Charles University

Faculty of Physical Education and Sport

Chronic lumbar intervertebral disc herniation

Bachelor Thesis

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Abstract

"Case study of physiotherapy treatment of a patient with the diagnosis of intervertebral disc herniation with radiculopathy"

"Kazuistika fyzioterapeutické péče o pacienta s diagnózou meziobratlové herniace disku s radikulopatií"

The purpose of this paper is to depict a case study of a patient with an intervertebral disc herniation of the L_5 segment, conservatively treated, while at the chronic state. Through it, I will attempt to elaborate on the nature of the injury, the medical and physiotherapeutic approach, and the rehabilitation plan and procedures that were performed, after giving an overview of the underlying principles of anatomy, physiology, kinesiology and biomechanics.

This thesis is divided into 2 parts; the first describes the current understanding of the anatomical, physiological, kinesiological and biomechanical norms that underlie the lumbar spine, and discusses some treatment and assessment approaches and their rationale; the second part is a detailed report of the clinical aspect of the rehabilitation of the patient, preceded by a presentation of her medical history.

Dates of practice: 15/01/2013- 07/02/2013

Name and location of healthcare facility: Ústřední vojenská nemocnice, Praha, 1200/1, 162 00, Praha 6.

Key words: Chronic state, Conservative treatment, Core stability, Corrective exercise, Low back pain, Lumbar spine, Manual therapy, Motor control, Physical therapy, Rehabilitation.

Declarations

This thesis is a presentation of my original work. Whenever contributions are made by others, every effort is made for that to be acknowledged, in the context of literature reference of collaborative, constructive guidance or discussion.

The clinical work presented here was done under the supervision of Mgr. Zuzana Sekaninová, at the Ústřední vojenská nemocnice military hospital, in Prague, 1200/1, 162 00, Praha 6.

The writing of the thesis was supervised by PhDr. Tereza Novaková, PhD.

Acknowledgements

First and foremost, I would like to extend my gratitude and thanks to my academic supervisor, PhDr. Tereza Novaková, PhD., who supported me throughout my studies, but also, and importantly, during the writing of the thesis, providing constructive feedback while allowing me space for individuality and creativity. In retrospect, I can say she was a very significant "helping hand" throughout my Bachelor's degree, and a very motivating and assistive factor throughout the preparation of my thesis. I could not have hoped for the role of an academic supervisor to be fulfilled any better than it was.

Additionally, I would hereby like to express my appreciation of the help and guidance offered by my clinical supervisor, Mgr. Zuzana Sekaninová, who offered essential and detailed comments and support throughout the work, and even invested extra hours into helping my clinical praxis, while maintaining a friendly, humane approach to the situation.

Without the aforementioned, the writing of this Bachelor thesis would be nothing short of impossible.

Nikolaos Rogdakis

Dedications

I would like to dedicate this paper to my family, for their constant support to my studies, both financial and moral.

I would also like to thank the core teachers of my degree, who captivated my interest and initiated my in the astonishing, vast science that is physiotherapy. Special thanks go out to PhDr. Tereza Novaková, PhD., the supervisor of this thesis.

Last but not least, I would like to thank Katerina Krassa, for being the sweet, wonderful person that she is and helping me keep it together when I got frustrated and mentally fragile during my stay in Prague, while motivating me to become a stronger version of myself.

I thank you all. I sincerely hope I did not disappoint your trust in me while here- and never get to.

Contents

1 Introduction

The purpose of this paper is to depict the physiotherapeutic work done on a patient at the chronic stage of an intervertebral disc herniation of the 5th lumbar segment. It is meant to evaluate the response of the patient to the rehabilitation effort, as well as to describe the procedures that were employed in the effort of its materialization, and to do so in as unbiased and objective a manner as possible.

The above took place in the Ústřední vojenská nemocnice (ÚVN) military hospital, as part of my clinical practice there, which happened in January, 2013. Specifically, the procedures listed in the treatment-specific section later in this paper, took place at the outpatient department of the aforementioned hospital, where the patient visited 2 times prior to our first meeting.

For the purpose of a more concrete understanding of the condition and basis of therapeutic rationale, it is deemed rational to present an outline of the basics of the anatomy, physiology and kinesiology of the lower back, as well as the etiopathogenesis and prognosis of the intervertebral disc herniation, and relevant physiotherapeutic techniques.

2 General part

This part of the thesis will make a reference to the anatomical, physiological and kinesiological norms relevant with the condition, before elaborating on what the herniation of the intervertebral disc is, and how it is managed generally.

2.1 Anatomy of the spine

The vertebral column is essentially a multiplicity of linked individual bones (vertebrae). It is functionally separated into 5 parts; the cervical, thoracic and lumbar spine- which normally include 7, 12 and 5 vertebrae respectively; the sacrum- a triangular ossified fusion of 5 vertebrae; and the coccyx- a small triangular, often asymmetrical bone, usually consisting of 4 fused rudimentary vertebrae (13, 18).

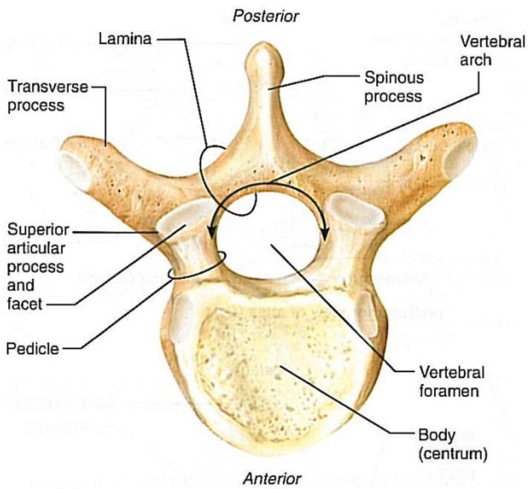


Figure 1: Structure of a typical vertebra- superior view. Adapted from (13).

There are characteristic differences among the vertebrae of different spinal sectors, as well as unifying characteristics. A typical vertebra (figure 1) has a ventral body, a dorsal arch extended by processes, and a foramen occupied by the spinal cord, meninges, and their vessels (13, 18). There are 7 processes projecting per vertebral arch. Two transverse processes, extending laterally from the vertebral arch and giving rise to a flattened plate (lamina) each, and a spinous process; a posterior medial projection arising at the junction of the two laminae. Additionally, there bilaterally exist superior and inferior articular processes that emerge from the junction of the lamina and pedicle (small bony projection, posteriorly and bilaterally on the vertebral arch) superiorly and inferiorly, respectively (13, 18). There is a smooth hyaline cartilage-based joint surface on these articular processes and the superior articular processes of a given vertebra articulate with the inferior processes of the vertebra just above it, forming the facet, or zygapophysial joints (18).

The ligaments of the vertebral column in general include the interspinous, intertransverse and supraspinous ligaments, the ligament flava, and the anterior and posterior longitudinal ligaments (figure 2). The interspinous ligaments act to connect the facing ends of consecutive spinous processes, while the intertransverse ligaments attach to the transverse processes of adjacent vertebrae. The supraspinous ligaments connect the tips of the spinous processes of the vertebrae C_7 to L_3 or L_4, with the most superficial of their fibers extending over 3 or 4 vertebrae, and their deeper fibers connecting adjacent vertebrae. The longitudinal ligaments extend from the C_1 vertebra anteriorly and the C_2 vertebra posteriorly down to the sacrum, attaching to the intervertebral discs, end-plates and adjacent intervertebral bodies (13, 18).

2.2 Anatomy and functions of the intervertebral disc

The opposed surfaces of adjacent vertebral bodies, from the 2nd cervical vertebra caudally, are held together by fibrocartilage intervertebral discs. The thickness of the discs varies according to their localization; the upper thoracic discs are the thinnest, and the lumbar discs are the thickest. Additionally, the discs of the cervical and lumbar regions are thicker at their anterior portion, contributing to the lordotic curvature of the spine at those areas (13, 18). The discs adhere to vertebral end-plates, which contain hyaline cartilage and fibrocartilage, and do not reach the periphery of the vertebral body, but rather are enclosed by the ring apophyses. All discs are attached anteriorly and posteriorly to the anterior and posterior longitudinal ligaments, respectively. Thoracic discs are further fixated laterally, by intra-articular ligaments to heads of ribs articulating with adjacent vertebrae (13, 18).

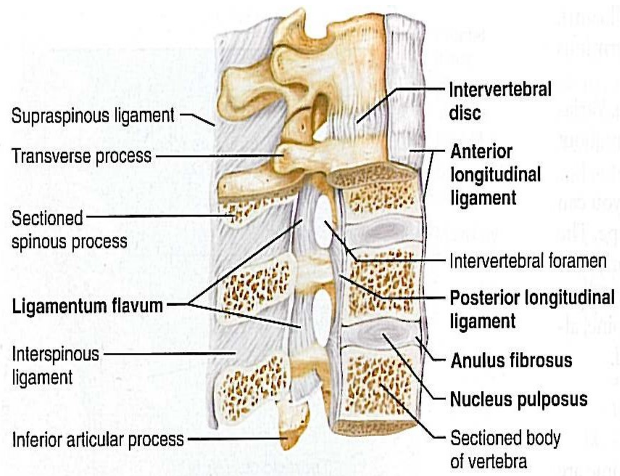


Figure 2: Median section of 3 vertebrae, displaying the composition of the intervertebral discs and ligaments. Adapted from (13).

