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Discogenic low back pain

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GENERAL INTRODUCTION

Back pain and sciatica have plagued mankind for many thousands of years. The earliest description of sciatica is in an Egyptian manuscript, dated about 2.500 B.C..³⁰ In this case report a patient is presented with low back and leg pain, exacerbating with leg raising. The cause of the back and leg pain was attributed to vertebral strain and treatment was by (bed) rest. Later on in history, it was Hippocrates who introduced the term “sciatica”, but it were ancient Roman authors, like Soranus and Caelius Aurelianus, who defined sciatica and introduced the terms “psoadica” and “ischiadicus dolor” for pain in the psoas and ischia regions.³⁰

Although Aurelianus and Soranus clearly described different types of back pain, no contributions were made with regard to the anatomy of the lower back and to the pathogenesis of low back pain.³⁰ It was not until human dissections were performed by Vesalius in the 16th century⁶¹ before an anatomical basis for the etiology of low back pain was suggested. In the 18th and 19th century, many authors like Cotugno, Von Luschka, Lasègue, Oppenheim, Babinski, Virchow and Kocher^{19,30} attributed to the understanding of back pain. A reasonable and scientific explanation of one source of low back pain in combination with leg pain did emerge in 1934 with the publication of the classic paper by Mixter and Barr.³⁵ These investigators, for the first time, assigned prolapse of the intervertebral disc as the etiologic factor of - especially the sciatic part of - the symptoms. Nineteen patients with a prolaps of the intervertebral disc who underwent surgery were discussed. The operation consisted of laminectomy followed by transdural removal of the herniated disc. Mixter himself was convinced that this type of surgery increased the change of instability of the spine and therefore he recommended additional spinal fusion.

Steinler⁵⁰ first highlighted a relation between low back pain and degeneration of the intervertebral disc in the late forties. The impact of disc degeneration on the spinal motion segment and its role in causing low back pain has been studied extensively ever since (see Ch 3).

Although many factors presumed to be involved in causing low back pain have been studied thoroughly, it is remarkable that in most patients with low back pain seen nowadays, no actual cause can be held responsible. Some factors that are thought to either induce or potentially affect low back pain are shown in figure 1.1.

1.1 CLASSIFICATIONS OF LOW BACK PAIN

Getting the diagnosis does not only enable the attending physician to inform the patient about prognosis and treatment modalities, but it is also the first step for the patient in dealing with low back pain. Unfortunately, in contrast to a lot of well defined diseases like appendicitis, myocardial infarction or gonarthrosis, back pain is only a symptom; a personal and subjective experience usually without any objective signs.⁵⁹ Therefore, we have to rely on the individual verbal report and behavior in the appraisal of the severity of

low back pain. Only in less than 15% of all the people suffering from low back pain, an accurate cause-related diagnosis can be made.

Differentiation based on the duration of symptoms

Transient low back pain. Almost everyone is likely to experience transient twinges in the lower back area once in a while in his or her life. The passing awareness of discomfort, or perhaps sharper sensations, related to the back is brief and typical. Because of the universality of such symptoms, transient low back pain is the largest group of back pain. However, it is unlikely that this complaint is presented to a doctor, so it tends to be neglected in the consideration of this problem.

Acute low back pain. This is the type of back pain that most people are likely to think of, although this class is exceeded by the transient experiences in terms of magnitude. The key distinction between acute and transient low back pain is the duration of the symptoms. Acute back pain refers to symptoms present for sufficient time to compel most sufferers to take note of them. This category embraces a very considerable range of variation, extending from some hours up to three months.

Chronic low back pain. The smallest, but by far the most difficult to treat/handle, type of pain is the pain experienced by the group of chronic low back pain sufferers. In the literature, patients who suffer for periods in excess of three to six months are included. The critical distinction between acute and chronic low back pain is therefore largely a function of duration; people who experience low back pain for over 3-6 months are considered chronic low back pain sufferers.

The differentiation between transient, acute, and chronic low back pain is solely based on the duration of symptoms and says nothing about the onset or severity of the complaints. The onset of complaints may be dramatic, as with the “Hexenschuss” or witch’s blow, or it may be gradual, while the severity of suffering may extend from the mild to severe. The symptoms may be confined to the lumbar region (=lumbago) or they may radiate to other areas (e.g. to the lower limb = sciatica).

Clinical classification of low back disorders

A strict pathophysiological classification associated with low back pain is presented in table 1.1. Essential in making a diagnosis are objective clinical criteria, obtained through thorough history taking, physical examination and further evaluation (radiographs).

Although it is very difficult to make cause-related diagnosis in the group of back pain sufferers, an important role appears to be attributed to the intervertebral disc. The disc may be either a direct source of the pain (“painful” disc), or indirectly by exerting pressure on a nerve root (“herniated” disc). Furthermore disc degeneration causes decrease of the interbody height, which may induce wearing and tearing of any innervated constituent element of the motion segment, i.e. facet joints, ligaments, bone and muscles. Other diseases like Bechterew, Paget’s disease, Scheuermann’s disease, osteoporosis, primary- and secondary spinal tumors, rheumatoid arthritis, scoliosis, infections of the vertebral column, spondylolisthesis, and spondylolysis only make up a small portion of the low back pain symptoms.

Figure 1.1 Factors that may induce and/or maintain low back pain.

