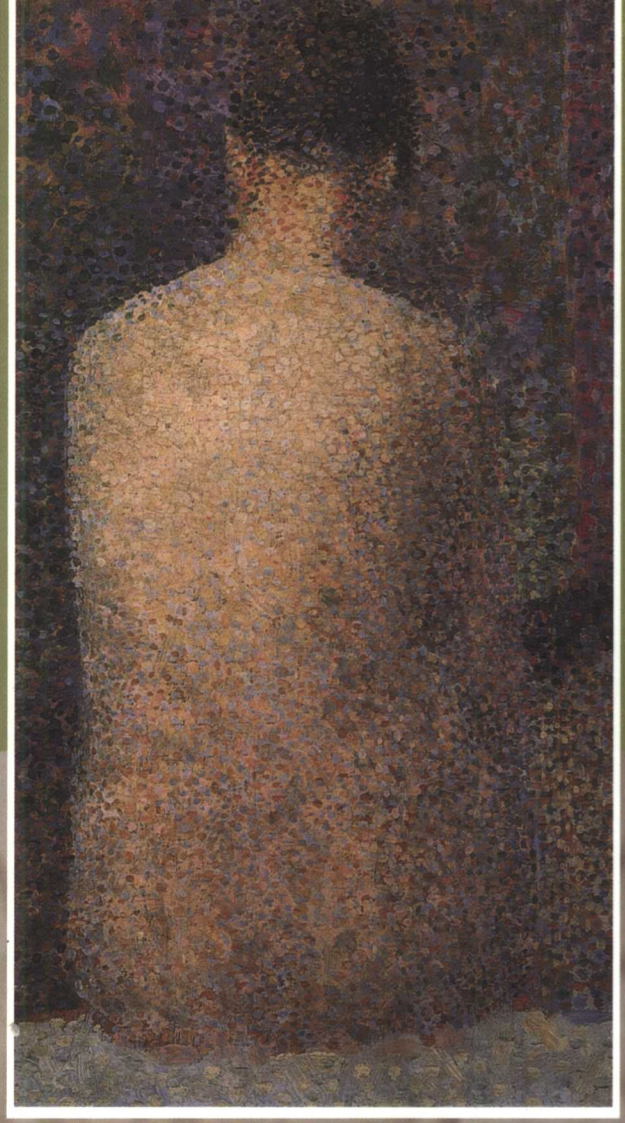

Wendell Liemohn

EXERCISE PRESCRIPTION

and the **BACK**

EXERCISE PRESCRIPTION AND THE BACK

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EXERCISE PRESCRIPTION AND THE BACK

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PREFACE

In addition to being a major problem in medicine, low back pain (LBP) presents as a major problem in sport, for dependent upon the sport, LBP is often seen across strata of skill levels, whether they be seen in a weekend athlete or in a highly toned professional athlete. LBP is a condition that does not appear to be related to gender from the perspective of susceptibility, thus although the incidence of LBP in sports such as tennis and swimming may be comparable between genders, gymnastics may present more low back injuries for females (with age accounting for some of this disparity), and American football would of course present more back injuries for males.

This book could be used as an adjunct text in courses in physical therapy, athletic training, and exercise science. Because of its research basis, it could also be used as a reference by the aforementioned as well as a reference for physicians. The contributing authors include five physical therapists (two are also ATC's and three are Ph.D.'s and two are working on their Ph.D.), three M.D.'s (all physiatrists), and four Ph.D.'s (one is an ATC and one is a D.C.).

Part I of the book is entitled *Musculoskeletal Form and Function of the Back.* It includes a chapter on the anatomy and biomechanics of the trunk that endeavors to provide the reader with a basic foundation, based on a synthesis of the most recent research, for the ensuing chapters. Because flexibility can be an important element in both exercise therapy and in prevention, the second chapter in this section is devoted to it. In addition to addressing factors that specifically relate to the functioning of the spine, this chapter also reviews generic aspects of flexibility including range of motion improvement programs.

Part II of the book is entitled *Epidemiology and Diagnosis.* The first chapter in this section (Ch. 3) is written by two M.D.'s; they present the reader with techniques of assessing the individual who presents with low back pain. Chapter 4 addresses

the role of aerobic condition and the spine. It is followed by a chapter that examines different sports and the types of stresses incumbent in each that can lead to low back pain.

