by using, or not using, the voluntary muscles incorrectly. By using one hand to bend the fingers of the other hand backward can cause pain. It is a perfect example for using the voluntary muscles incorrectly.

This discovery, called Denlinger's Discovery, is another cause of pain throughout the human body and how to fix it. Denlinger's Discovery came about by applying engineering basics to the human body. Using these engineering basics one can also increase the load carrying capacity of the spine.

In 1759, a Switzerland born scientist named Leonardo Euler (1707-1783) developed the first, most basic formulas about the relationship of the height to the thickness of a column. A summary of this formula is that the thinner a column or post, as compared to its height, the more likely it
will fail (i.e., break) by bending rather than by crushing. Also, if the column has supports in the middle to keep it from bending, it will be able to carry a much heavier load.

The spine in the lower back of the human body, which has voluntary muscles which can act like guy wires to keep the spine from bending from side to side. Looking in the Doctor's Bible, "Gray's Anatomy", it can be seen that, these muscles in the drawings (fig.6) looking at the rear of the body. These muscles are called "quadratus lumborum”. Correctly using these voluntary guy-wire-type muscles per Euler's formulas could fix a problem called scoliosis. Currently doctors use braces and even surgery to correct scoliosis, As long as the muscles and nerves are in place and not damaged and the person is willing and able to learn how to use them.

The same basic principle of preventing too much bending, using other muscles, can be applied in another direction to strengthen the spine by preventing too much curve forward and backward.

2 Physiology and Anatomy of Spine [7]

In the womb and for a period of time following birth, a baby’s spine is shaped like the letter C. This curve is termed a primary curve, which is Kyphotic. During the time the baby is learning to lift his head and eventually walk, muscles develop. As muscular strength and ability is gained, the baby’s activity will shift body weight to the spine. Gradually secondary curves develop in the cervical and lumbar regions.

In a normal spine there are four types of spinal curvatures important to balance, flexibility, and stress absorption and distribution. Normal lordosis is the two forward curves seen in the neck (cervical spine) and low back (lumbar spine). Normal kyphosis is the two backward curves seen in the chest (thoracic spine) and hip areas (sacral spine). Each of the naturally occurring and normal soft curves serves to distribute mechanical stress incurred as the body is at rest and during movement. The spinal column (or vertebral column) extends from the skull to the pelvis and is made up of 33 individual bones termed vertebrae. The vertebrae are stacked on top of each other group into four regions.

2.1 Spinal Curves [7]

<table>
<thead>
<tr>
<th>Type of Spinal Curves</th>
<th>Curve Description</th>
</tr>
</thead>
</table>

## Research Article

**Figure 1: Spinal Curves**

<table>
<thead>
<tr>
<th>Term</th>
<th>Normal Curvature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical Lordotic</td>
<td>20 to 40 degrees</td>
</tr>
<tr>
<td>Thoracic Kyphotic</td>
<td>20 to 40 degrees</td>
</tr>
<tr>
<td>Lumbar Lordotic</td>
<td>40 to 60 degrees</td>
</tr>
<tr>
<td>Sacral Kyphotic</td>
<td>Sacrum fused in a Kyphotic curve</td>
</tr>
</tbody>
</table>

**Curvature**

<table>
<thead>
<tr>
<th>Body Area</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>L</td>
</tr>
<tr>
<td>Thoracic</td>
<td>K</td>
</tr>
<tr>
<td>Lumbar</td>
<td>L</td>
</tr>
<tr>
<td>Sacral</td>
<td>K</td>
</tr>
</tbody>
</table>

**Figure 2: Vertebral Column**
The upright thoraco-lumbar spine resembles an Euler column buckled in the second mode (n = 2) when viewed in the sagittal plane. An advantage of n = 2 buckling is that further load can be carried without adopting a stooped posture. Flexion of the spine is considered as the first quarter cycle of an Euler pendulum. [6]

2.2 Guy Wire Mechanism [1]

The spine in the lower back of the human body has voluntary muscles which can act like guy wires to keep the spine from bending from side to side. Looking in the Doctor's Bible, "Gray's Anatomy", these muscles are called "quadratus lumborum" (fig.6). Correctly using these voluntary guy-wire type muscles per Euler's formulas could fix a problem called scoliosis. Currently doctors use braces and even surgery to correct scoliosis.