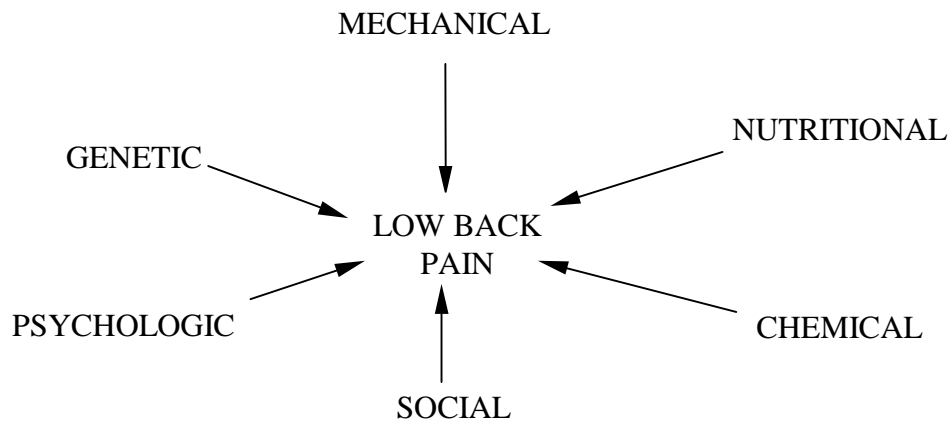


Table 1.1 Pathophysiological classification: causes of low back pain.

Classification	
<i>Vertebral and paravertebral causes</i>	
Degenerative disc disease	disc prolaps, anular tears
Degenerative joint disease	disc space narrowing, spinal stenosis, facet abnormalities, segmental instability
Arachnoiditis	postsurgical, postradiographic contrast study
Musculoskeletal disorders	strain, sprain, spasm
Neoplasm	metastatic, primary spinal tumors
Infectious	discitis, epidural empyema, vertebral osteomyelitis, spondylitis tuberculosa (Pott's disease)
Rheumatic conditions	ankylosing spondylitis, Reiter's syndrome
Traumatic	vertebral fracture
Idiopathic	
<i>Referred causes</i>	
Vascular origin	abdominal aortic aneurysm, arterial occlusive disease
Biliary origin	obstructed bile ducts, distended gall bladder
Gastrointestinal	visceral perforation
Uterine origin	ovarian carcinoma, endometrial carcinoma
Renal origin	renal carcinoma, kidney stones, ureteral stones, pyelonephritis, bladder carcinoma

The Quebec study classification

In 1987, a group of experts on low back pain agreed on a classification of disorders of the lower spine^{3,5,49}, useful in clinical decision making, establishing a prognosis, evaluating the quality of care, and in guiding scientific research. The study was funded by the Institute for Worker’s Health and Safety of Quebec and is therefore also known as the Quebec classification for disorders of the lumbar spine (see table 1.2). The classification is based on three assumptions: 1) the majority of patients with low back pain do not have verifiable structural abnormalities; 2) the majority of low back pain symptoms are self-limiting in a relatively short period of time; 3) the most valuable information for classification is the patient’s description of pain localization: in the lower back alone, in the lower back and the upper buttocks or thigh, or in the lower back and radiating to below the knee.

In the Quebec classification, emphasis is laid on objective documentation of the back pain symptoms, and, only when necessary, on possible causes of the pain. Possible sources of pain in category 1, 2, and 3 are, for example, injuries to soft tissues, the facet joints or the intervertebral disc. Lumbar disc herniation, specific nerve root lesions, and cauda equina syndrome due to (massive) lumbar disc prolaps are classified in categories 4 and 6. Category 5 includes acute spinal trauma and segmental instability, category 7 all forms of spinal stenosis. Issues related to spinal surgery and “chronic pain syndrome” are grouped in 8, 9, and 10. Other causes of low back pain like spondylolisthesis, primary and secondary tumors, and inflammatory lesions are in category 11.

Table 1.2 The Quebec classification for disorders of the lumbar spine.⁴⁹

Classification	Duration of symptoms from onset	Working status at time of evaluation
1 Pain without radiation		
2 Pain + radiation to extremity, proximally	a (< 7 days) b (7 days - 7 weeks) c (7 weeks - 6 months)	} W (working) } I (idle)
3 Pain + radiation to extremity, distally		
4 Pain + radiation to upper/lower limb + neurologic signs		
5 Presumptive compression of a spinal nerve root on a simple roentgenogram (i.e., spinal instability or fracture)		
6 Compression of a spinal nerve root confirmed by: - modern imaging techniques (computerized axial tomography, CT-myelography, magnetic resonance imaging) - ancillary diagnostic techniques (e.g., conventional caudography, electromyography, epidural venography)		
7 Spinal stenosis		
8 Postsurgical status, 1-6 months after intervention		
9 Postsurgical status, > 6 months after intervention		
9.1 asymptomatic		
9.2 symptomatic		
10 Chronic pain syndrome		} W (working)

How to classify low back pain

A major factor in the problem of making a diagnosis in back pain sufferers is the incongruence between findings on physical examination, radiographs, and histopathological studies. So, instead of categorizing by strict pathophysiological criteria it is often more useful to classify low back pain by non-specific findings, like the duration of symptoms and working status, because these parameters are strongly related to the eventual treatment outcome and socio-economic costs of low back pain.³⁶ Only when objective documentation is certain, classification by strict medical criteria can be attempted.