The disc itself is composed by the nucleus pulposus and the annulus fibrosus. The latter is a soft, gelatinous "ball" containing mucoid material and giving the disc its cushioning and elastic properties (13, 18). With increased age, the nucleus pulposus becomes progressively less differentiated from the remainder of the disc, less hydrated and more fibrous. The annulus fibrosus is a narrow -collagenous externally and fibrocartilagenous internally- ring that surrounds the nucleus, limiting its expansion as the spine is compressed (18). It also acts as a strap to contribute in the binding of successive vertebrae with each other, resist tension in the spine and endure twisting forces (13).

2.3 Spinal nerves and segmental innervation

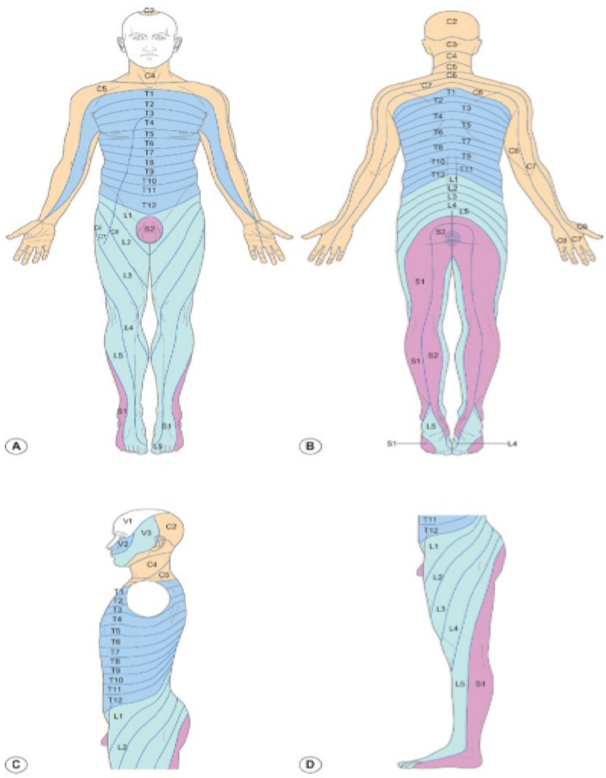
Excluding the head and some parts of the neck, all areas of the body are innervated (disregarding autonomic innervation) by 31 pairs of spinal nerves, originating at the spinal cord. They are named after the segment at which they originate, and all are mixed nerves. There normally exist 8 pairs of cervical spinal nerves (C_1 to C_8; C_8 being the segment between the C_7 and T_1 vertebrae), 12 pairs of thoracic spinal nerves (T_1 to T_{12}), 5 pairs of lumbar spinal nerves (L_1 to L_5), 5 pairs of sacral spinal nerves (S_1 to S_5), and 1 small pair of coccygeal nerves (Co_1) (2, 3, 13, 18).

Each spinal nerve connects to the spinal cord by a dorsal and a ventral root, with each root forming a sum of rootlets that fasten along the length of the respective segment. Ventral roots contain efferent (motor) fibers and arise from the ventral horn of the spinal cord and acting to innervate muscles, while dorsal roots contain afferent (sensory) fibers arising from the dorsal ganglia and act to conduct stimuli from peripheral sensory receptors to the spinal cord (3, 13). These roots pass laterally from the spinal cord, uniting distally to the root ganglion to form a spinal nerve with both afferent and efferent fibers, before leaving the intervertebral foramina (13). These spinal nerves are relatively short (1-2cm) and branch almost immediately after exiting their foramen into a dorsal and ventral ramus, and a meningeal branch. The dorsal and ventral rami (also being mixed in function) innervate the dorsal trunk, and ventral trunk and extremities, respectively, while the meningeal branch reenters the vertebral canal to innervate the meninges and blood vessels (3, 13).

Excluding the segments from T_2 to T_{12}, all ventral rami are organized into nerve plexuses as they branch and join each other laterally to the vertebral column (13, 18). These plexuses are termed the cervical (C_1-C_4, part of C_5 occasionally), brachial (C_5-C_8, part of T_1), lumbar

(L_1-L_4) and sacral (L_5-S_3) plexus according to their localization, and primarily serve the limbs (7, 13, 18). The purpose of that branching and redistribution of nerves is that each ramus travel to the periphery via multiple pathways, as well as each plexus contains multiple spinal nerves. Consequently, although each muscle has a “predominant segmental origin”, each muscle is generally innervated by more than one spinal nerve. An advantage to that fact is that damage to 1 segment’s root does not completely paralyze any muscle, though maximum paralysis occurs at a specific muscle when its predominantly innervating nerve is damaged (13).

Practically, each spinal segment is functionally connected to a specific area of the skin (dermatome, see figure 3), the musculature (myotome), the skeleton (sclerotome), and the internal organs (enterotome) (3, 13). When a lesion occurs in any of the segments, the above factors are affected, to a higher or lower degree, according to the locality and severity of the lesion. In fact, paresthesia, diminished stretch reflexes and muscular weakness are routinely assessed when intervertebral disc herniation is suspected. The localization and magnitude of symptoms serves progress tracking, as well as diagnostic purposes (2, 3, 8, 9, 10, 12, 13, 18).



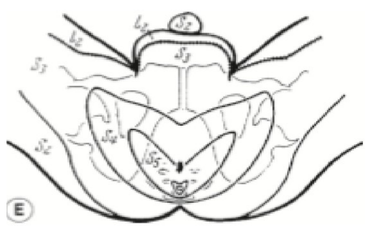


Figure 3: The dermatomes.

A: Anterior view

B: Posterior view

C,D: Lateral views

E: Perineum.

Adapted from (9).

2.4 Muscles relevant with the lumbar spine

Many muscles act on the lumbar spine, either as movers or as stabilizers. As is usually the case, the more superficial, long muscles chiefly act to macroscopically move the spine in all planes, and the deeper and intersegmental, ligament-like muscles primarily act as stabilizers (7, 8, 9, 10, 12, 13, 14, 16, 17, 18). As stability is a significant clinical issue in intervertebral disc herniations, special emphasis will be given to the deeper stabilizing muscles and their interplay when stability is challenged. These muscles include the diaphragm cranially, the pelvic diaphragm caudally, the transversus abdominis and internal oblique muscles anteriorly, the lumbar components of the multifidus, iliocostalis and longissimus posteriorly, and the quadratus lumborum and iliopsoas muscles bilaterally.

From a dorsal perspective, the deepest muscles of the lumbar vertebral column include the (lumbar) intertransversarii, rotatores, multifidi and interspinales muscles (figure 4). The interspinales lumboum act originate at the spinous processes of the lumbar vertebra and insert at the spinous process of the lower vertebra, one on either side of the interspinous ligament, or at the median sacral crest (in the case of the muscle originating at the L5 vertebra). The multifidi of the lumbar spine originate at the mammillary process (a feature unique to the lumbar vertebrae; a rough process on the posterior border of the superior articular facets) of each vertebra and insert at the neighboring vertebra's spinous process. The rotatores connect the mammillary process of one vertebra to the base of the spinous process of the vertebra cranially. The lumbar intertransversarii muscles consist of two parts: medial, connecting the accessory process of one vertebra with the mammillary process of the next, and lateral, connecting the transverse and accessory processes of a vertebra to the next vertebral transverse process (13, 18). The intertransversarii muscles act to perform lateral flexion when unilaterally active, and extension when bilaterally active. The multifidi and rotatores act to execute segmental lateral

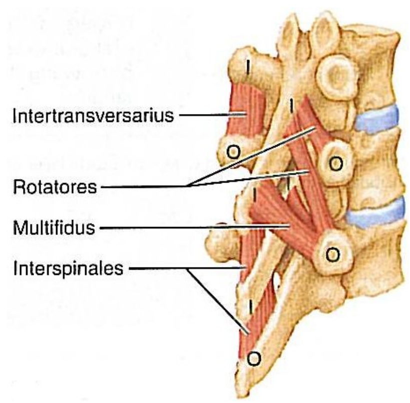


Figure 4: The deepest musculature of the dorsal vertebral column. Adapted from (13).

flexion and rotation when unilaterally activated, and segmental extension when bilaterally activated. The interspinales' action is segmental extension. As stated before, however, these deep muscles act more to stabilize against translatoric movement and "buckling" than to primarily move, as opposed to the erector spinae and other longer muscles that have higher leverage and act as prime movers (7, 8, 9, 10, 12, 13, 14, 16, 17, 18).