There are two main types of braces. Braces can be custom-made or can be made from a prefabricated mold. All must be selected for the specific curve problem and fitted to each patient. To have their intended effect (to keep a curve from getting worse), braces must be worn every day for the full number of hours prescribed by the doctor. It corrects curvature by pushing with small pads placed against the ribs, which are also used for rotational correction.
2.3 Mechanics Of Spine [4]

The intervertebral discs lie between two vertebrae. These are visco-elastic materials having high viscosity. These act as the shock absorbers and having the capability to expand and shrink. The human intervertebral disc is a highly inhomogeneous fiber composite pressure vessel. The water content of the disc material was found to dominate its mechanical behavior. The incidence of disc problems with advancing age is explained in terms of the decrease in the moisture content of the disc.
The role of the intervertebral discs is mechanical. They are the joints of the spine, enabling it to bend and twist in all directions. They support compressive loads arising from body weight and muscle tension and anchor one vertebral body to the next. Since the discs occupy around one third of the length of the vertebral column, changes in the behavior of the disc can affect other spinal structures such as ligaments and muscles.

3.4 Thoracolumbar Fractures [2]
Thoracolumbar region in the human vertebral column represents Euler column buckling in the mode II (n=2). Management of thoracolumbar and sacral spinal fractures remains controversial. Early fusion with instrumentation is generally accepted for unstable injuries with complete neurological deficit; it results in more rapid mobilization, fewer complications, and lower medical costs.

Instability of spine - “Biomechanical spinal instability can refer to an abnormal response to applied loads, and can be characterized by motion in spinal segments beyond the normal constraints”[3].

3.5 Possible Fracture Patterns [2]
- Compression fractures
- Burst fractures
- Flexion-distraction injuries
- Fracture-dislocations

3.6 Compression Fractures [2]
1. Axial loading on a flexed spine.
2. The anterior column fails in compression but middle column remains intact.
3. The posterior column may remain intact or fail in tension, depending on the energy level of the injury.
4. The integrity of the posterior ligamentous structures making up the posterior spinal column is the primary determinant of spinal stability in this fracture pattern.
3.7 Burst Fractures [2]
1. Burst fractures are typically unstable than compression fractures and, by definition, involve an injury to the middle column.
2. There is often some degree of canal compromise, and the risk of neurological injury is correspondingly greater.
3. The extents of collapse as well as the integrity of the posterior column are key determinants of stability.
4. A drop-weight method was used to create burst fractures in bovine spinal segments devoid of a spinal cord

3.8 Flexion Fracture [2]
1. Flexion-distraction injuries can occur through bone, soft tissue, or a combination of both. It is also called “seat belt” injury.
2. Management of “seat belt” injuries is determined by the extent of bony versus soft tissue injury

3.9 Assumptions for Modeling Using STAAD.Pro
1. Material is isotropic, elastic, and homogeneous.
2. Anterior part of the vertebral column is only considered for analysis.
3. Bottom and top of the vertebral column is fixed.
4. Constant thickness of intervertebral disc is considered.
5. Geometry of the vertebrae is assumed as circular.
6. The vertebral column is devoid of diseases.

3.10 Material Properties for Vertebral Column [4]
1. Young's modulus for thoracolumbar bones  = 0.12Xe^5 N/mm^2
2. Poisson’s ratio for thoracolumbar bones  = 0.3
3. Young's modulus for intervertebral disc  = 7 N/mm^2
4. Poisson’s ratio for intervertebral disc  = 0.35
5. Bone density = 7.84 KN/m^3
3.11 Structure Information
Total number of nodes=34
Total number of beams=33
Total number of supports=2
Total height of thoracolumbar column=380 mm

3.12 Loads Applied
Axial load=0.1 KN at top of the column.
Horizontal load=0.1 KN at mid-torso region
Moment= 5KN-m at the bottom support

3.13 Dimensions
Diameter of bone varies from 25mm(top) to 40mm(bottom)
Height of bone varies from 8.5mm(top) to 20mm(bottom)
Thickness of intervertebral disc is 3mm

3.14 Drawings from STAAD.Pro
Figure 6: Vertebral Column With Nodes

Figure 7: Structure Outline

Figure 8: 3D Image Of Spine (Side View)

Figure 9: 3D Image Of Spine (Front view)
Figure 10: Axial Load
Figure 11: Horizontal Load
Figure 12: Moment
Figure 13: Combined Load Application
( Accident Case )
Figure 14: Deflected Shape
4 Conclusions

1. Maximum horizontal displacement is found to be 5.7 mm. It is not so vulnerable as far as the displacement is concerned. The results show that the model is capable of giving very detailed quantitative information on the mechanical behaviour of the spine, and as such could be considered to be a very useful spinal analysis tool.

2. The spine model is subjected to various loads to assess the overall behaviour of the thoracolumbar spine. The purpose of this study is to illustrate the usefulness of the model in illustrating the mechanical behaviour of the spine and also to demonstrate the sensitivity of this behaviour to variations in the applied loading conditions.

3. One main conclusion from this is that, the model predicts that the biomechanical response of the spine is very sensitive to relatively small changes in the loading condition.

4. This model is a very useful for the comparative study of various sitting postures. This can be done by analyzing the magnitude of force distribution corresponding to various sitting postures.

5 References

1. Dennis Denlinger, “Muscle and bone” (First edition).