1.2 EPIDEMIOLOGY OF LOW BACK PAIN

In understanding low back pain, epidemiology offers insights in the magnitude of the problem, the natural history of low back pain and in individual and external risk factors associated with low back pain.¹ Unfortunately, a major problem in the epidemiology of low back pain is the lack of a generally accepted diagnostic classification, (see above 1.1). Some authors even argue that the epidemiology of back conditions should be restricted to sciatica and disc herniations, because they are easier and more uniformly defined and classified.²⁵

The magnitude of low back pain: prevalence and incidence

The *prevalence* of back pain is defined as the number of people who have complaints at a particular time in a given population irrespective of whether back pain was present before the survey was started or not. Prevalence depends on the incidence and duration of the symptoms. The *point prevalence* of back pain means back pain at the time the question is asked, whereas, for example, a 1-month prevalence means back pain occurring during the past month. *Incidence*, on the other hand, is a measure of the number of people without back pain who develop such pain (new cases) over a defined period e.g. the “ten-year-incidence” or the “lifetime incidence” of low back pain. Incidence depends only on the rate at which the symptoms occur. The determination of prevalence has the advantage that it can be obtained from a single survey, while incidence often requires following a population free of symptoms over a period of time.

Valkenburg and Haanen⁵⁸ performed a well-known study concerning the incidence and prevalence of low back pain in the Netherlands between 1975 and 1978 in Zoetermeer (table 1.3). Their study was based on a population of 3091 men and 3493 women 20 years of age and older. Evaluation was by questionnaires and standard physical examination. In people over 45 years of age, additional radiographs were made. Of all the people studied the lifetime incidence of low back pain was 51 % in males and 58 % in females. The point prevalence of low back pain was 22 % and 30 % respectively, both increasing with age up to 55 and 65 respectively, and decreasing thereafter. Thirty percent had suffered from low back pain for more than three months. In 85% recurrences occurred. Disc prolapse, defined by clinical signs and symptoms, was found in 1.9% of the men and in 2.2 % of the women. Compared to other countries the lifetime incidence of low back pain is rather low and the point-prevalence is rather high (table 1.4).

Data on the prevalence and incidence of low back pain are retrieved from insurance and hospital resources and from prospective and retrospective clinical

studies.^{9,23,32,33,34,40,58,62} From these data the impact of low back pain on a specific population can be estimated. The outcome, however, must be interpreted with caution for several reasons¹: 1) since a global definition of back pain is lacking in/exclusion criteria vary; 2) differences in the consequences of low back pain largely reflect individual (working conditions) and social differences (worker's compensation programs); 3) back pain is often intermittent resulting in false-positive as well as false-negative back pain observations in cross-sectional studies; 4) under-reporting often takes place in questionnaire data, illustrated by Svenson and Anderson^{52,53} who showed that of the men who said they had never had back pain, one fourth in fact had been off work with that diagnosis.

Table 1.3 Lifetime incidence and point prevalence of low back pain in the Netherlands, related to age and sex (EPOZ 1975-1978). (Based on data from Valkenburg and Haanen⁵⁸)

	% according to age group							
	20	25	35	45	55	65	75	total %
<i>Men (number in sample)</i>	292	662	778	674	398	201	86	3091
Lifetime incidence*	51.7	50.6	53.8	53.0	53.8	41.8	32.6	51.3
Point prevalence**	19.5	20.7	23.5	23.0	26.6	17.0	15.2	22.2
<i>Women (number in sample)</i>	298	764	833	684	415	305	194	3493
Lifetime incidence*	46.0	56.1	61.1	64.9	60.0	52.7	46.4	57.8
Point prevalence**	23.6	26.0	31.4	32.6	34.4	33.4	28.4	30.2

* Lifetime incidence defined as: low back pain ever

** Point prevalence defined as: low back pain now

Table 1.4 Prevalence and lifetime incidence of low back pain in different countries.

Lifetime incidence (%)	Prevalence (%)		Study group			Country	References
	Point	1-month	N	Age	Sex		
62.6	12.0	-	449	30-60	M	Denmark	Biering-Sørensen ⁶
61.4	15.2	-	479	30-60	F		
60.0	-	-	1193	25-59	M	Sweden	Hult ²⁷
48.8	-	-	692	15-72	F		Hirsch et al ²⁶
61	-	31	716	40-47	M		Svensson et al ⁵³
67	-	35	1640	38-64	F		
51.4	22.2	-	3091	20+	M	The Netherlands	Valkenburg/Haanen ⁵⁸
57.8	30.2	-	3493	20+	F		
-	18.0	-	1135	18-64	M	United States	Nagi et al ³⁹
69.9	-	-	1221	28-55	M		Frymoyer et al ¹⁶

Impairment and disability

Back pain is an impairment, which can give rise to functional limitations, disability or even to a handicap. The World Health Organization (WHO) has defined impairment as “any loss or abnormality of psychological, physiological, or anatomical structure or function” (1980). Body injury may result in impairment. Disability is defined as “any restriction or lack of the ability to perform an activity in the manner or within the range considered normal resulting from an “impairment”. The definition for a handicap is “a disadvantage for a given individual, resulting from an impairment or a disability, that limits or prevents the fulfillment overall that is normal (depending on age, sex, and social and cultural factors) for that individual (WHO 1980). The concept of disability includes the presence of illness, reduced capacity to function, actual reduction in functioning, and handicap. The relation between impairment and disability rates is not necessarily linear, as pointed out by Haber²⁴ (see table 1.5). For example, although the impairment rate for heart trouble is less than half the impairment rates for arthritis and rheumatism, the disability rates for the conditions are similar. Reports on back and spine impairments are high, but the disability rates are less impressive and less than one tenth of the impaired are severely disabled and handicapped. This has probably to do with the fact that many people will experience low back pain in their lives, usually of short duration followed by a brief interval of restricted activity. Only a small percentage will have persisting low back pain leading to health care consumption, inability to work, and eventually to a disability status.¹³ Haber²⁴ also pointed out that selective factors in the distribution of the disorder in the population (age, work, and educational level) could influence the disabling potential of the impairment.