Part III of the book is entitled *Exercise Prescription.* The first chapter of this section (Ch. 6) reviews exercise protocols starting with the one proposed by Williams in the 1930's; this is followed by a discussion of the respective programs popularized by McKenzie and the San Francisco Spine Institute (i.e., lumbar stabilization). In the next chapter, the Feldenkrais and Alexander techniques are discussed. Chapter 8 presents exercise protocols for those low back conditions. Both Chapters 9 and 10 are on aquatic therapy; the first gets into history and hydrodynamics and the next gets into aquatic exercise per se. Chapter 11 presents the latest research on back strength development. The concluding chapter presents research on the efficacy of clinically controlled trials of exercise regimens.

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I would like to thank Gene Asprey, my M.S. and Ph.D. advisor at the University of Iowa, who initially kindled my interest in the low back many years ago. With tongue in cheek, I express my thanks for having had the opportunity to have an acute disc problem, for this experience enabled me to better appreciate the nuances of LBP for it helped teach me what I could do to combat it.

I would like to thank Tinah Utsman for her photography and my former students who posed as subjects. Although cited in the figure captions, I also am most appreciative of the pictures that were courtesy of the Lady Vol Media Relations Office, the Vol Sports Information Office, and Football Time in Tennessee. I am particularly indebted to Flora Shrode, Associate Professor and Science Coordinator, University of Tennessee Libraries, who volunteered and proofread the majority of the chapters and offered extremely helpful advice.

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PART I

MUSCULOSKELETAL FORM AND FUNCTION OF THE BACK

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CHAPTER 1

ANATOMY AND BIOMECHANICS OF THE TRUNK

Wendell Liemohn

INTRODUCTION

THE SPINE

Architecture of the Spine

Curvatures of the Spine
- Lordosis
- Kyphosis
- Scoliosis

Vertebrae

Intervertebral Discs
- Annulus Fibrosis
- Nucleus Pulposus
- Vertebral Endplate
- Functional Adaptations of Discs

Facet (Zygapophyseal) Joints

MUSCULOLIGAMENTOUS SUPPORT STRUCTURES

Ligaments of the Spine

Muscles and Related Connective Tissue

Considerations in Prescribing Trunk Flexion Exercises
- Examination of Mechanical Considerations
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Mechanical Considerations Inherent in Lifting

Flexion–Relaxation Response

Intraabdominal Pressure

Thoracolumbar Fascia

Further Research on Lifting

Trunk Bracing

Neutral Spine/Abdominal Brace/ Trunk Stabilization

SUMMARY

INTRODUCTION

The purpose of this chapter is to present a review of those aspects of anatomy and biomechanics that are pertinent to the functioning of the spine and low back pain (LBP). This synthesis will include a review of anatomy, a discussion of vertebrae and disc biomechanics, an examination of trunk flexion exercises, and a description of pertinent synergies of the muscular and connective tissues of the trunk. The latter will be followed by a brief discussion on some research on lifting, and how it relates to trunk stabilization (also called trunk bracing). The San Francisco Spine Institute (1) was one of the first entities to espouse trunk stabilization as a technique to be used in rehabilitation. Learning to stabilize the trunk when it is in a neutral and pain-free position is a major element in therapeutic exercise in most back rehabilitation programs.

THE SPINE

The segmental mobile spinal column, coupled with its fascia and muscular counterparts, has been called a biomechanical masterpiece (2). Its uniqueness is attributed in part to its being able to balance lordotic curves in the cervical and lumbar regions, with kyphotic curves in the thoracic and sacral regions. This results in a double "S" curvature that enables the spine to absorb vertical forces in spring-like fashion (Fig. 1-1).

The spine is an important contributor to many movements; however, its role in these movements is often overlooked. After seeing negligible differences in spine movement in a man engaged in bipedal locomotion compared with that of a man without legs walking on his ischial tuberosities, Gracovetsky contended that the spine and its surrounding tissues are in essence the primary "engine" of locomotion in the human species (3,4). Many examples depicting an "engine role" for the spine in sports exist; for example, shot putters and hammer and discus throwers in particular display how a winding and unwinding rotation-type movement of the spine contributes to success in their athletic activities (Fig. 1-2).