The intermediate layer of the muscles of the lumbar spine is formed by the erector spinae muscle complex, which in turn is made up by the iliocostalis, longissimus and spinalis muscles (figure 5). The iliocostalis lumborum, the most lateral of the 3, connects the 5th or 6th-12th ribs, at their angles, with the iliac crest, thoracolumbar fascia, spinous processes of lumbar vertebrae and sacral crest. Just medially to the above muscle lies the longissimus thoracis, that originates along with iliocostalis lumborum at the spinous processes of the lumbar vertebrae and sacral bone, and inserts at the lumbar vertebrae (5th mammillary process, rest accessory processes-roots of lumbar transverse process) deep thoracolumbal fascia and costal angle of the 2nd -12th ribs. The most medial muscle of the 3 is the spinalis thoracis, originating at the 1st 2 or 3 lumbar vertebra and the 2 last thoracic vertebra, and inserting at the spinous process of the 2nd- 9th or 10th thoracic vertebrae. All the erector spinae act to execute lateral flexion when unilaterally active, and extension when bilaterally active, as prime movers (7, 8, 9, 10, 12, 13, 14, 16, 17, 18).

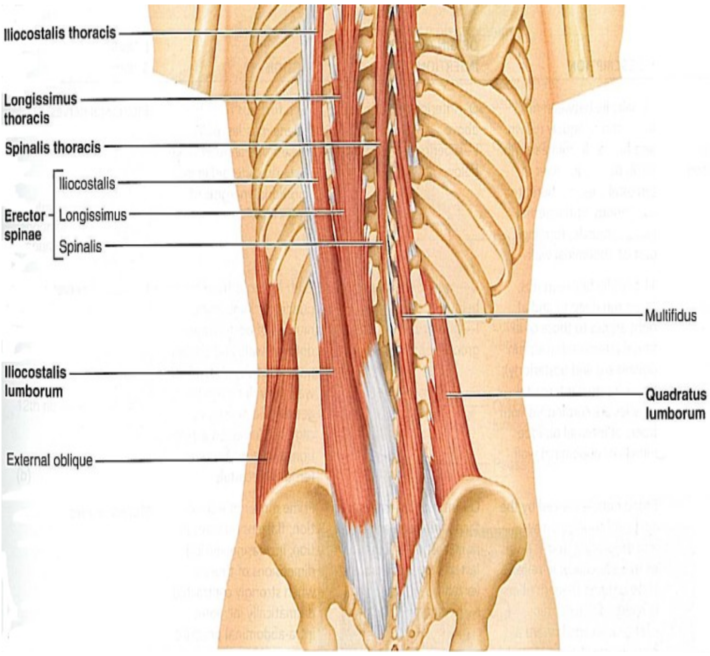


Figure 5: Posterior musculature of the vertebral column, with the superficial muscles and thoracolumbar fascia removed. Adapted from (13).

The aforementioned muscles are covered by the thoracolumbar fascia. In the lumbar region, the thoracolumbar (lumbar) fascia is organized in three layers- the posterior (attaching to the spines of lumbar and sacral vertebrae and supraspinous ligaments), middle (attaching to the tips of transverse processes and intertransverse ligaments, as well as the iliac crest and the lower border of the 12th rib) and anterior layer (covering the quadratus lumborum, attaching to the transverse processes behind the psoas major, iliolumbar ligament and iliac crest, and forming the arcuate ligament cranially). The posterior and middle layers unite at the lateral border of the erector spinae, while they connect with the anterior layer at the lateral border of the quadratus lumborum, to form the aponeurotic origin of the transversus abdominis. Finally, the most superficial muscles are the serratus posterior inferior and latissimus dorsi. The former originates at the spinous processes of the 11th and 12th thoracic, and 1st and 2nd lumbar vertebra to insert at the caudal margin of the 9th -12th ribs and works in expiration. The lattisimus dorsi originates at the spinous process of the 5 lumbar and last thoracic vertebrae (through the thoracolumbar fascia), last 3 or 4 ribs and external iliac crest, and inserts at the intertubecular groove of the humeros, acting to perform adduction, internal rotation and extension in the shoulder joint, depress the scapula, but also act on the trunk and pelvis to perform lateral trunk flexion and anterior and lateral pelvic tilt (when unilaterally active) or trunk extension and anterior pelvic tilt (when bilaterally active), but can even act to flex the trunk, depending on the current axial relationship (7, 13, 18).

The anterior aspect of the trunk is occupied by the rectus abdominis, external oblique, internal oblique and transversus abdominis muscles, from the most superficial to the deepest layer (figure 6). The rectus abdominis is a long stap-like muscle, originating at the pubic crest and symphysis and extending vertically up to the xiphoid process, and the 5th-7th ribs. The external oblique originates at the outer 5th through 12th ribs and inserts at the outer lip of the iliac crest, linea alba and its aponeurosis (forming the inguinal ligament) down to the anterior superior iliac spine and pubic tubercule. The internal oblique originates at the superficial thoracolumbar fascia, iliac crest and inguinal ligament and inserts at the linea alba, pubic crest and inferior border of 10th through 12th ribs. The

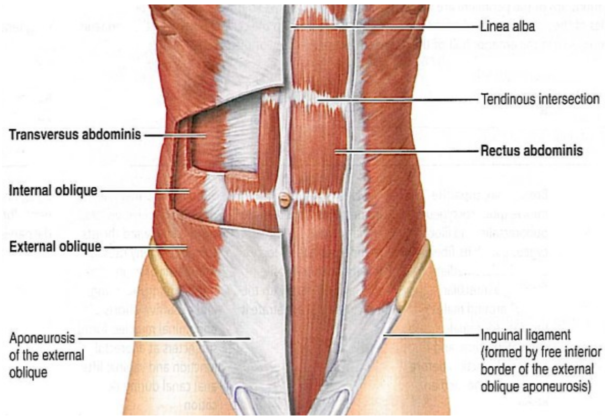


Figure 6: Muscles of the anterior abdominal wall. Adapted from (13).

transversus abdominis muscle is attached to the inner, anterior iliac crest, thoracolumbar fascia lower 6 costal cartilages and inguinal ligament. All of the aforementioned muscles act to compress the abdomen and participate in expiration. The external and internal oblique muscles, when unilaterally activated, rotate the thorax while simultaneously flexing the vertebral column (the external oblique contralaterally, and the internal ipsilaterally). The rectus abdominis participates is the prime mover of trunk flexion (7, 13, 18).

The above muscles form the anterior and lateral abdominal wall, while the muscles iliacus, psoas major and quadratus lumborum form its posterior aspect. The quadratus lumborum originates at the iliolumbar ligament and contiguous iliac crest and inserts at the inferior border of the 12th rib and the transverse processes of the lower 3 or 4 lumbar vertebrae. The psoas major connects the transverse processes of the lumbar vertebrae with the minor trochanter of the femur, while the iliacus connects the inferior superior iliac spine and iliac fossa with the minor trochanter. The two latter muscles converge at a significant percentage of their fibers, and act as 1 muscle- the iliopsoas- acting to flex and medially rotate the hip, as well as to laterally flex and hyperextend the lumbar spine. The quadratus lumborum performs lateral trunk flexion, while also participating in expiration by drawing the 12th rib downwards (7, 13, 18).

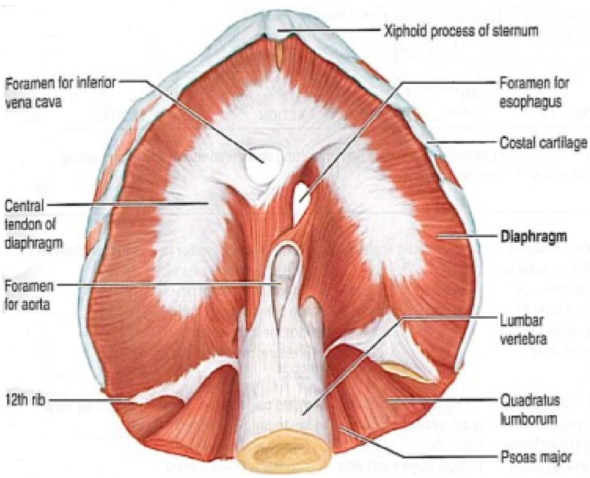


Figure 7: The diaphragm- inferior view. Adapted from (13).

The diaphragm is an important muscle to be considered here, which is widely considered as a respiratory muscle only, but significant has postural and stabilizing function (8, 9, 10). It can be viewed in 3 different parts, all of which merge in its central tendon. The sternal part is that originating at the rectus sheath and xiphoid process, the costal part originages at the 6th-12th ribs and indented with the transversus abdominis, while the lumbar part originates at the bodies and transverse processes of the 1st through the 3rd lumbar vertebrae and the 12th rib. As its fibers contract in inspiration, the dome shape of the diaphragm flattens against the abdominal viscera, compressing the abdomen, while the costal part eventually elevates the lower ribs and flares them outwards (7, 13, 18).