Table 1.5 Morbidity and disability from selected conditions in Great Britain (rates per 1.000 persons).²⁴

Condition	<u>Impairment</u>	<u>Disability</u>	
		All grades	Severe
arthritis and rheumatism	79	21	7
back and spine impairments	52	18	4
heart trouble	29	20	7
high blood pressure	47	9	4

In 1992, Nachemson³⁷ reported on the international incidence of disabling low back pain. Table 1.6 is partially based on his data. Nachemson emphasizes the influence of insurance factors on the disability of low back pain. The patient, believing that the back pain is work-related, will seek remuneration. This process will take quite some time, and, meanwhile, the patient will adapt to the sick role resulting in pain behavior.

Table 1.6 International comparison of the yearly incidence of disabling low back pain, based on data from Nachemson.³⁷

Country	Inhabitants (millions)	% sicklisted with back diagnosis*	Average days of absence**
USA	240	2	9
Canada	23	2	20
Great Britain	55	2	30
West Germany	61	4	10
The Netherlands	14	4	25
Sweden			
1980	8	3	25
1983	8	5	30
1987	8.5	8	40

* % of workforce sicklisted with back diagnosis per year;

** average number of days of back pain-related absence per patient per year.

Social-economic consequences

In the United States, low back pain is the most expensive health care problem in the 20-50 year old age group and the most common cause of disability in the population less than 45 years old.^{15,24} The major costs of back pain are associated with people suffering chronic disabling low back pain. Approximately 5.2 million persons are disabled by low back pain, 50 % of them permanently.^{22,46} The total estimated costs attributed to low back pain in the United States are between \$16-\$50 billion and at least 85 % of these costs is related to recurrent or chronic disability (1986).^{2,17,48,51} Low back pain is, when compared with other health conditions, also costly in terms of earning losses, productivity losses, and debility costs.¹⁰

Van Tulder et al.⁵⁷ estimated the costs of back pain to society in The Netherlands to be 1.7 % of the gross national product (GNP) in 1991. The total direct medical costs were estimated at \$367.6 million and the total indirect costs (result from productivity losses) for the entire labor force at \$4.6 billion.

The natural history of disabling low back pain

After an acute episode of idiopathic low back pain, data reflecting functional return reveal an excellent prognosis (see figure 1.2).³⁷ Within four weeks from the onset of the low back symptoms, 50 % of the patients will return to work and after six weeks 90% is working again. Little can be done, in way of treatment, to alter this course. Only 5 % of the low back pain sufferers will be disabled for over three months, 2-3% for over six months and about 1% will experience disabling low back pain for over a year. Some factors are known to complicate the natural course and include sciatica, certain radiographic findings, and a variety of social, psychological, and economic conditions.⁶³ In a prospective cohort study on low back pain in the Netherlands by Van den Hoogen et al.⁶¹ (1997), similar results are reported. However, 10% of the patients still experience back pain after one year.

Attacks of low back pain recur rather frequently but they may not be so severe as the first attack. Normally, recurrences are less common during the third year than during the

first two. This perhaps demonstrates a tendency of low back pain to last for a couple of years but then to subside.⁵⁶

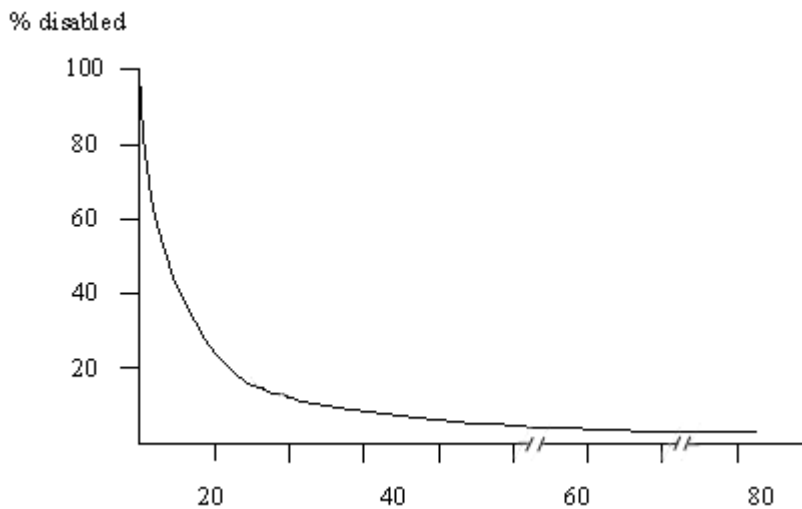


Figure 1.2 Timecourse of disabling low back pain.³

Risk factors

Age

A study by Biering-Sørensen⁶ indicates an increasing risk of low back pain with age until the fifth decade of life. Thereafter, the relative risk decreases in men but not in women. In the study by Valkenburg and Haanen⁵⁸, a similar course can be seen in men but a decrease in the prevalence of low back pain can not be noticed in women until after the age of 65 (see table 1.3 again). A study by Svensson⁵⁴ also shows an increasing risk of low back pain until the age of 64 in women. A hypothesis for the later decrease in the prevalence in women is that the high prevalence of osteoporosis in women after the menopause makes them more susceptible for low back pain. The risk of disc herniation at the L4-L5 and L5-S1 levels also increases until the fifth decade, followed by a decrease.⁴⁷ The relative risk of disk herniation at the L2-L3 and L3-L4 levels is greater in people over 50 years old.⁴⁷