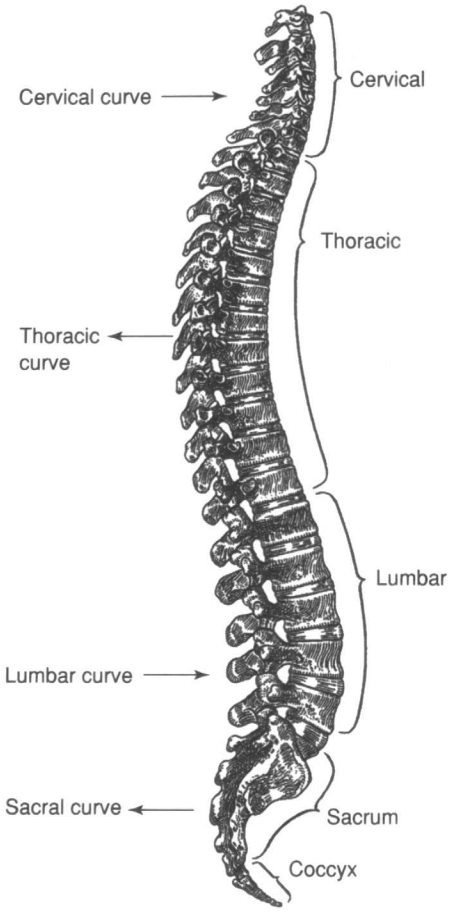

Fig. 1-1 Lateral view of the spinal column. (From Pansky, B. *Review of Gross Anatomy.* © 1996. Reprinted with permission from the McGraw-Hill Companies, Inc.)

Architecture of the Spine

The architecture of the spine that will be included in this section includes spine curvatures, the vertebral and intervertebral disc components and their articulations, and the ligaments of the spine.

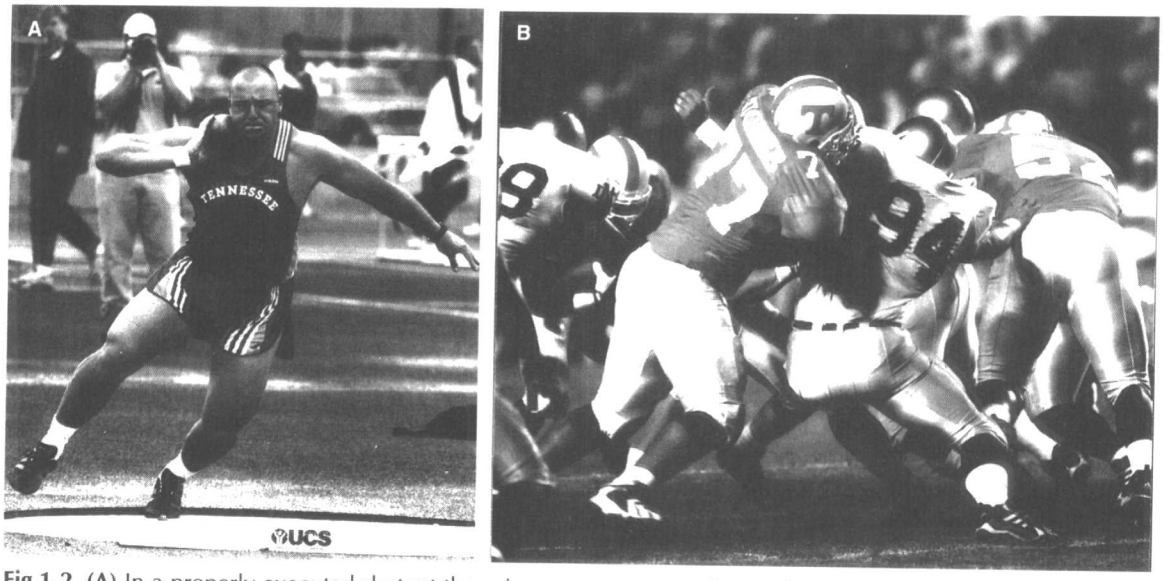

Fig.1-2 **(A)** In a properly executed shotput the spine can serve as an "engine" as it moves body parts (*Courtesy of the Vol Sports Information Office*). **(B)** The spine of number 94 is obligated to resist torsional and lateral flexion and translation force (*Courtesy of Football Time in Tennessee*).