The pelvic floor is the final component of the muscular mechanism of deep spinal stabilization, as it supports the pelvic visceral organs (8, 9, 10). The important muscles of the region for that purpose are the levator ani and coccygeus muscles. The levator ani muscle is formed by the pubococcygeus and iliococcygeus muscles, which originate at the inner pubic bone near the symphysis and ischial spine, and insert at the inner surface of the coccyx. The coccygeus muscle originates at the ischial spine and inserts at the sacrum and coccyx (7, 13, 18).

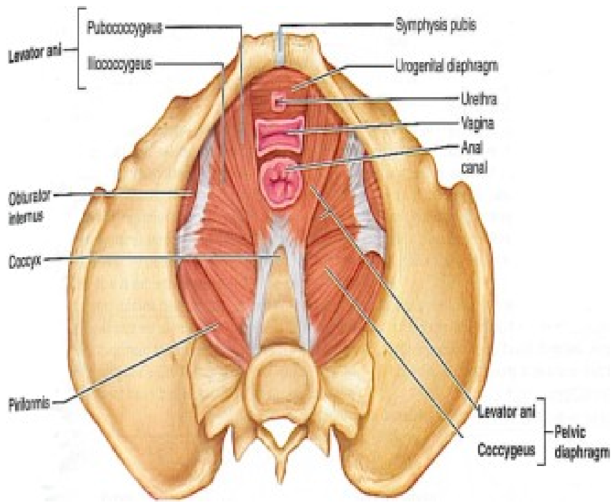


Figure 8: The pelvic floor/ diaphragm. Superior view of the female pelvis. Adapted from (13).

It is important to note that the lumbar spine position can be directly affected by all the muscles that move the hip, especially in sagittal and frontal planes. That practically includes the hip flexors (not only iliopsoas, but also the sartorius, tensor fascia lata and rectus femoris muscles) and extensors (gluteal and hamstrings muscles) in sagittal pelvic movement, and the hip adductors (pectineus, adductor brevis, longus, magnus and gracilis muscles) and abductors (tensor fascia lata) (7, 13, 18). The rationale behind this is rather straightforward- if one consideres , for example, the sagittal movement of the hip joint, comparatively increased activity of the hip flexors in upright standing would bring about an elongation of the extensors, and compensatory increased lumbar lordosis, if the subject in question is to remain erect. This latter muscular dysfunction and its adaptive perpetuated imbalance of length and strength in the basis of the lower cross syndrome concept. It is imperative that there is sufficient length

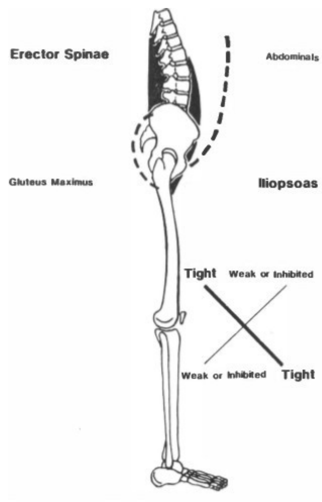


Figure 9: The lower crossed syndrome. Adapted from (10).

in all those muscles that act on the hips and lumbar spine, so as to allow the maintenance of a neutral- or close to neutral- spinal position during movement (5, 7, 8, 9, 10, 14, 16, 17, 18, 20).

2.5 Mechanism of deep stabilization

Understanding of the mechanisms of action of the musculature of the spine in stabilization is critical when rehabilitating injuries grounded in instability and lack of motor control, as is the case in this paper. Important considerations, from that perspective, are the muscular co-contraction patterns, which are counter-productive to torque generation and enable stability in all axes of movement, and inter-abdominal pressure, which converts the abdomen and spine into a stiffened cylinder, bringing about a stiffer structure of the ligamentous, multi-segmented spine (4, 5, 8, 9, 10, 11, 12, 14, 15, 17, 20). The ligament and other soft tissue involvement is also important, but a) the injury of these structures usually results in some loss of their contributing passive stiffness, b) the ligamentous involvement in maintaining posture, especially in certain positions close to end-range, eliminates the muscular ability to act on controlling intersegmental shearing forces (and in fact adds shearing loading), and c) the spine appears to be most prone to failure either when the load is low and muscular involvement is also low, or when the load is very high (12, 14). In fact, McGill proved that a ligamentous spine (stripped of muscle) fails, or buckles, at a compression load of 90Newtons; just over 9 kilograms (14).

It is important to promptly stress the fact that virtually all torso muscles play a role in stabilization, and that the most important stabilizer of all is a variable depending on the task. One important stabilizer, that is more scarcely considered as such, is the quadratus lumborum muscle. The recruitment pattern of the muscle goes hand in hand with the abdominal wall activation when stability is required in the absence of major movement demands (i.e. when compression is applied). Also, considering the fact that the quadratus lumborum muscle interconnects vertebrae through their transverse processes, thus having a large movement lever, while passing through attach to the ribcage and iliac crests, it can be understood that it is anatomically positioned well for a stabilizer in all planes. Thus, it can be concluded that the quadratus lumborum muscle is a significant stabilizer both from an anatomical and a functional perspective (10, 14). Considering its structure and responses to

EMG, the optimal way to train the quadratus lumborum would be the lateral bridge. However, in most back pain patients, the quadratus lumborum muscle displays hypertone, shortness and/or trigger points; thus, the treatment of choice is relaxation/stretching initially (5, 8, 9, 10, 14, 17).

Another stabilizer complex to be considered is the short, deep extensors of the lumbar spine, and specifically the rotatores, intertransversarii, and multifidus muscles. The multifidus is one of the better muscles with respect to its capability for segmental support and control. It has been shown to bilaterally activate, in both ipsilateral and contralateral trunk rotation, in sitting and standing, suggesting its action as a stabilizer in that motion, and in fact, a tonic, almost constant activation of the muscle has been demonstrated in active trunk movements and upright postures (5). McGill also confirms that the unchanging geometry of the multifidus in a wide range of postures suggests that it is involved in the fine adjustment of neighboring vertebrae, rather than being a prime mover. In low back pain patients, dysfunction of the multifidus has been found in the context of decreased activity, fatigability, composition (fiber type- selective atrophy of type II, internal structure altering of type I fibers), and size and consistency (especially bilateral discrepancy), with the smallest muscle being that of the symptomatic segment. The intertransversarii and rotatores, on the other hand, are especially interesting in the fact that they are rich in muscle spindles (4-7 times more than the multifidus), pinpointing the fact that they are not as much responsible in torque production, as they are in sensing vertebral position, thus aiding in motor control and injury prevention through that point of view (5, 10, 14, 17).

When considering the erector spinae group, it is apparent that those muscles are better at generating torque and causing movement than the short, intersegmental muscles, from a mechanical perspective. However, they have an important stabilization role in controlling the shearing forces. When bilaterally active, the lumbar longissimus and iliocostalis muscles can draw their vertebra of origin posteriorly and thus counteract the anterior shear, while in contrast, the multifidus muscle contraction would produce posterior sagittal rotation of the originating vertebra, rather than posterior translation. It appears that this balance is maintained by the co-activation of these muscle groups, in activities like bending forward and lifting (5, 10, 14, 17).

The transversus abdominis, apart from its respiratory and visceral supporting function, contributes to the stability and intra-abdominal pressure (IAP) increase. Although all the abdominal muscles contribute to a varying degree in flattening the abdominal wall, the structural arrangement of the transversus abdominis muscle is such that makes it have the greatest efficacy in doing so (5, 17). This is important especially in activities where the trunk flexion, occurring with the contraction of other abdominal muscles, is unwanted, but the IAP increase is needed. Other than that, the transversus abdominis muscle has minimal ability to produce spinal movement, with a possible rotation component. Via its attachment to the thoracolumbar fascia, the transversus abdominis might also cause a restriction in segmental movement directly, while also providing a slight posterior segmental compression. The onset activity of transversus abdominis is delayed in low back pain patients, and there is loss of independent control.

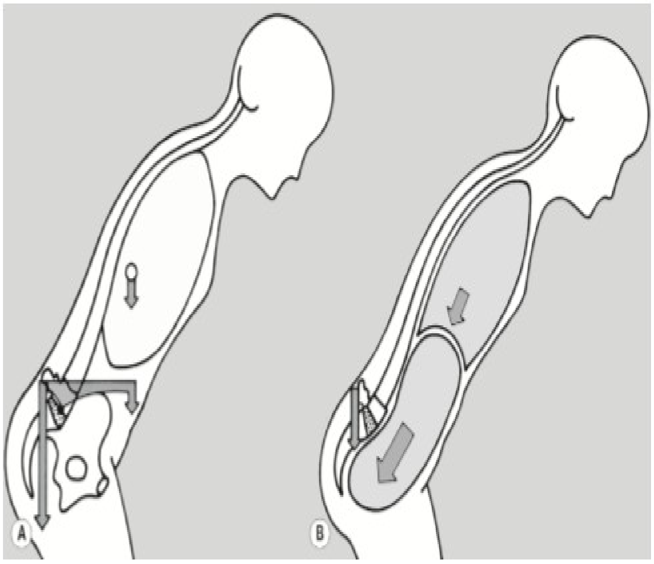


Figure 10: Schematic representation of the lumbo-sacral stress occurring without (left) and with (right) consequtive IAP increase. Adapted from (9).

