THE INTERVERTEBRAL JOINTS I : THE INTERVERTEBRAL DISC

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Summary

The structure of the intervertebral disc is described in detail, some reference being made to clinically relevant aspects of the anatomy. Some biomechanical terms, such as motion and force, creep and hysteresis, are explained and discussed in relation to the intervertebral disc as a clinically important structure.

Opsomming

Die struktuur van die intervertebrale diskus word in detail beskryf, met verwysing na toepaslike kliniese aspekte van die anatomie. Party biomeganiese terme, soos beweging en krag, "creep" en "hysteresis", word verduidelik en bespreek met betrekking tot die intervertebrale diskus as 'n kliniese belangrike struktuur.

INTRODUCTION

Man, the finest example of bipedalism, shows remarkable adaptation to the erect posture and movements, particularly in the structure and functioning of the spine or vertebral column. This partly rigid, partly flexible central axis,[1,2] extending from the base of the skull to the end of the coccyx, is stabilised by strong ligaments and muscles which also limit the wide range of movements[3] taking place at the intervertebral joints. These movements occur at both the facet joints and the intervertebral discs.

Anatomical structure of the intervertebral discs

These intervertebral joints are anterior[1], unpaired, non-synovial cartilaginous joints of the secondary type[2,4]. That is, they are fibrocartilaginous discs[2] between the vertebral bodies, their shape corresponding to the articulating surfaces of the adjacent vertebral bodies[4]. They are designed for strength[3], and under normal circumstances, retain their fibrocartilaginous structure throughout life.

Each intervertebral disc is composed of:

(a) the **annulus fibrosus** which consists of approximately 10 to 12 concentric lamellae of collagenous fibres[3] running parallel to each other[11] (Figure 1). Between adjacent vertebrae, the fibres of these lamellae are positioned at an angle of about 70 degrees to the vertical and 30 degrees to the horizontal[5,6]. This gives the appearance, in side-view, of the fibres running obliquely between adjacent vertebral bodies[1,7] in such a way that some fibres are at right angles to others[1,3] (Figure 1). This criss-cross arrangement of fibres limits rotational movements in both directions[2]. The lamellae are attached to the bony margins of the articular surfaces of the vertebral bodies[1,3,6]. It is of clinical importance to note that the lamellae are thinner and fewer in number, and thus weaker, posteriorly[1,3,5,6]. Posteriorly too, the fibres of the lamellae run mainly vertically[2], adding to their inherent weakness in this area[1]. Slightly posterolaterally, where there is poor support by the narrow posterior longitudinal ligament, the majority of herniations or protrusions of disc material occurs[3].

(b) the nucleus pulposus which is derived from the embryonic notochord[2,3,4,7]. It is better developed in the cervical and lumbar regions of the spine[2], and consists of reticular and collagen fibres embedded in a mucoid or gelatinous material,[1,2,3,5,6,7,8], with an 88 per cent water content[1,2,5,6,7]. It is in contact with the hyaline cartilage covering the articular surfaces of the vertebral bodies[3]. The nucleus pulposus is enclosed within the annulus fibrosus and, as such, obeys the laws of hydrodynamics[1], acting as a "shock absorber"[6] for approximately 75% of the axial forces[7] through the spine[3]. It is positioned more towards the posterior aspect of the disc[1] because of the wider anterior part of the annulus fibrosus (Figure 1). In the cervical and lumbar regions of the spine, this allows the axis around which movement occurs to pass through the vertebral column slightly posterior to the anatomical centre of the intervertebral disc, and directly through the nucleus pulposus. In the thoracic region, however, the axis of movement passes anterior to the nucleus pulposus[7].