Sex

Cross-sectional studies show little or no differences in the relative risk of low back pain between the sexes until the fifth decade of life.¹⁶ Thereafter the risk is greater in women (osteoporosis, see *Age*).^{6,47,54,58} However, for uncertain reasons, the disability risk of low back symptoms and the risk of hospitalization for disc herniation are greater in men than in women.^{24,29} Socioeconomic factors rather than biologic differences appear to be responsible for this phenomenon.

Pregnancy

Low back pain is also common during pregnancy³ and the relative risk ratio is approximately 3 to 1 in multiparous versus nulliparous.¹⁴

Hereditary factors

Until now, there is some evidence that low back pain has a genetic component.¹⁵ Some researches^{12,31,60} found a significant increase in the prevalence of disc herniation in the first-degree relatives of patients with disc herniation. A case-control study by Simmons⁴⁵ shows a familial predisposition for degenerative disc disease. Furthermore, in a recent study of Annunen et al.⁴ examining the COL9A2-gene, which codes for one of the polypeptide chains of collagen IX, an allele of this gene was identified that is associated with intervertebral disc disease. The intervertebral disc contains small amounts of collagen IX. This collagen is thought to serve as a bridge between collagens and noncollagenous proteins in discs. The analysis identified a putative disease causing sequence variation in an allele of COL9A2 that converts a codon for glutamine to one for tryptophan. The tryptophan allele was correlated with the disease phenotype and found in the families studied with low back pain. A genetic antecedent is also present in specific but rare conditions associated with low back pain like congenital spondylolisthesis, Scheuermann's disease and achondroplasia.

Body weight/height/physical fitness

Some studies indicate that body weight and height are related to the prevalence and incidence of low back pain while others do not find such a correlation.^{12,42} Lots of attention has been paid to physical fitness and sports in relation to low back pain and it is thought that low back pain is more common in the physically unfit.^{15,17,29,54}

Smoking

The relation between smoking and low back pain has been described by several investigators^{8,17,55} and many explanations have been postulated such as: 1) coughing from smoking increases the internal abdominal pressure and the intradiscal pressure and thus strains the spine³⁸; 2) nicotine reduces vertebral body blood flow, disc nutrition will be reduced promoting disc degeneration¹⁷; 3) smoking may be associated with anxiety and depression, which exacerbate or prolong back pain.¹¹

Occupation

Next to certain movements and actions related to work (bending, twisting, vibration, heavy lifting¹⁵), the psychosocial factors of work are also important in relation with low back pain.⁷ Job satisfaction might be as important as the physical burden of labor itself in being free from low back pain. These psychosocial factors even become more important in the development of chronic low back pain.¹⁸ However, it is not quite sure if the observed psychosocial difficulties either caused or resulted from the disability.

Concluding remarks

National statistics from the different European countries and from the United States indicate a (point) prevalence of low back pain in the 15-35% range. Although the natural history of low back pain shows an excellent recovery within weeks, approximately 1% of the low back pain patient will become chronically disabled. The socioeconomic consequences of this group of chronic disabled low back pain patients are enormous in terms of earning losses, productivity losses, and debility costs. Important risk factors for prolonged low back pain disability are psychological and psychosocial factors including work dissatisfaction.

1.3 CLINICAL ANATOMY OF THE LUMBAR SPINE

The spine can be considered as a multi-curved column, perfectly designed for its main functions: distribution of body forces, provision of flexibility for motion, and protection of the spinal cord.²⁰ The vertebral column consists of 33 vertebrae, of which, in the adult, nine are fused together to form the sacrum and coccyx. The sacrum is integrated into the pelvis in such a way that, normally, only little motion can occur in the sacro-iliac joints (SI-joints). The 24 mobile vertebrae can be divided into 5 lumbar vertebrae, 12 thoracic vertebrae and 7 cervical vertebrae, joined together by intervertebral joints, intervertebral discs, and ligaments. The different structures of the spinal column each serve specific functions but, with respect to a single vertebral level, they all act together in a functional and anatomical unit called the “motion segment”. The term, originally called “motor segment”, was introduced by Junghanns^{28,44} who suggested that, in order to understand and study the motion of the lumbosacral spine, all articular tissue, spinal muscles, and segmental contents of the vertebral canal and intervertebral foramen had to be combined in a single functional unit.⁴¹ In the following, the different structures, their functions, and the functional motion segment of the lumbar region will be discussed.

The lumbar vertebrae

The lumbar vertebra can be divided into three functional parts: 1) the vertebral body; 2) the pedicles; 3) the posterior elements. The different parts have unique functions but they act together in the integrated function of the whole vertebra (figure 1.3).