The IAP increase involves, rationally, all the walls of the abdominal cavity, i.e. the transversus abdominis, pelvic floor, and diaphragm. In fact, the diaphragm displays extensive reactivity to postural change, pinpointing its postural function; it has been observed that the diaphragm flattens and contracts as subjects stand on tiptoes. Also, the diaphragm is downwardly angled in ventro-dorsal direction when abdominal musculature is inhibited, and contrastingly, normal abdominal function of abdominal muscles allows the diaphragm to work in inhalation as the abdominal musculature contracts eccentrically, as well as stabilize the thorax to the pelvis, and thus the lumbar spine. Hence, the deep stabilizer musculature dysfunction goes hand-in-hand with faulty breathing, and vice versa (9). As long as the pelvic floor and transversus abdominis and the diaphragm are healthy in their activation pattern, they can be used in conjunction to “lock” the abdominal cavity from all directions and stabilize the low back, either subconsciously (as is the case in healthy subjects), or consciously, like in the Valsalva maneuver, typically used prior to maximal physical exertion in sport (whereby all the aforementioned muscles are contracted, while breath is held) (5, 8, 9, 10, 14, 17). High IAP has also been shown to generate an extensor torque; effectively, during bending forward with increased IAP the spinal column is supported on the diaphragm. Such is the significance of the diaphragm and transversus abdominis muscles in stabilization, that they precede deltoid activation in the action of raising the limbs; and in fact, lack of such reaction is indicative of instability and dysfunction. It is critical to recognize that the deep stabilizers act as a functional unit, as well as in conjunction with the less profound muscles, controlling intersegmental and global movement, respectively, through co-activation and, often, pre-activation (10, 17).

2.6 Kinesiology of the spine and mechanisms of disc herniation

The consequently articulating 5 vertebrae of the lumbar spine are free to move in all planes and axes; i.e. into flexion, extension, lateral flexion and rotation. The 10 (2 pairs) facet joints of the lumbar spine normally carry about 20% to 25% of the axial loading that occurs at the region, but that number can rocket up to 70% as the disc degenerates. The facets also account for up to 40% of the shear and torsional strength (12). The superior facets, or articular processes, are normally facing medially and backwards, and are concave; the inferior counterparts face laterally and forward, and are convex. It is the posterior facets that dictate the lumbar spine movement from an articular perspective. Because of the facets' shape, rotation is shearing force- oriented and minimal, while flexion, extension and lateral flexion are possible as controlled by the facets. The resting position of the facets is midway between flexion and extension, and the closed packet position is maximum extension. The capsular limitation pattern is equally limited lateral flexion and rotation, followed by extension (12).

The norms in range of motion of the lumbar spine may vary, but a guideline of physiological range is flexion of 40°- 65°, extension of 20° -35°, lateral flexion 15° -25° and rotation of 3° -18° (10, 12). However, the factor of general (as opposed to segmental) ROM has limited use in a clinical milieu. First and foremost, it there is limited evidence that increased trunk flexibility improves back health- from a perspective of prevention of injury, pain or other clinically significant dysfunction- to begin with (10, 14). Additionally, the movements usually employed to test spinal mobility clinically (e.g. Thomayer's distance, i.e. bending forward and downwards as far as possible) account for the multiple segments of the spine, as well as (possibly, as is the case with Thomayer's distance) hip mobility, and it is up to the examiner to differentiate where the movement occurs primarily by esthetic criteria, like the spinal curve fluency; matters that are highly subjective, even though clinically useful (14). Moreover, the simple range of motion measurement does not account for the tissue responsible for its normality or abnormality (i.e. be it fascia, ligaments, muscles etc.) outside the context of the "barrier" feeling, and muscle length testing (6, 8, 9, 10, 12). Also, the stabilization approach of rehabilitation emphasizes control within (or as close as possible to) the neutral spine, and suggests that extreme positions should be done non-weighted and slowly, if at all (10, 14). What is more significant during active spinal movement in clinical praxis is how symptoms react to different movements at different points within the available range, as well as the tracking of progress possible by those means of simple assessment (10, 12, 14).

The two facet joints and the intervertebral disc joint of 1 segment, along with the ligaments, muscles and neurovascular structures that surround them and the adjacent

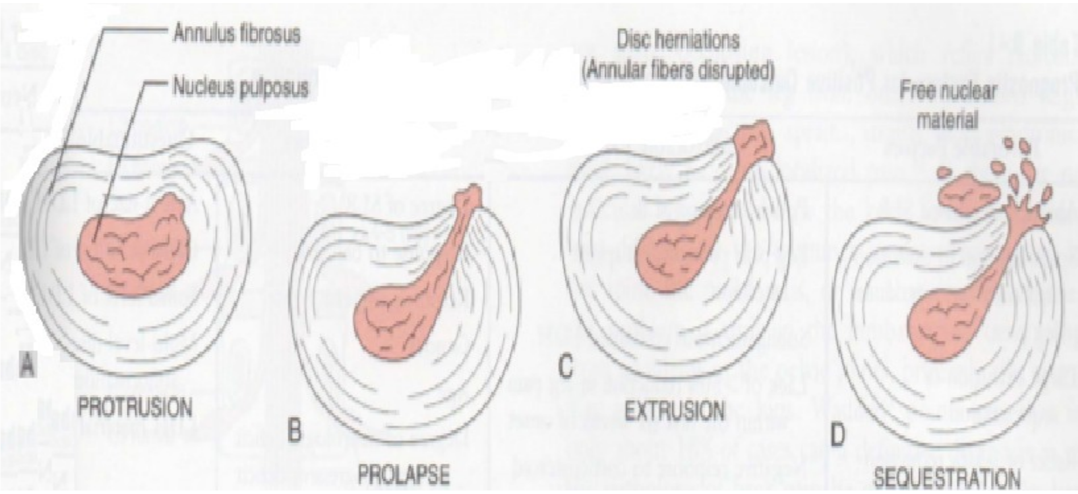


Figure 11: Types of disc herniations. Adapted from (12)

vertebrae, are viewed in a complex called the mobile segment. The disc, apart from providing the cushioning and elasticity, it also acts to maintain sufficient distance between vertebrae to allow movement, as well as to stabilize and restrict excessive intervertebral disc mobility. A healthy disc with an intact annulus fibrosus will be compressed anteriorly and posteriorly during segmental flexion and extension, respectively (6, 12). If its structure is disrupted, however, the nucleus pulposus reacts to project towards the place of least resistance (in the direction of the annular structure damage), where it either bulges or herniates. The most frequent herniations are in the posterior-lateral direction, and their characteristic acute mechanical cause is flexion, with lateral flexion and rotation, which is also the movement coupling (see next paragraph) for the markedly flexed lumbar spine according to Kaltenborn (6, 12). The above scenarios apply to the patient of the case study viewed in this paper. As for the disc itself, its injury can have 4 forms (figure 11): protrusion (commonly, bulging disc), whereby it bulges outward with no rupture of the annulus; prolapse, in which case it is only held in place by the outermost fibers of the annulus; extrusion, where the annulus' continuation is disrupted and nuclear material projects into the epidural space; and sequesteration, where there is fragmented material of the nucleus outside of the disc. All of those conditions can cause symptoms of pain, as well as nerve and/or meningeal involvement (12).

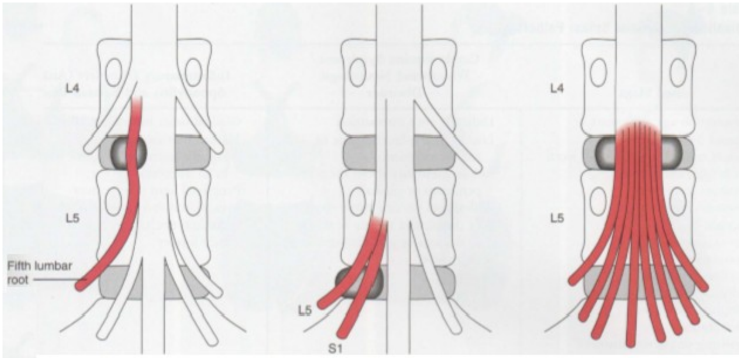


Figure 12: Left: Herniation between the L_4 and L_5 vertebra, compressing the 5^{th} lumbar root. Middle: Larger herniation at the L_5-S_1 disc, compressing not only the first sacral root, but also the L_5 root, exiting from the same foramen. Right: Massive sequesteration of the L_4-L_5 disc, compressing all the roots of the cauda equina, possibly resulting in bladder & bowel paralysis. Adapted from (12)

The combination of movements that brings about the greatest range of motion, the least resistance and the softest barrier sensation is termed the coupled movement. Neurophysiologically, coupled movements are the easiest to perform by the subject, and occur more automatically. The coupled movement differs according to whether the spine is in flexion or extension, and is greatest when all of its components occur simultaneously. The movement of vertebrae with relation to each other is described by the Kaltenborn concave-convex rule. This rule is as follows: if the surface of the movable bone that is part of the joint is convex and its movement is restricted in a particular direction, the gliding between the two bones is restricted in the opposite direction. Contrastingly, of the mobile part of the joint is concave, the restriction of gliding is in the same direction as that of the movement. The vertebrae from C_2 to L_5 move in relation to their caudal partner according to the concave rule. Specifically, and concretely, in the lumbar spine, the inferior articular process (facet) functions as a concave surface, allowing the cranial facet to move ventrally in flexion, and dorsally in extension (12). Because the position of the facets is such, the rotation and lateral flexion movements (which, as stated above, couple together unless otherwise required) occur with the one- contralateral to the rotation and lateral flexion- facet joint “opening”, and the other “closing”; while, in flexion and extension, both facet joints “open” and “close”, respectively. It can be concluded that one facet joint maximally “opens” when the maximum range of coupled movement is reached. This is also part of the rational of mobilizing the vertebral joints into a rotation and flexion position (6, 8, 9, 10, 12).

