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Review Communication

A Focused Review – Thoracolumbar Spine: Anatomy, Biomechanics and Clinical Significance

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Abstract: *The knowledge of the Thoracolumbar Spine (TS) Anatomy and Biomechanics is important for prevention of mechanical damage of spine; which is very common and presented with the Low Back Pain (LBP). It is still unknown that how the TS commonly gets damaged during daily activities of life. This paper aims to give a comprehensive account of biomechanics of TS and its anatomical and clinical correlation for the occurrence and prevention of mechanical damage of spine.*

Keywords: *Thoracolumbar spine, Biomechanics, Lower back pain*

Introduction

The knowledge of TS anatomy and biomechanics is important for prevention of mechanical damage of spine. How the thoracolumbar spine works during routine activities of life and commonly get damaged and linked to back pain and tissue degeneration; are yet to be explained clearly. Then they could properly be prevented and treated.

LBP is most common disorder in the community and is commonly caused by the mechanical factors. To solve this problem, few researchers have proposed explored study of these topics. Kelsey JL et al[1] and Mundt DJ et al[2] demonstrated that the activities such as lifting heavy weight from the ground, in a twisted position is a risk factor for the disc prolapse. Fathallah FA et al[3] and Marras WS et al[4] also noted the activities involving a combination of rapid bending and twisting of TS as the cause of back pain and its dysfunction. There are strong epidemiological evidences that physical demands of work like manual materials handling, lifting, bending, twisting and whole body vibration can be associated with increased report of back symptoms, aggravation of symptoms and injuries[5].

The present article discusses the anatomy, biomechanics and clinical relevant of TS, so that correct knowledge could be used to prevent the LBP associated with it.

Discussion

The purpose of paper is to explore the biomechanics of the TS. Particular attention is paid to the clinical relevant of the kinetics part of TS.

Anatomy

The vertebral column resembles a curved rod and is composed of 33 vertebrae & 23 intervertebral discs; and divisible into 5 regions i.e. cervical, thoracic, lumbar, sacral and coccygeal. Each vertebra consists of two major parts, anterior and posterior. The anterior part is vertebral body which forms weight bearing structure of the spinal column. In order to minimise the weight of the vertebra and allow dynamic load bearing, the vertebral body is not a solid block of bone but a shell of cortical bone surrounding a cancellous cavity[6], which helps to resist compressive forces. The posterior part of vertebra is called neural arch, which is further divided into the pedicles and posterior elements. The function of the pedicle is to transmit tension and bending forces from the posterior elements to the vertebral bodies. The posterior elements transmit the forces to the pedicles and through them to the vertebral body. In between the vertebral bodies the complex structure is called intervertebral disc which transfers compressive forces evenly from one vertebral body to next.

The intervertebral discs are composed of 3 parts (i) Annulus fibrosus which consists of approximately 15-25 concentric lamellae[7]. The outer lamellae have high proportion of type 1 collagen fibres which resist excessive bending and twisting of adjacent vertebra[8]. The middle lamellae can behave like a fluid in young non-degenerated disc, although after the age of 35 year behave like fibrous solid and resist high compressive loading, even when unsupported by the nucleus[9,10]. The innermost lamellae are sufficiently deformable that the tissue normally behaves like a pressurised fluid, even though the collagen fibres form distinct lamellae (ii) Nucleus pulposus, which is a high water content and loose collagen network of the nucleus giving the tissue unusual mechanical properties. The water ensures that the tissue has very low rigidity, so it deforms easily in any direction and equalises any stress applied to it[11] and (iii) Vertebral end plate, which is a thin layer of hyaline cartilage covering the central region of the vertebral body and its function appears to help equalise loading of the vertebral body[12].

Biomechanics

According to European Society of Biomechanics, the biomechanics is the subject which deals with the study of forces acting and generated within the body and the effect of these forces on the tissues. Biomechanics can be used for diagnostic, therapeutic and research purposes. So let us first see the various forces acting on the TS, as shown in Figure 1. The forces acting on TS are compression, shear bending and torsion. It can be seen that the component acting perpendicular to the mid plane of the disc is defined as the compressive force and the other component acting parallel to the disc is shear force. The component causing the spine to move in sagittal and frontal planes, these movements are referred to as the bending movement whereas the component causing the spine to twist about its long axis is defined as the axial rotation (torsion).