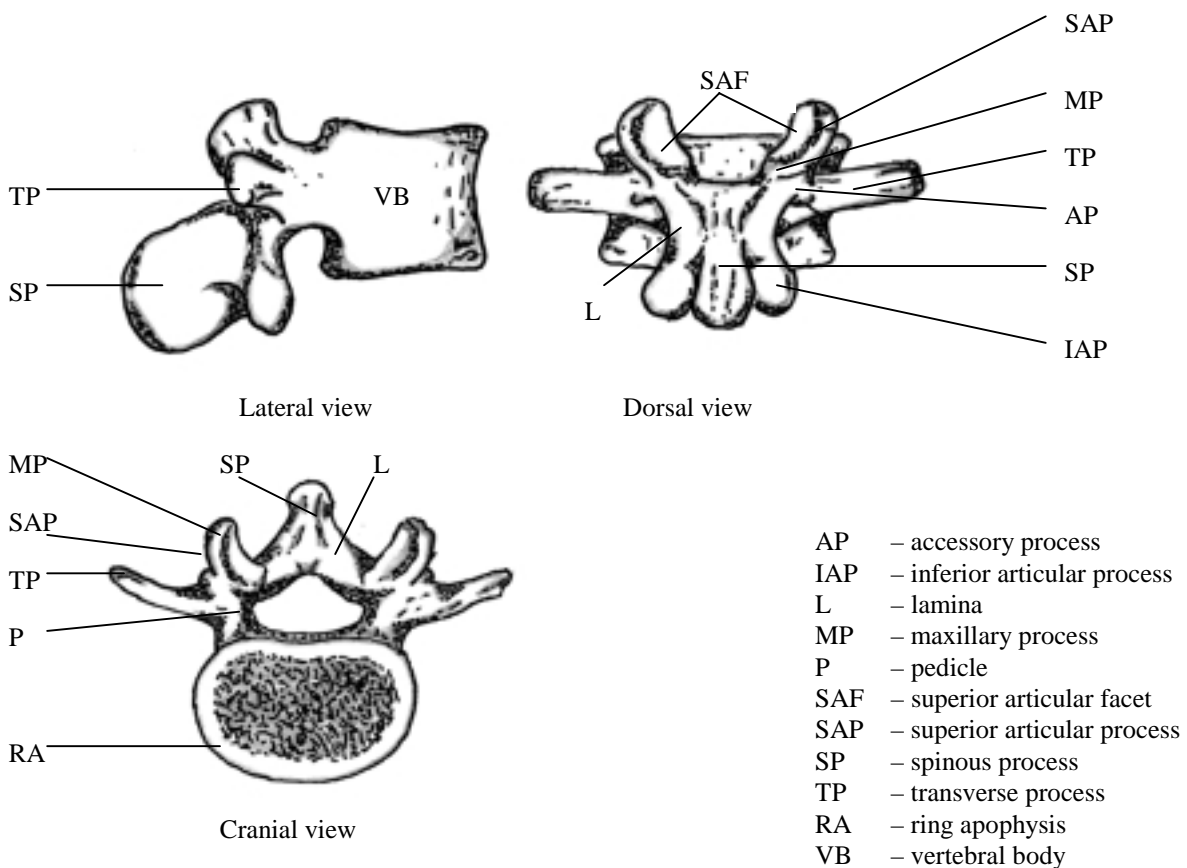




Figure 1.3 The lumbar vertebra.

The vertebral body

The vertebral body is a large block of bone, perfectly designed for its - longitudinally applied - weight-bearing purpose. Its internal structure consists of a cancellous cavity with vertical and transverse trabeculae surrounded by a layer of cortical bone. The main advantages of having the trabecular internal structure over a solid bone block is the lesser weight of the vertebra, the ability of sustaining static as well as dynamic loads, and the possibility of being well supplied by the arteries and veins running through the trabecular cavity. The trabecular cavity of the vertebral body filled with blood appears as a sponge and is therefore also known as spongiosa. Although the weight-bearing capacity of the vertebral bodies is enormous, the vertebral bodies can not resist sliding and twisting movement of the lumbar spine.

The pedicles

The pedicles function as a bridge between the vertebral body and the posterior elements. They transmit both tension and bending forces acting on the posterior elements of the vertebra to the vertebral body.

The posterior elements

The posterior elements of the vertebra consist of the articular processes, the spinous processes, and the laminae. The posterior elements are submitted to various forces acting on the vertebra. The inferior and superior articular processes, for example, resist forward sliding and twisting of the vertebral bodies. The spinous, transverse, accessory and mamillary processes are muscles-attachments and are therefore submitted to muscular forces acting on the vertebra. The laminae conduct forces from the spinous and articular processes to the vertebral body resulting in movement and providing stability. A specific part of the laminae at the junction of the vertically oriented lamina and the horizontally projecting pedicle, the pars interarticularis, is subjected to forces transmitted by the lamina into the pedicle. The laminae have, in addition to the conduction of forces, a protective function of the neural contents of the vertebral canal.