Curvatures of the Spine

The natural curvatures of the spine as viewed from the side include a concavity in the cervical and lumbar regions and a convexity in the thoracic and sacral regions. These curves are viewed as normal, although they are described as lordotic and kyphotic, respectively (see Fig. 1-1). If these curves are excessive, they are often called hyperlordosis in the lumbar area (or a swayback) and a dorsal kyphosis or round upper back in the thoracic area.

When viewed from the back, the spine is in an almost straight vertical line; an appreciable lateral deviation would be called *scoliosis*. Lordotic, kyphotic, and scoliotic deviations are functional if they can be removed voluntarily by modifying posture; they are structural if postural adjustments do not immediately affect the deviation.

Lordosis The lumbar lordosis is dictated primarily by two factors: the shapes of both the lumbosacral intervertebral disc and the fifth lumbar vertebra (Fig. 1-3). The disc between L5 and S1 and the L5 vertebra are thicker anteriorly than posteriorly, about 6 to 7 mm and 3 mm, respectively (5). Although this positioning might suggest a degree of precariousness because of an apparent shear stress (e.g., L5 slipping over S1), this factor is counterbalanced by the reinforced structure of the superior and inferior articular processes of L5 and a strong reinforcing ligamentous structure.

However, if injury occurs to the supporting structures, slippage of L5 over S1 or of L4 over L5 can occur and result in the condition spondylolisthesis. Fujiwara et al. (6) studied the morphology of the iliolumbar ligament and found that its length and direction can be a predisposing factor to the development of disc degeneration between L5 and S1 and subsequent spondylolisthesis. Nagaosa et al. (7) and Berlemann et al. (8) independently found facet orientation to be a pathoanatomic risk predisposing one to the development of degenerative spondylolisthesis.

A lumbar lordotic curve helps the discs in cushioning compressive forces and shocks. Although it

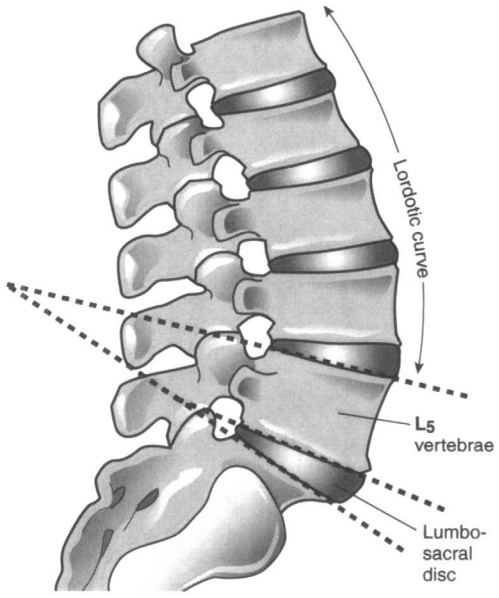

Fig. 1-3 Shape of the lumbar lordosis. The lordotic curve is due to the wedge-shapes of the lumbosacral disc and the L5 vertebra.

has been a common belief that excessive lordosis is a risk factor for LBP, a relationship between the shape of the lumbar lordosis and low back symptomatology is not evident (9). Intrinsic features set the lumbar curve; extrinsic factors such as overweight, use of high heels, or shortened muscles can modify it. Although strength-training programs have not been effective in reducing the lordotic curve (10), tightness in the hip flexors (e.g., psoas) could serve to increase the curve, whereas tightness in the hamstrings could reduce it. Aging is another factor that affects the curve because the lumbar lordosis often decreases with age (5).

Kyphosis In activities of daily living, spinal extension movements and postures are used less often than spinal flexion ones. Continued flexion postures (e.g., slouching) could cause an increased dorsal kyphotic curve in the thoracic area. This faulty posture is characterized by muscle imbalances including (a) stretched and weakened thoracic erector spinae and scapulae retractors (rhomboids and trapezius) and (b) tight anterior shoulder girdle muscles (pectoralis minor and serratus anterior). A greater than average thoracic kyphosis is also frequently associated with a compensatory increase in the cervical and lumbar lordoses; however, these postures have not been proven to predispose one to LBP (11).