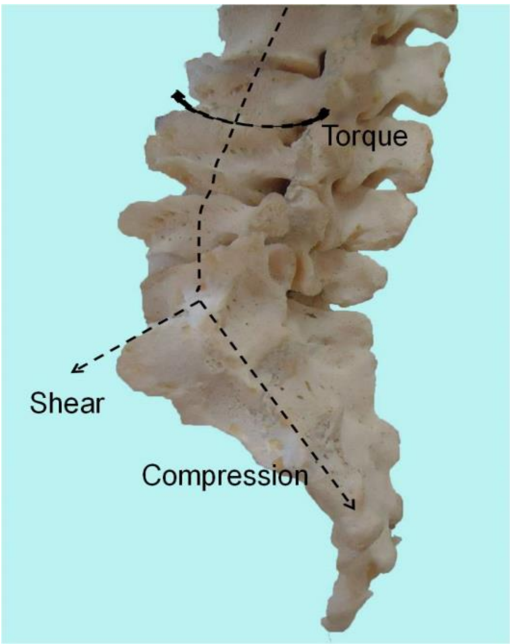


Figure 1: Components of force acting on the lumbar spine. Compression, Shear bending and Torque (Axial rotation) movements in sagittal plane

The compression of spine occurs as a result of the force of gravity, ground reaction force; and the force produced by the ligaments and muscular contractions. The compressive force of thoracic spine is more as comparison to cervical spine because of the greater amount of body weight and kyphotic shape. The line of gravity falls anterior to the thoracic spine. This produces flexion movement on the thoracic spine that is counteracted by the posterior ligaments and spinal extensors. The primary function of the lumbar region is to support for weight of the upper part of the body in static as well as dynamic situations. Dolan P et al[13] argue that the most of the compressive force acting on the lumbar spine arise from tension in the back muscle. The sheer force tends to cause each vertebral spine to undergo translation (move anteroposteriorly or side to side in relation to the inferior vertebra).

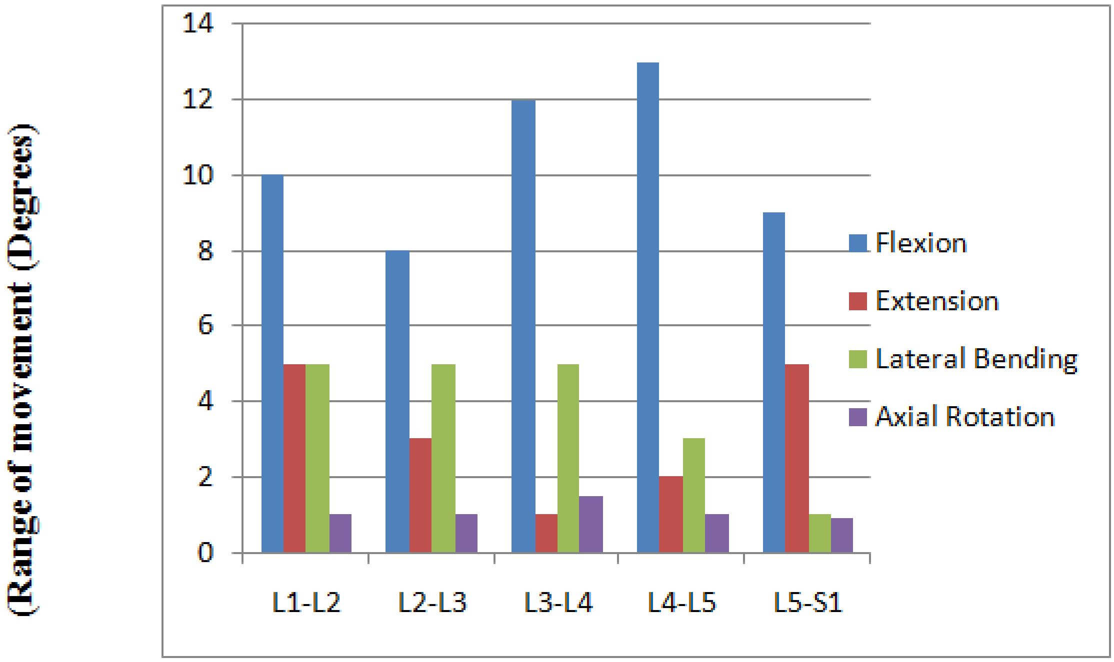
The ElectroMyoGraphic (EMG) studies suggest that shear force is limited to 250N by back muscle activity[14,15] while the co-contraction of the abdominal muscle has been reported to increase shear by up to 70 %[10]. The bending causes both compression and tension on the structures of the spine. In forward flexion, the anterior structures (anterior portion of the disc, anterior ligaments, and muscles) are subjected to compression; the posterior structures are subjected to tension. The resistance of the bending is limited by the posterior outer annulus fibrosus, zygapophyseal joint capsule and posterior ligaments. In the extension, the posterior structures are subjected to compression while the anterior structures are subjected to tension[16]. In general resistance to extension is provided by the anterior outer fibres of the annulus fibrosus, the zygapophyseal joints capsule and passive tension in the spinous processes. Torsion forces are created during the axial rotation, the torsion stiffness in flexion and lateral bending of the upper thoracic region from T1 to T6 is similar but torsion stiffness increases from T7/T8 to L3/L4. The torsion stiffness is provided by the outer layer of both the vertebral bodies and intervertebral discs and orientation of facets[17].