Intervertebral joints

Between two consecutive lumbar vertebrae, there are three joints: a joint between the vertebral bodies, and two joints between the articular processes (zygapophyseal joints or facet joints). Part of the interbody joint is the intervertebral disc, a layer of strong, deformable, soft tissue allowing load transfer and movement of the vertebrae in all directions. The structural and functional properties of the intervertebral disc will be discussed in detail below. The zygapophyseal joints are typical synovial joints, covered by articular cartilage, synovium, and enclosed by a fibrous capsule. The zygapophysial joints prevent forward displacement and rotary dislocation of the vertebrae. The extent to which a zygapophyseal joint can prevent movement strongly depends on the shape and position of the articular processes.

The intervertebral disc

The lumbar intervertebral discs consist of a central nucleus pulposus surrounded by an annulus fibrosus. A third component of the disc is the vertebral end-plate, which covers the top and bottom of the disc. The central fibers of the inner two-thirds of the annulus fibrosus attach directly to the cartilaginous end-plates and the peripheral fibers insert along the bony vertebral body margin (ring apophysis) as the so-called Sharpey's fibers (figure 1.4).

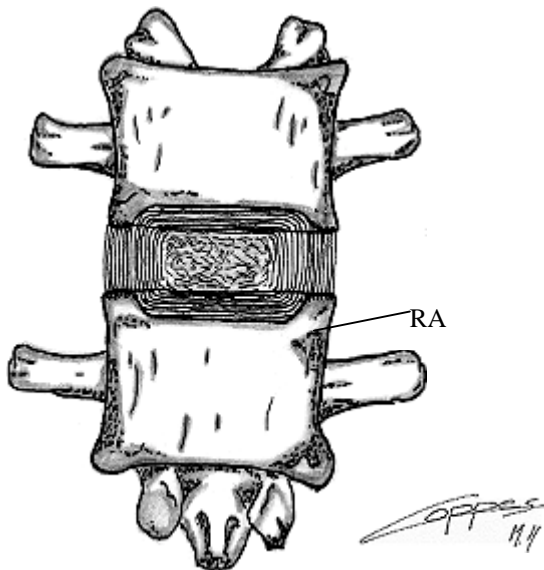


Figure 1.4 Detailed structure of the vertebral end-plate.

The collagen fibres of the inner two-thirds of the annulus fibrosus sweep around into the vertebral end-plate, forming its fibrocartilaginous component. The peripheral fibres of the annulus are anchored into the bone of the ring apophysis (RA).

The nucleus pulposus is an acellular meshwork of proteoglycan units, aggregates, and collagen fibers collectively called the nucleus matrix. The proteoglycans make up 65% of the dry weight of the nucleus, the collagen (predominantly type II) 15-20%. The proteoglycan units are formed by many glycosaminoglycans linked to a core protein. These proteoglycans contain water, the main component of the nucleus pulposus. The high water content of the nucleus pulposus (70-90%) is essential for maintaining its principle function: sustaining and transmitting weight. When the intervertebral disc is compressed, the pressure in the nucleus pulposus will increase resulting in deformation of the nucleus pulposus. The pressure is then exerted radially onto the annulus fibrosus. Subsequently, the tension in the annulus fibrosus will rise and this will prevent further radial expansion of the nucleus pulposus.

Water is also the main component of the annulus fibrosus (60-70%) but collagen (mainly type I) makes up 50-60% of the dry weight and only 20% of the dry annulus is proteoglycan. This high concentration of collagen thickens the annulus. Another difference between the nucleus and the annulus is the high concentration of elastic fibers in the annulus (10% of the dry weight). These elastic fibers are arranged circularly, obliquely and

vertically in the lamellae of the annulus and are predominantly located towards the attachment sites of the annulus on the vertebral end-plate. Because the collagen fibers of the annulus are elastic they can stretch and thereby retain energy. This energy can be exerted back onto the nucleus pulposus and restore its deformation.

The vertebral end-plates are also composed of water, proteoglycans, and collagen. The relative concentrations of the components in the end-plate are similar to that in the disc: high water and proteoglycan concentrations in the part of the end-plate adjacent to the nucleus; high water and high collagen concentrations in parts of the end-plate in contact with the annulus. Small molecules can therefore freely diffuse from the vertebral sinusoids to the avascular disc elements, important for nutritional needs. Once the tension in the annulus has increased after compression of the intervertebral disc, nuclear pressure is exerted on the end-plates by the annulus as well as by the nucleus. This pressure eventually transmits the load from one vertebra to the next.

Ligaments of the lumbar spine

In general, ligaments provide much of the joint-stability and limitation to the range of motion. The ligaments of the lumbar spine may be divided in those connecting:

- 1) the bodies of the vertebrae;
- 2) the laminae;
- 3) the spinous processes;
- 4) the articular processes;
- 5) the 5th lumbar vertebra to the sacrum and ilium;

Finally, so called false ligaments are present.

Ligaments connecting the bodies of the vertebrae

The ligaments that interconnect the vertebral bodies are the *anterior longitudinal ligament* and the *posterior longitudinal ligament*. The two ligaments are strongly related with the *anuli fibrosi* of the intervertebral discs. During extension, the anterior longitudinal ligament resists anterior separation of the vertebrae, while the posterior longitudinal ligament prevents posterior separation during flexion. The annulus fibrosus resists distraction, bending, sliding, and twisting of the intervertebral joint during all kinds of motion.

Ligaments connecting the laminae

The *ligamentum flavum* is a short, thick ligament interposed between the laminae of two consecutive vertebrae. The ligaments consist of yellow elastic tissue and are therefore often called the yellow ligament. Its unique elastic properties are thought to be necessary for returning the flexed lumbar spine into the extended position and for preserving the upright posture.