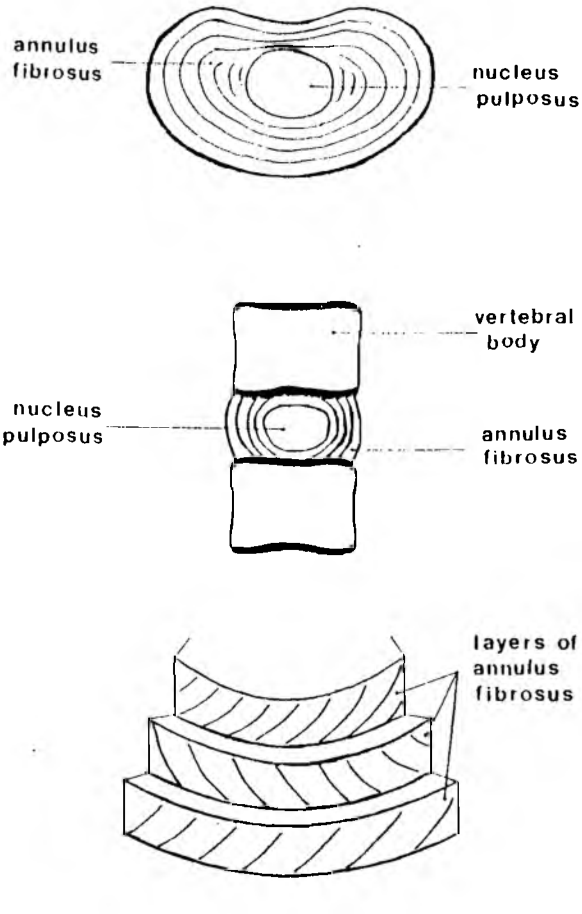

Fig. 1 The intervertebral disc

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All the intervertebral discs together constitute approximately one-quarter of the length of the spine[4], the remaining three-quarters of the length being made up by the vertebral bodies[3]. As would be expected because of their function to withstand stresses, the intervertebral discs increase in size (height and diameter) and strength from the second cervical to the first sacral vertebra of the spine[2,7]. (There are no discs between the occiput and the atlas or the atlas and the axis[3,4]). The cervical and lumbar regions of the vertebral column are wedge-shaped, being thicker anteriorly to accommodate the anteriorly convex secondary spinal curves[2,4].

The intervertebral discs are connected to adjacent vertebral bodies by the strong anterior longitudinal ligament anteriorly and the thinner, weaker posterior longitudinal ligament posteriorly, both of which run the entire length of the vertebral column[2,3,4]. The former prevents hyperextension of the spine, while the latter prevents hyperflexion of the vertebral column[3].

Each intervertebral disc is innervated by branches of the sinuvertebral nerve[9,10] (also known as the meningeal nerve[3] or the recurrent[9] spinal nerve[2]). These nerve endings are found in the outer lamellae of the annulus fibrosus only[10], and the normal nucleus pulposus is devoid of nerves[7,10]. Similarly, the peripheries of the intervertebral discs only, obtain their blood supply from branches of adjacent blood vessels, such as the anterior radicular arteries. The central parts of the discs, including the annulus fibrosus and the nucleus pulposus, are avascular[2,8].

With normal ageing process, the intervertebral discs become thinner due to dehydration[8] and degeneration of discal materials, resulting in slight height loss[3]. Desiccation of the nucleus pulposus and weakening of the annulus fibrosus[3] renders the ageing discs more subject to damage due to minor strains. Such trauma may lead to a herniated or prolapsed disc which involves the protrusion or herniation of nucleus pulposus material between the torn fibres of the annulus fibrosus, usually in a posterolateral direction[2,3]. This material may impinge on the adjacent spinal nerve root[2,3], causing the typical symptoms of nerve pressure. The most commonly occurring disc protrusions are the C5/6 and C6/7 intervertebral discs in the cervical region[2,3], and the L4/5 and L5/S1 intervertebral discs in the lumbar region of the spine[2].

Clinically relevant biomechanics of the intervertebral disc

(a) Motion and Force

Normal functional movements of the vertebral column cause forces to be exerted on the intervertebral discs. For example, flexion and extension, and side-bending or lateral flexion involve compression of that part of the disc closest to the side to which the spine is moved[6,7]. Similarly, stretching forces are experienced in the opposite sides of the discs[6,7]. On rotation, the lamellar fibres of the annulus fibrosus, running between the adjacent vertebrae, are stretched[6,7], due to the twisting movement of the spine (Figure 2).

The normal forces acting through the vertebral column and, therefore, on the intervertebral discs are thus due to compression (approximation), stretching (traction or distraction), shearing (gliding forces), bending (compression and stretching forces), and twisting (rotational forces)[1,6,7]. The intervertebral discs must be strong enough to withstand such forces so as to avoid injury[5,6].