Generally speaking, the L_5-S_1 segment is the most common source of trouble in the lumbar spine, as it is the point of transition from a more to a less mobile sector, and also sustains the most weight loading than any other vertebral level. Because the angle between the L_5 and the sacrum is greater than it is in between the other lumbar vertebrae, this joint has a greater chance of mechanical stress being applied to it; however, there is a unique ligament in the region- the iliolumbar ligament- connecting the L_5 to the posterior aspect of the ilium, preventing anterior displacement of the vertebra (6, 10, 12). Apart from anatomical position, factors that influence the loading of segments are movement and posture. Nachemson et. al. presented a list of activities and/or postures, and the respective loading each of those brings about, at the L_3 segment (12). All in all, it is crucial to recognize the fact that the absolute load and its distribution at the tissues of a segment, at any given time is a function of the

Coughing or straining:	5% to 35%
Laughing:	40% to 50%
Walking:	15%
Side bending:	25%
Small jumps:	40%
Bending forward:	150%
Rotation:	20%
Lifting a 20-kg weight with the back straight and knees bent:	73%
Lifting a 20-kg weight with the back bent and knees straight:	169%

Figure 13: Activity and consecutive loading of the L_3 segment. Adapted from (12).

posture, muscle activity, segment in question and anatomical position of the segment (8, 9, 10, 12, 14, 16).

2.7 Physical assessment and its rationale

The rationale behind the physical assessment of a patient with an intervertebral disc herniation of the lumbar spine will be described in this chapter of the thesis. The repertoire of examination of the lumbar spine must contain postural observation, global active and segmental movements' assessment, pelvic assessment, local muscle tone, and nerve stretch tests. If a herniation with radiculopathy is suspected the dermatomes and myotomes relevant with the pathology must be examined, along with tendon reflexes, and functional implications of any deficits (i.e. gait, balance). In a functional, muscle activation timing context, the relevant key movement patterns must be assessed. Finally, the complete picture of the patient will be drawn with the identification of reflex changed in any region of the body, but importantly the low back and lower extremities. All the aforementioned examinations are complemented with imaging methods, and preferably magnetic-resonance imaging or computed tomography (which are able to depict soft tissues, as opposed to an X-ray) (12).

The default static posture of the patient is an important parameter to be viewed, as it offers an integrative perspective on the preferred manner of loading, the muscle balance, and any adaptive or antalgic shifts that the patient might be adopting, (or might have adopted at the time of injury), and their interaction. In fact, posture can either be defined in terms

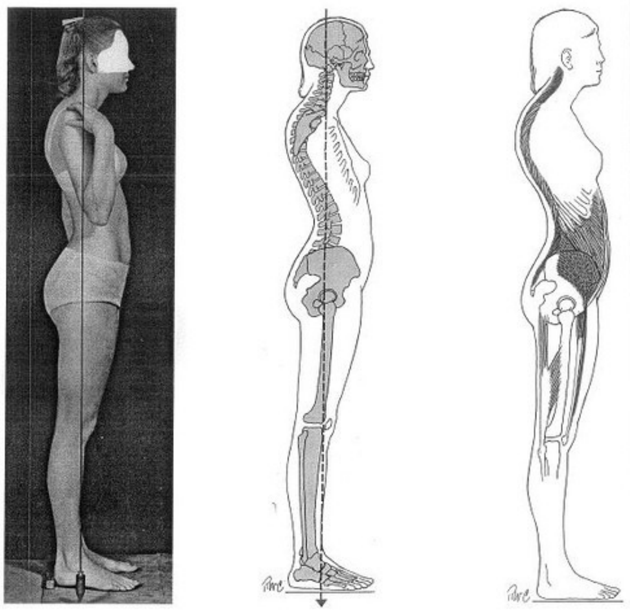


Figure 14: The kyphotic-lordotic postural pattern. Adapted from (7).

of integration of all the joints' position at any given time, or in terms of muscle balance. If we view one of the postural patterns (kyphotic-lodrotic, which is also the posture of the case study patient) that Kendall et.al. described, we can see that it is described not only by the position of key joints (ankle plantar flexion, knee hyperextension, hip flexion, pelvic anterversion, lumbar lordosis, thoracic kyphosis, scapular abduction, cervical lordosis), but also by the concurrent muscle (im)balance (hip flexors, cervical and low back extensor shortness, along with abdominal, gluteal and deep neck flexor musculature weakness)(7). From an anterior or posterior view, the bilateral discrepancies in joint position and muscular appearance can be seen, a fact that can lead the diagnostic procedure correctly, as, for instance, a lower extremity that has weakened due to neural involvement will be reflexively unloaded in part (7, 8, 9, 10, 12).

The global trunk movement of the patient, which is described in the thesis as a dynamic postural examination, is important for multiple reasons, as it may reproduce neurological and/or painful symptoms (at the lumbar spine or lower extremities), serve as an assessment (and hallmark for future control) of lack or excess of range of motion, and also, importantly, it depicts the fluency of spinal curves as it is being executed. The appearance of a suboptimal angle in the arrangement of the spine during movement pinpoints the region around which the movement is reduced, and on which the movement is compensatively excessive. The possible apparent prominence of muscles during movement is another clinically significant finding, depicting imbalances and reflexive spasms meant to protect injured structures. This guides the assessment to further evaluation of responsible joints and soft tissues. The reproduction and nature of symptoms, when viewed from the perspective of kinesiology and anatomy, can orient the clinician towards differentiating injured structures. The segmental movements, which have to be done by the clinician, are a follow-up assessment that is oriented at depicting the reasons if movement faults. Physiological movements in all

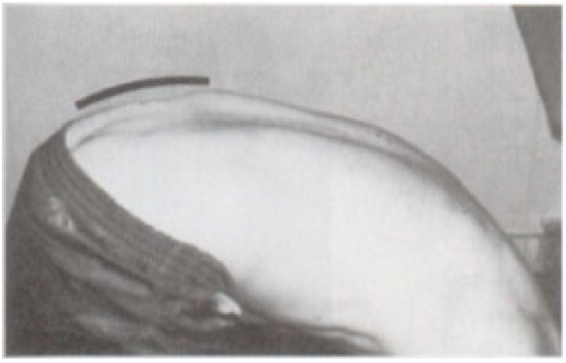


Figure 15: Forward flexion curve. Ideally, the lumbar spine should flatten, of flex, in a fluent manner, as the patient attempts forward flexion, as if to touch the floor with the fingers. If this does not happen, muscular spasm and/or soft tissue tightness are restrictive, either segmentally or generally. Adapted from (12).

planes, as well as certain translatoric movements, should be present, as well as not excessive or limited, in order for the entire trunk to function appropriately. In the context of dynamic trunk movement, it is important to also assess the sacroiliac joint state, as it may reflexively block, or be distorted muscularly (7, 8, 9, 10, 12).

The muscle tone distribution is a vast subject that can have multiple causes and results. Through palpation, the tone of the muscle can be subjectively quantified into hypertone and hypotone. A hypotonic muscle is inhibited, reflexively, due to a dysfunctional movement pattern that has been perpetuated, or neurologically through the peripheral lesion of the nerve that primarily supplies it. This muscle will also appear weak in force exertion. Such muscles in an L5 intervertebral disc herniation with radiculopathy are the tibialis anterior and the extensor hallucis longus. Also, as discussed earlier, all the deep stabilizers are reflexively moving to a hypotonic state, by the injury and back pain alone (although they were most likely dysfunctional previously as well) (8, 9, 10, 14). As far as hypertone is concerned, it is either compensatory (due to overuse, pain or loss of function of a joint/ other muscle), reflexive, or has a central neurological origin. The erector spinae of the patient were found in hypertone, and the rationale behind it is that they were substituting the function of the deep stabilizers (a task they are poorly fit to execute, from a mechanical perspective), and artificially "splinting" the spine into a painless position, avoiding the irritation of the injured structure (8, 9, 10).