The force acting on the TS is produced by gravity, inertial effect, muscles, fasciae, ligaments and Intra-Abdominal Pressure (IAP). Gravity exerts a vertical force on each parts of body in direct proportion to its mass. Pfirrmann CW et al[18] showed that when a person stands upright, the mass of trunk, head and arms press vertically on the lower lumbar spine with a force of approximately 55% of body weight, because the lumbosacral disc is inclined at an angle of approximately 30 degree to the horizontal, which gives compressive and shear stress on the lumbosacral disc. Muscles of the trunk and abdomen act to protect the spine by stabilising it upright posture[19] and by preventing excessive bending and axial rotation movements. Anderson CK et al[20] and Dolan P et al[21] indicate that during the activities such as bending forwards and lifting weights, the back muscles need to generate much higher forces in order to overcome the effect of gravity acting on the upper body. Fasciae and ligaments are passive structures that can sustain high tensile force when stretch. Stretch passive tissue stores elastic energy, when the spine is flexed and then releases the energy when the person straighten up again, so that back muscles do less work[22,23]. The IAP also exerts pressure over the TS. Dolan P et al show EMG study that volunteers were able to generate an extensor movement of 20-25Nm in the absence of any erector spinae muscle activity and without flexing forwards to stretch intervertebral ligaments and lumbodorsal fascia, and this extensor movement could possibly be due to a raised IAP.

Commonly motions which occur in TS are flexion, extension, lateral flexion, and rotation. The motion of flexion and extension occur as a result of tilting and gliding of superior vertebra over the inferior vertebra. In the flexion, anterior tilting and gliding of the superior vertebra occur which cause widening of the intervertebral foramen[24], the range of flexion and extension is extremely limited in the upper thoracic region (T1 to T6) because of the rigidity of the rib cage and the orientation of zygapophyseal facet in the frontal plane. In the lower part of the thoracic region (T9 to T12), the facets lie closer to the sagittal plane, allowing an increased amount of flexion and extension. The flexion in the thoracic region is limited by the tension in the posterior longitudinal ligaments, the ligamentum flavum, the interspinous ligaments, and the capsule of zygapophyseal joints whereas extension of the thoracic region is limited by the contact of the spinous processes, laminae and zygapophyseal facets; tension in the anterior longitudinal ligament, zygapophyseal joint capsules and abdominal muscles. The lateral flexion is restricted by impact of the zygapophyseal facets on the concavity of the lateral flexion curve and limitation imposed by the rib cage[25].

The lateral flexion and rotation are free in the upper thoracic region and is decreased in the lower thoracic region because of change of the orientation of the facet direction. The lumbar facets favour flexion and extension because of the predominant sagittal plane. The amount of flexion varies at each interspace between lumbar vertebrae but most of the flexion takes place at the lower spine[26, 27]. Pearcy M, Portek I et al[28] and Pearcy Mj, Tibrewal SB et al[29] studied the ranges of movement in the lumbar spine in healthy young men as shown in Graph 1 and found that the overall range of sagittal plane movement is approximately 14 degree at most lumbar level, although the changing proportion of flexion and extension involves more at L3-4 and L4-5 than at other lumbar levels whereas lateral flexion and rotation are most free in the upper lumbar region and diminish in the lower region.

Graph 1: Range of Movements in the lumbar spine in healthy young man



Clinical Correlation

The Spinal biomechanics and Spinal disorder are related to each other. To understand the origin of limited structural failure in spinal tissue, is linked to back pain and tissue degeneration and may be both preventable and treatable. In general, patients with back pain move more slowly[30], and through a smaller range of movement presumably because full range movement exacerbates their pain. Patients with degenerative spondylolisthesis tend to move the slipped level first when bending forwards, sometimes in a disordered way, and when returning to the upright position again the affected level can be slow to extend[31].