The annulus fibrosus, under normal circumstances, can withstand the compressional forces due to the body's weight under the influence of gravity. These and other forces exerted during normal movements of the spinal column, are transmitted to the cartilaginous end plates of the adjacent vertebrae[6]. From here, they are absorbed into the vertebral bodies and thus dissipated[6]. The discs themselves are capable of absorbing some of the forces and, as a result, temporarily deform before transmitting the forces to the vertebral bodies[6]. A counteracting force may be exerted within the lamellar fibres of the annulus fibrosus part of the discs, as they are stretched or deformed[6,7]. This force will resist the force-producing motion, such as rotation[6,7] for example. However, prolonged, sustained or excessive force leads to more permanent deformation of the discs, followed ultimately by degenerative changes in the discs and adjacent vertebral

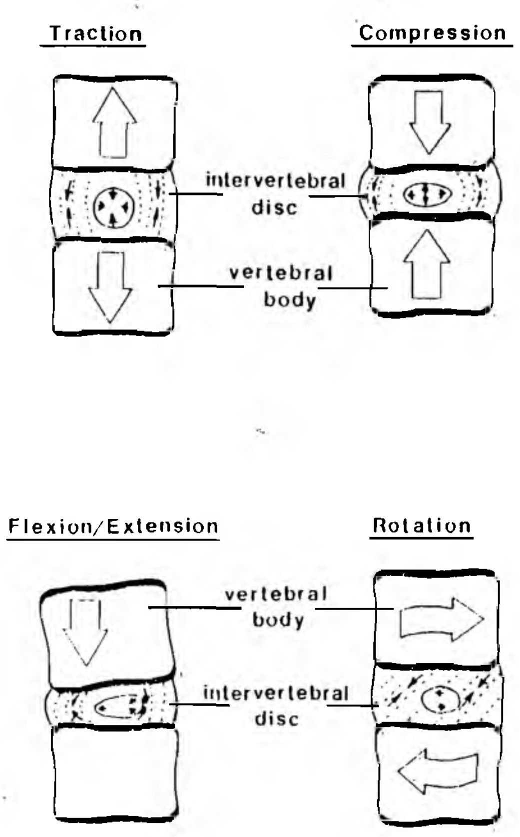

Fig. 2 Forces acting on the intervertebral disc

bodies.

The nucleus pulposus too is designed to sustain and transmit forces[6,7] due to normal weight-bearing and movements. In the normal, unloaded state, the nucleus pulposus exerts an internal pressure due to its water-absorbing capacity[6,7]. On applying a load or force to the disc, this internal pressure will increase as the force is absorbed by the nucleus pulposus, and subsequently decrease as the force is transmitted to the annulus fibrosus and then to the adjacent vertebral bodies as before[5,6].

If the load on the vertebral bodies is asymmetrical, the normal intervertebral disc exhibits a self-stabilising mechanism[7]. That is, the annulus fibrosus and nucleus pulposus nearest the side of the disc which is stressed becomes compressed, and the opposite side of the annulus fibrosus and the nucleus pulposus is stretched[6,7]. The stretched fibres of the annulus fibrosus lengthen[6,7] momentarily and, at the same time, the increasing pressure in the nucleus pulposus exerts a horizontal outward force[7]. This latter force exerts a pressure on the stretched fibres of the annulus fibrosus, causing them to return to their original length[7]. This applies a stabilising force on the adjacent vertebral bodies[7].

Thus, the intervertebral disc, because of these inherent properties, accommodates the various normal movements of the spinal column, transmits the various forces to which it is subjected, and adds to its stability.

(b) Creep and hysteresis

These concepts are characteristic of all visco-elastic tissues, such as the intervertebral disc[5,11].

Creep may be defined as that deformation which occurs in the tissue when a constant force is applied to it[11] (Figure 3). This deformation is immediate and constant with time until it reaches a steady state, provided the force remains constant[5]. The degree of deforma-