Scoliosis Although most spines when viewed from the posterior would not be perfectly straight, a marked deviation or a lateral curvature of the spine is called *scoliosis.* Although many causes have been identified for scoliosis, the cause is usually unknown (12). It is not surprising that leg length discrepancy, leading to pelvic obliquity, is associated with both scoliosis and LBP. Nevertheless, little hard evidence of scoliosis causing LBP exists in the general population (13). Junghanns (2) noted that hammer and discus throwers had a high percentage of scoliosis and subsequent LBP. Because of this finding, he contended that an extreme number of throws per year leads to (a) asymmetric trunk strength development and scoliosis and (b) annular tears in the intervertebral discs due to torsional stresses.

Vertebrae

The seven cervical vertebrae display a lordotic curve and rest on the 12 thoracic vertebrae. The thoracic vertebrae display a kyphotic curve and provide anchorage for the ribs, which contributes to circumferential stability (see Fig. 1-1). The last thoracic vertebra rests on the first lumbar vertebra; the lumbar vertebra and its four counterparts are stacked lordotically on top of the sacrum.

Panjabi et al. (14) detailed the differences of the thoracic and lumbar vertebrae by doing a three-dimensional surface anatomy study. They found that L4 and L5 seemed transitional toward the

sacral region, whereas L1 and L2 seemed transitional toward the thoracic region.

The primary curves (i.e., those present at birth) are the thoracic and sacral curves. Cervical and lumbar curves are referred to as secondary curves; they are not present at birth and develop during the process of maturation. The five fused segments of the sacrum transmit weight laterally through the sacroiliac joints to the pelvis; caudally, the fifth segment provides attachment for the vestigial coccyx. As depicted in Figure 1-1, the vertebrae become progressively larger from the cervical to the lumbar spine as their load-bearing functions increase.

The vertebrae are cancellous (trabecular) bone with a thin cortical shell. They adjust to stress as defined by Wolff's law; thus the positioning and density of the vertical and transverse trabeculae within the cortical shell of each vertebra change with the stresses placed on the spine (15,16). The extremes of how much bone mineral density are present are exemplified by vertebrae's (a) inability to support body weight and collapsing in osteoporosis of the spine (2) and (b) being able to support 28,000 N (>6000 lb) in world-class weight lifters (16).

A vertebra is often subdivided into three functional components, namely the body, intermediary pedicle, and posterior elements (Fig. 1-4). Two vertebrae and their intervening disc are called a *motion segment* (or a functional structural unit); a motion segment of the lumbar spine is presented in Fig. 1-5. A motion segment is the smallest func-