During the normal living, most of the compressive force acting on the spine is generated by tension in the muscles of back and trunk and any activity which requires maximal contraction of these muscles can threaten the spine with compressive overload. Such activities are responsible for fatigue and failure; and lead to microdamage accumulation at a faster rate than the body's adaptive remodelling response. The structure anatomy of vertebral body of end plate is the weak link of the lumbar spine and when the compressive forces rise to high levels, the first unequivocal sign of damage usually occurs in the end plate or in the trabeculae which supports it[32,33,34]. In the normal disc, the pressure in the nucleus pulposus prevents the lamellae of annulus from collapsing inwards in response to high compressive loading, while in the case of end plate damage decompresses the nucleus and increases the direct compressive loading on the annulus, as shown in the figure 2. Under this circumstance, the inner lamellae can collapse into the nucleus. Vertical gravitational loading creates a forward shear force on the L4 and L5 vertebrae because these tend to be inclined forwards to horizontal. Standing in a very lordotic posture would increase the inclination on L5 and S1.

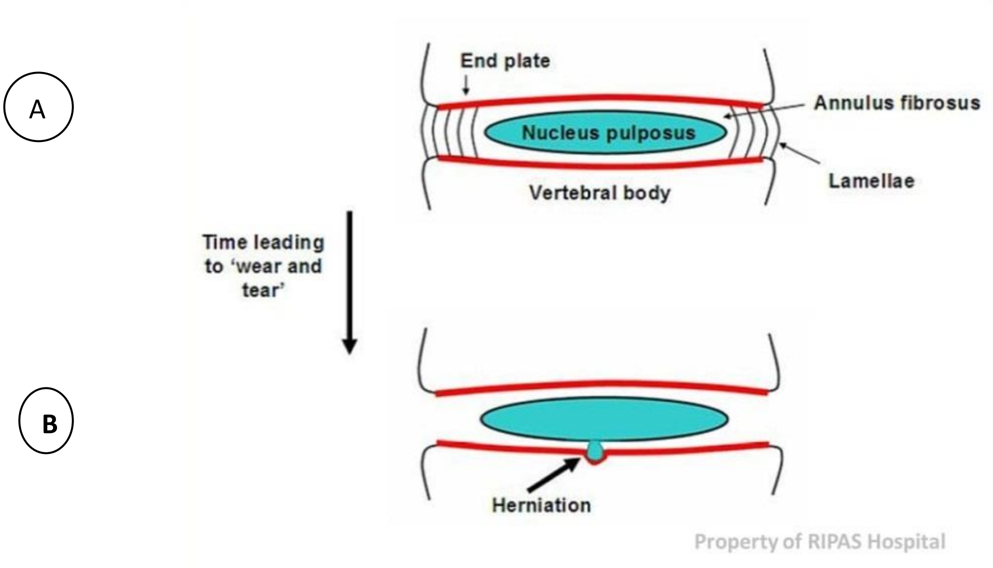


Figure 2: (A) Normal disc, the pressure in nucleus pulposus prevents the lamella of annulus from collapsing inwards in response to high compressive load (B) End palate damage decompresses the nucleus and increases the direct compressive loading on the annulus.

The forward shear force is increased if the trunk is inclined forwards, so marching long distance with a heavy backpack can be a common cause of shear failure of the neural arch[35]. The lumbar spine would be subjected to large torsion when someone bends forward and twists round to one side. Such awkward twisting movement are closely related to the disc prolapse and back pain[36,37] but it is likely that the main movements of the lumbar spine are forward and lateral bending rather than torsion. Exertions in the upright or extended posture are also likely to generate substantial antagonistic activity of the trunk muscle and lead to high compressive loading of the spine[38]. Activities which can injure the spine in forward bending like long period of flexed posture (for example driving a car), because stress relaxation will occur in ligaments and other collagenous tissues which have been stretched for a long time. This present a double risk to spine, firstly it allows the spine to creep into more and more flexion[39] so that condition is then more favourable for disc prolapse; and secondly stress relaxation of ligaments and tendons desensitise their muscular protection of the spine. During repetitive bending and lifting activities, this loss of reflex muscular protection is exacerbated by muscle fatigue[13] which reduces the muscle ability to generate maximum force in emergency[40]. Compressive damage to the vertebra allows the end plate to bulge into the vertebral body to a greater extent[41]. This effectively increases the volume available for the nucleus pressure[42,43].

Conclusion

From the outcome of our discussion it is possible to conclude that the knowledge of TS anatomy and biomechanics is important, because it plays a significant role for the prevention of the mechanical damage of spine in daily activities which is linked to low back pain and tissue degeneration. In our future research we will intend to concentrate on the management of patho-mechanics of spinal instability by therapeutic exercise intervention to extend our knowledge of biomechanics of TS.

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