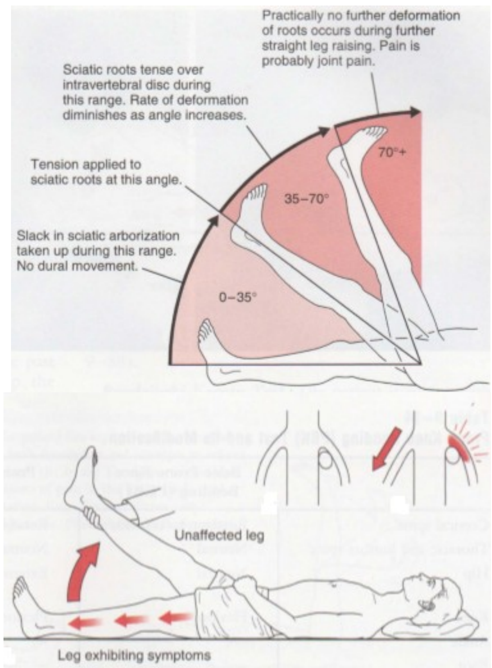


Figure 16: The normal, and well-leg, SLR tests. Up: Dynamics of the single, ipsilateral SLR. Down: Mechanism of the well-leg SLR. Adapted from (12).

Tests or neurological dysfunction are executed to assess whether there is mechanical movement of nerves, and to view their sensitivity to stress, or compression. Disc herniation diagnosis is, for a significant part, corroborated by positive neurodynamic tests, relevant history, and reduced range of motion, regardless of the degree of disc injury (12). There are multiple nerve stretch tests available; the test employed at the patient studied in this paper is the Lasègue, or straight-leg raise

(SLR) test. In that test, the completely relaxed patient has his lower extremity flexed at the hip, with the knee extended and the ankle and toes relaxed. If pain of neurological symptoms (stabbing, burning, tingling, paresthesia) or pain occur at the leg or low back with hip flexion less than 70º, the test is positive, and depicts a nerve involvement of any of the nerve roots at the L_5, S_1 or S_2 segments. If the pain is suspected to be caused by hamstring tightness (although it differs in nature), that should be clinically differentiated. Importantly, the test might be positive while raising the affected leg, but when raising also the healthy leg (well-leg raising test). This test can also be positive due to sacroiliac joint abnormalities, thus emphasizing the need to assess the sacroiliac joint mobility in the context of dynamic spinal movements, as previously discussed. Alternatively, this can be differentiated by performing a bilateral SLR test, which is positive for sacroiliac lesions when pain is produced within the 70º hallmark. The stretch of the nerves tested in this maneuver can be provoked further, by ankle dorsiflexion (Bragard's sign), as well as neck flexion (Brudzinski's sign) (2, 6, 8, 9, 10, 12).

The dermatome, myotome and tendon reflex examination is a rational follow-up when a disc herniation is suspected, to detect the location, and extent, of the peripheral nerve impingement by the disc. Each of the nerve roots has characteristic patterns of resulting

Root	Dermatome	Muscle Weakness	Reflexes/Special Tests Affected	Paresthesias
L1	Back, over trochanter, groin	None	None	Groin, after holding posture, which causes pain
L2	Back, front of thigh to knee	Psoas, hip adductors	None	Occasionally front of thigh
L3	Back, upper buttock, front of thigh and knee, medial lower leg	Psoas, quadriceps—thigh wasting	Knee jerk sluggish, PKB positive, pain on full SLR	Inner knee, anterior lower leg
L4	Inner buttock, outer thigh, inside of leg, dorsum of foot, big toe	Tibialis anterior, extensor hallucis	SLR limited, neck-flexion pain, weak knee jerk; side flexion limited	Medial aspect of calf and ankle
L5	Buttock, back and side of thigh, lateral aspect of leg, dorsum of foot, inner half of sole and first, second, and third toes	Extensor hallucis, peroneals, gluteus medius, ankle dorsiflexors, hamstrings—calf wasting	SLR limited to one side, neck-flexion pain, ankle jerk decreased, crossed-leg raising—pain	Lateral aspect of leg, medial three toes
S1	Buttock, back of thigh, and lower leg	Calf and hamstrings, wasting of gluteals, peroneals, plantar flexors	SLR limited	Lateral two toes, lateral foot, lateral leg to knee plantar aspect of foot
S2	Same as S1	Same as S1 except peroneals	Same as S1	Lateral leg. knee. heel
S3	Groin, inner thigh to knee	None	None	None
S4	Perineum, genitals, lower sacrum	Bladder, rectum	None	Saddle area, genitals, anus impotence

Figure 17: Lumbar root syndromes. SLR: Straight leg raise. PKB: Prone knee bend. Adapted from (12).

neurological dysfunction when affected, as can be seen in figure 17 (note that not all of those symptoms are necessarily always present; the presentation varies among individuals, and extents of nerve involvement). The patient discussed in this paper has an L_5 herniation, and indeed exhibited some lack of strength in dorsal flexion of the ankle and the great toe; however, since she was in a chronic state, the SLR was negative, and her dermatome sensation was normal, as were all of her reflexes. To the above overall description of L_5 root syndrome presentation, Lewit adds the commonly painful piriformis muscle that usually is presented with a trigger point; a finding that was present in the subject of the thesis.

There are 6 movement patterns that have been described and, although individual in performance, can be said to maintain typically physiological, and dysfunctional, execution stereotypes among subjects. These include the hip (hyper)extension, hip abduction, trunk flexion (curl-up), neck flexion, shoulder abduction, and push-up patterns. From those, the hip extension and trunk flexion were evaluated on the subject. The hip extension is executed in prone lying, and evaluates the activation pattern of the gluteus maximus, hamstrings, erector spinae and scapular muscles. An ideal execution is that in which the gluteus maximus muscle leads the activation, followed by the hamstrings, contralateral and then ipsilateral lumbar erector spinae, contralateral and then ipsilateral thoracolumbar erector spinae, while the shoulder girdle muscles remain silent. The trunk flexion pattern evaluates the interplay between the abdominals and iliopsoas muscles, and is executed in supine lying. Ideally, the execution of rising to a sitting position occurs with the pelvis in a retroversion position and the trunk flexing while the lower extremities rest on the floor, signalizing a dominance of the abdominal muscles. The movement patterns must be assessed while giving minimal verbal queues to the subject, in order to detect his spontaneous pattern of executing the activities requested. Movement pattern evaluation is a very easy, fast and clinically useful diagnostic method that integrates a lot of information in one functional picture (10).

The gait is another key function that can be affected by multiple parameters of an intervertebral disc herniation, including the reflexive changes, the muscle weakness that occurs, the hypertonic musculature and the pain itself. Over-activity of the erector spinae during gait is a common finding in those patients with low back pain, as is the lack of coordinated movement between the thorax and pelvis; both of which were present in the case study patient (10). Also, the toe and ankle dorsal flexor muscle weakness was manifested with abrupt initial contact, which was even more apparent during the attempt of heel-gait.

Finally, as far as other reflex changes are concerned, these occur in the form of soft tissue restrictions, joint blocks, periosteal point pain and altered muscle tone. The fasciae of the low back are often markedly restricted on a patient with a lumbar disc herniation. Another form of reflexive change, encountered in the L_5 patients is the increased resistance of the interdigital folds of the 1^{st} 3 toes, and the reduced dorso-plantar mobility of the respective metatarsal heads. It is essential to detect as many of those reflex changes as possible, in order to treat them in conjunction and restore normal function, which is the most important goal of the chronic intervertebral disc herniation patient, once pain is relieved (8, 9, 10).

2.8 Treatment approaches for a lumbar intervertebral disc herniation patient

The intervertebral disc herniation can be treated surgically or conservatively. Surgery is done when there is bladder and/or bowel paralysis due to a cauda equina syndrome, or when the conservative approach efforts fail, and the functional level is unacceptable. Additionally, surgery is indicated when there is rapid onset of muscular weakness (paralysis) that does not improve within 24 hours (so as to avoid permanent paralysis), or when the intense pain of the patient is constant throughout the acute state (to spare the patient of further agony). Surgery should be avoided to the extent that this is possible, as a successful surgery outcome (which is absent in 10%-30% of cases) is not assistive in restoring function in the long run compared to conservative treatment, when the above conditions are not met, and in fact, opens the gate for other issues, such as infection, iatrogenic damage and other comorbidities. Also, the reoccurrence of symptoms occurs in sciatica and low back pain after lumbar disc surgery occurs in 22%-45%, and 30%-70%, respectively (9, 10).

The repertoire of conservative treatments is aimed at restoring function alleviating pain (and possible inflammation acutely). The (directly aimed at) analgesic and/or inflammatory aspect can be achieved either through medication (non-steroid anti-inflammatory drugs (NSAIDs), oral steroids, over-the-counter painkillers, epidural injections etc.), physical modalities employing analgesic parameters (Transcutaneous electric nerve stimulation, Träbert current etc.) and rest. Notably, rest is because, rather than for, the pain; effectively, it is because many activities are painful in the acute state that rest is done, rather than because it has healing properties, and in fact the patient return to activity as soon as possible (8, 9, 10).