Ligaments connecting the spinous processes

The interspinous ligaments connect two spinous processes. They limit forward bending by preventing supraphysiological separation of the two spinous processes. The supraspinous ligament interconnects the apices of the spinous processes. The supraspinous ligament is closely blended with the aponeurosis of the back muscles.

Ligaments connecting the articular processes

The capsular ligaments form the capsules of the zygapophysial joints (see *intervertebral joints*). They function as ligaments by preventing excessive motion of these joints.

The lumbo-sacral and ilio-lumbar ligaments

The *lumbo-sacral ligament* is short, thick, and triangular and connects the lower and front part of the transverse process of the fifth lumbar vertebra to the lateral part of the base of the sacrum. The *ilio-lumbar ligament* binds the transverse process of the fifth lumbar to the ilium. The ilio-lumbar ligament consists of five parts: anterior, superior, posterior, inferior, and vertical.

False ligaments

The lumbar spine contains some ligaments that can not be considered as “real” ligaments for several reasons such as structure and origin.⁷ They include the *intertransverse ligaments*, the *transforaminal ligaments*, and the *mamillo-accessory ligament* (figure 1.5). The intertransverse ligaments are sheets of connective tissue connecting the upper border of one transverse process to the lower border of the transverse process above. They lack distinct borders, and the fibers are not densely packed nor are they oriented as fibers of true ligaments. The transforaminal ligaments are collagen fibers traversing the outer end of the intervertebral foramen, present in about 47% of the population.²¹ They do not connect two bones and their structure resembles bands of fascia rather than ligament. The mamillo-accessory ligament connects the tip of the ipsilateral mamillary and accessory processes of each lumbar vertebra and its structure appears more like a tendon than a ligament.

- ICL - inferior corporotransverse ligament
- ITL - inferior transforaminal ligament
- MAL - mamillo accessory ligament
- MTL - middle transforaminal ligament
- SCL - superior corporotransverse ligament
- STL - superior transforaminal ligament

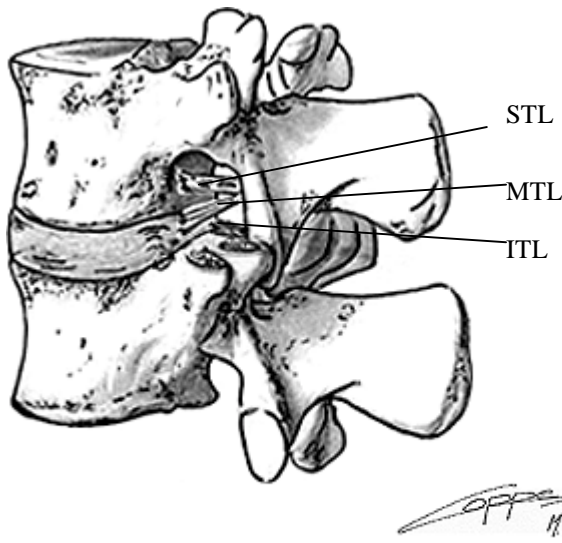
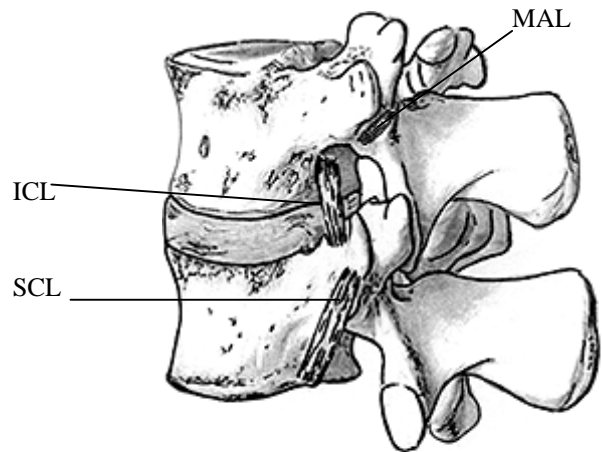


Figure 1.5 False ligaments.

The motion segment

As mentioned before, the motion segment can be considered as the basic functional unit of the spine (figure 1.6). The motion segment includes all articular tissue, the overlying spinal muscles, and the segmental contents of the vertebral canal and intervertebral foramen between two vertebrae and its concept is ideal for experimental studies. Although one motion segment relates two adjacent vertebrae exclusively, it must be considered as a link in a functional chain: the entire spine.⁴¹ The motion segment is viscoelastic, absorbs energy, moves with six degrees of freedom (three translations and three rotations), exhibits coupled motion (motion in one direction affects motion in others), has limited fatigue tolerance, and depends upon its bony and ligamentous components for mechanical tasks.⁴³



Figure 1.6 Motion segment, basic functional unit of the spine.

1.4 THE LUMBAR SPINE AND LOW BACK PAIN

Any structure of the lumbar spine that is connected to the nervous system can become a source of low back pain when affected by disease or disorder. The way in which the different structures of the lumbar spine are related to low back pain is discussed in Chapter 2. The specific role of the degenerated intervertebral disc in low back pain is discussed in Chapter 3. When certain structures of the lumbar spine are “identified” as a source of low back pain in individual patients, specific treatment can be attempted. In Chapter 5 we present the results of lumbar interbody fusion (Ch 4) in patients with severely disabling low back pain based on spinal degeneration.

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