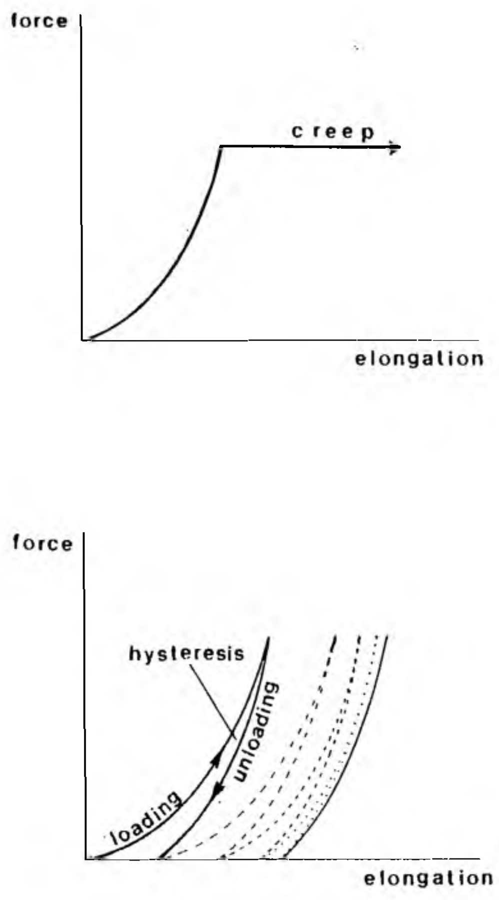

Fig. 3 Creep and hysteresis

tion depends on the force applied to and the type of material of the tissue[5]. An example of creep may be seen in sustained flexion of the vertebral column, when the posterior longitudinal ligament is stretched. There will be an immediate change in its longitudinal dimensions which will continue until there appears to be no further change occurring. Creep is said to have taken place in the tissue of the posterior longitudinal ligament. This phenomenon is evident in continuous traction techniques for the spinal column. However, it must be noted that as with all applications of force to tissues, excessive force will result in traumatisation of that tissue, which may be said to be due to excessive creep occurring.

Hysteresis may be defined as the difference in the deformation which occurs in the tissue during the loading and unloading of an intermittent force [5,11] (Figure 3). That is, when a force is applied to the tissue, there is an initial deformation of the tissue. On removal of this force, there is some recovery of the tissue as an attempt is made to regain its original dimensions. This recovery is not complete, however, as time is required before total recovery is possible. With further applications of this intermittent force, the change in the dimensions of the tissue between the loading and the unloading cycles, that is the hysteresis, is concomitantly less until a steady state is reached[5]. This phenomenon is seen in the use of mobilising techniques when a force is intermittently applied to the neural spine or over the facet joint of a vertebra, for example, in order to stretch the soft tissues between them. Again it must be noted that excessive force or force applied beyond the point of the steady state may result in injury to that tissue. In this instance, as in all cases of trauma, an added period to that time required for recovery from hysteresis must be allowed.

CONCLUSIONS

Both spinal mobility and stability are related to the intervertebral discs the important joints of the vertebral bodies. Antero-posterior movements in the sagittal plane, lateral movements in the coronal plane, and rotational movements around a vertical axis all involve changes occurring in these intervertebral joints. Moreover, intrinsic stability is afforded to the spine partly by the fibrocartilaginous intervertebral discs.

References

1. Morris JM. Biomechanics of the spine. *Arch Surg* 1973; **107**:418-423.
2. Williams PL, Warwick R, Dyson M, Bannister LH (eds). *Gray's Anatomy*. Edinburgh: Churchill Livingstone, (37th ed), 1989:**Ch 3,4**.
3. Moore KL. *Clinically Oriented Anatomy*. Baltimore: The William Wilkins Co, 1982:**Ch 5**.
4. Tobias PV, Arnold M, Allan JC. *Man's Anatomy: A study in dissection*. Johannesburg: Witwatersrand University Press, 1988; Vol III:**Ch 3**.
5. Gilmore KL. Biomechanics of the lumbar motion segment. In: Grieve GP, (ed), *Modern Manual Therapy*. Edinburgh: Churchill Livingstone, 1986; **Ch 9**:103-111.
6. Jensen GM. Biomechanics of the lumbar intervertebral disk: A review *Physical Therapy* 1980; **60(6)**:765-773.
7. Kapandji IA. *The Physiology of Joints*. Edinburgh: Churchill Livingstone, (2nd ed), 1979; Vol III:26-41.
8. Nachemson AL. The lumbar spine: An orthopaedic challenge. *Spine* 1976; **1(1)**:59-71.
9. Cloward RB. The clinical significance of the sinu-vertebral nerve of the cervical spine in relation to the cervical disk syndrome. *Neurol Neurosurg Psychiat*. 1960; **23**:321-326.
10. Edgar MA, Ghadially JA. Innervation of the lumbar spine. *Clin Orth Rel Res*. 1976; **115**:35-41.
11. Bogduk N, Twomey LT. *Clinical Anatomy of the Lumbar Spine*. Edinburgh: Churchill Livingstone, 1987; Ch 6:49-57.