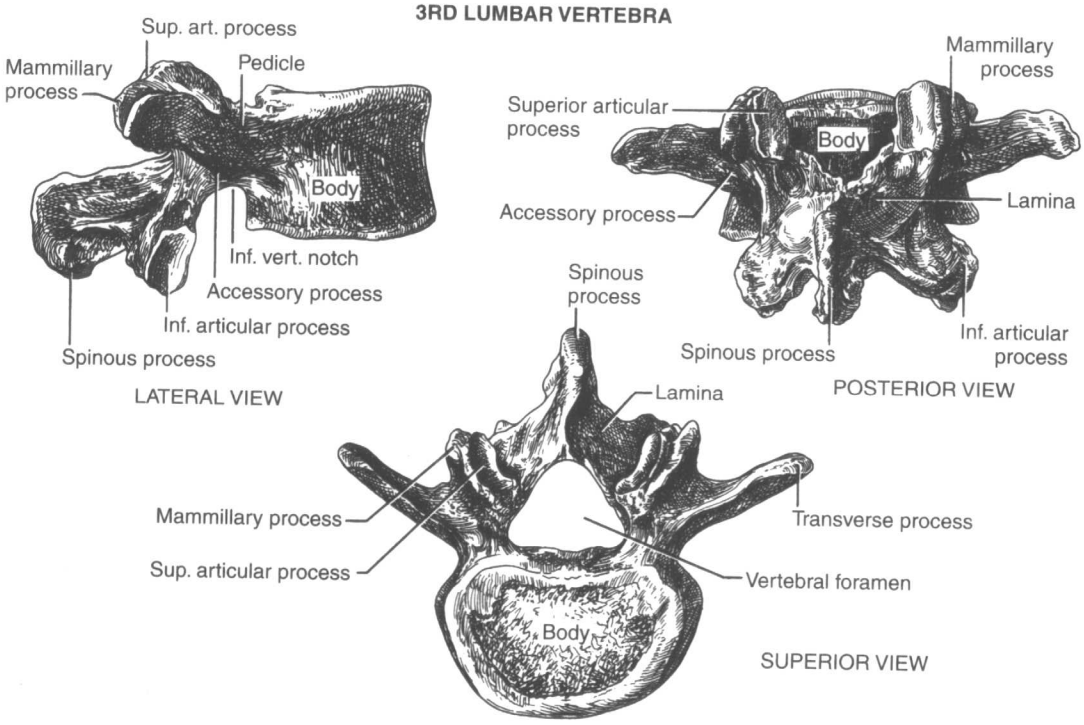

Fig. 1-4 Lumbar vertebrae. (From Pansky, B. *Review of Gross Anatomy.* © 1996. Reprinted with permission from the McGraw-Hill Companies, Inc.)

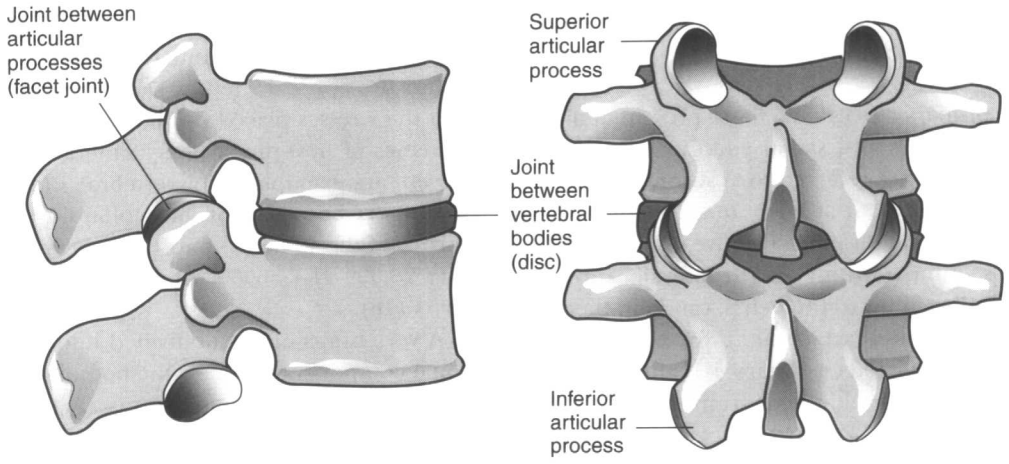

Fig. 1-5 Lateral **(A)** and posterior **(B)** views of a motion segment. The segment includes the junction of the intervertebral disc with its two adjacent vertebrae. In the posterior view, the joints between the superior and inferior articular processes can be seen; these joints are referred to as zygoapophyseal or facet joints.

tional unit of the spine; the joints that comprise it include the anterior joints between the vertebral bodies and the disc and the posterior joints between the paired facets (superior and inferior articular processes).

Intervertebral Discs

Intervertebral discs act as spacers and shock absorbers in addition to absorbing rotational stresses (Fig. 1-6). Although most low back problems in young athletes originate in the posterior elements (e.g., in the pars interarticularis as seen in spondylolysis and spondylolisthesis or facet joint injury), in adults the disc is the site of most of the problems. The disc consists of the annulus fibrosis, nucleus pulposus, and the vertebral endplates.

Annulus Fibrosis The annulus fibrosis contains 10 or more collagen reinforced concentric rings oriented in alternating angles of alignment; thus, if rotational stresses are placed on the spine, the fibers of the disc are so oriented that some fibers can always resist this strain (see Fig. 1-6). If strained excessively, for example, with repetitive microtrauma, the outer fibers of the annulus have nociceptors and therefore pain is perceived. The annulus is about 60 to 70% water and the concentration of collagen is about two to three times that of the proteoglycan.

Nucleus Pulposus The nucleus pulposus is a dense, randomly arranged network of collagen fibers and proteoglycan gel; it is without nociceptors. The nucleus pulposus is approximately 70 to 90% water, with the concentration of proteoglycans about three to four times that of collagen (5). Both the proteoglycan cells and their water imbibing properties are known to decrease with age and injury. Because the nucleus pulposus and the annulus fibrosis are similar in makeup, their lines of demarcation are not as definitive as those dis-

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