The restoration of function is sought after by the optimization of balance between segmental movement and stability, the disc centralization, the release of neural tissue involvement, and the abolishment of reflex changes, while the subject is taught how to maintain a functional pattern in certain activities that "shields" him/her from future injury through increased motor control levels. The disc (and pain) centralization is a concept that is prominent in the McKenzie management regime. The techniques described by McKenzie are very effective in lower lumbar disc herniation cases as they bring about significant pain and radicular symptom reduction, and are generally used in a simplified form. According to Lewit, only the simplest techniques of this school can be effectively mastered by the patient for self-therapy. In that context, the "extension" exercise will be described, which is commonly executed in the posterior/posterolateral direction disc hernias (anterior bulges are managed with the flexion exercise), and was also performed by the case study patient. During extension, the prone-lying patient uses his arms to lift his trunk from the table, while maintaining the pelvis on that table as much as possible, and stops as his arms straighten fully, or as close to that as is bearable by the pain (figure 9). It is important for the pain during, or after, this exercise to not project distally from the gluteal region, but rather to project proximally, or "centralize" (1, 9, 10).

Figure 18: The self-mobilization of the lumbar spine into extension, as described in the McKenzie concept. Adapted from (9).

Manual therapy is employed to mobilize those segments that become restricted as a result of the injury of the intervertebral disc, and subsequent movement stereotype alteration. In that context, lumbar traction and rotational mobilizations are used, with lumbar traction being the treatment of choice in lumbar disc herniations, both in acute and chronic states; in fact, if traction provokes alleviation, the diagnosis of a disc lesion is corroborated (9, 12). If traction provokes agreeable sensation to the patient, rotational rhythmic mobilization, and even a high velocity-low amplitude (HVLA) rotational segmental thrust might be attempted. The rotational thrust, especially when aimed at the painful side, should be done into flexion, to alleviate root compression and maximally "gap" the facet joint (6, 8, 9, 10).

Deep stabilizer musculature insufficiency is addressed through exercise aimed at facilitating those muscles, and then integrating them into functional patterns. Considering the group of muscles that act as core stabilizers, many approaches of re-training have been described. Corrective breathing exercises can act as a gateway of activation of the diaphragm-transversus abdominis-pelvic floor muscularure, alone or in conjunction with a trunk stabilization task, as is described in the developmental kinesiological context by Pavel Kolář (9, 10). Richardson et.al. advocate the use of lower extremity synkinesis and conscious transversus abdominis muscle activation, with or without biofeedback (or hands uses for feedback), in order to facilitate core stabilizers and re-integrate the lower extremity movement being led by transversus abdominis activation (5, 17). In the SMS context, it is found that tools traditionally employed in this type of training (wobble boards, body-blades etc.) facilitate stabilizer contraction in the trunk; consequently, this form of exercise can also have a place in re-educating deep stabilizer function (10, 15).

Motor control and movement pattern re-education is the top of the pyramid of rehabilitation exercise, as all the muscular activation and segmental mobilization bits previously achieved are tied together into functional activities. This type of retraining has prompt implementation into the daily living activities that the patient engages into. Movements like lifting or squatting off of/to progressively lower levels, while maintaining correct posture and deep stabilizer activation are emphasized in this type of training. Progressively, SMS parameters might be implemented to force correct weight carrying and core stability, while posing a greater challenge to the trainee's concentration as well.

Research pinpoints the beneficial addition of effects that motor control education offers to other forms of therapy and exercise (4, 10, 11, 20).

With all of the above in mind, a spherical approach was employed in the treatment of the subject discussed in this paper: analgesic current application, reflex change abolishment through muscular relaxation and fascia mobilization soft tissue techniques, manual mobilization and traction, deep stabilizer education, SMS training and motor control exercises.

3 Special part

This part of the thesis describes the history taking, physical assessment, treatment and clinical condition progress relevant with the therapy of the case study patient, before giving presenting a concluding and summarizing the process with an evaluation of the overall effects and the progress in retrospect.

3.1 Methodology

The therapy sessions happened in the time frame between 15/1 and 7/2, 2013, at the Ústřední vojenská nemocnice (ÚVN) military hospital, outpatient physiotherapy department. In that interval, I had the chance to work with my patient for 7 sessions of about 30 minutes each. My patient was at a chronic state of an intervertebral disc herniation of the L_5 segment, with radiculopathy on the left side.

Prior to the implementation of any assessment and treatment procedures, the patient signed an informed consent form, clarifying her acceptance of the use of the data of our clinical interaction for my bachelor thesis project.

This undergraduate research was approved by the ethics board of the Faculty of Physical Education and Sport of Charles University (see attachments, page 59), and the patient signed an informed consent form (an example of which is in attachments, page 58).

3.2 Anamnesis

Name of patient: A.J.

Sex: Female

Age: 64

Height: 1.75 meters

Weight: 89 Kilograms

BMI: 29.1

Diagnosis (ICD-10 code): L5 Intervertebral disc herniation with radiculopathy on the left side (M51.1)

Chief complaint: The patient's most important issue at the moment is back pain and a feeling of tightness in the postero-lateral thigh and calf area.

History of present problem: 3 years prior to the first meeting with this rehabilitation team, the patient's 5th lumbar intervertebral disc was herniated, when she performed a rotatory movement in the trunk while getting out of the car. The condition relapsed in the summer of the previous year, while she was gardening on her knees. At that time she felt a "typical", for her, low back pain which, 3 weeks later, evolved to her not being able to stand on 1 leg due to its weakness, as well as numbness in its postero-lateral aspect, and a pain sensation from the low back, to the sacroiliac joint, down through the leg, past the ankle, to the foot (consistent with the typical L5 projection site).

Prior rehabilitation: Following the latter incident of back pain, the patient visited a neurological department, where she was diagnosed and treated with painkillers and NSAIDs. Those did not bring relief, leading to her 10-day hospitalization (3/9 to 13/9), at which time she received infusion therapy and basic stabilization exercises, which improved her condition but did not resolve the numbness sensation around the ankle. Onward in her rehabilitation progress, she underwent McKenzie exercises (chiefly extension, which she still performs), which centralized the back pain and improved her radicular symptoms. Currently, she is feeling a lot better, but admits to not being in an optimal condition; hence her visit in this physiotherapy department.

Medical/Surgical history: The patient has suffered, apart from the common childhood diseases, from gastroesophageal reflux, and mild depressions following her husband's recent loss (which she treated pharmacologically also, and has overcome now). She has arterial hypertension and dyslipidemia, and has had urinary bladder stabilization exercise and medication for incontinence prevention. She has given 1 normal birth.

Excerpt from patient's healthcare file: A computed tomography was performed on the patient, on the 21/8/2012. Degenerative changes were found in the lumbar and lumbo-sacral region. The intervertebral discs of all the segments L_2-S_1 bulge circularly, while L_2, L_3 and L_4 protrude to the left also, with no sequester, while causing no nerve root impingement. Slight spinal stenosis at the level of L_3-L_4 is noted. There is also osteochondrosis on the L_2-L_4, apart from the intervertebral disc degeneration.

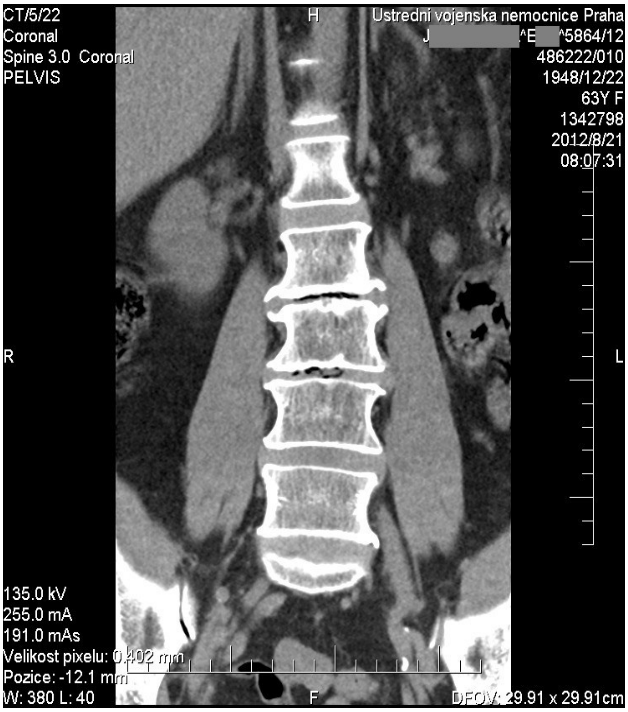


Figure 19: Computed tomography imaging of the patient's lumbar spine in coronal plane.

Family history: There is a history of myocardial infracts (mother has had 2, and father had 1) on both sides of the family of the patient, and her father died of a stroke; however, the advanced age in which these occurred render them less conspicuous of a risk. No other related diseases are present in the family tree.

Functional history: The patient suggests that there is some functional loss due to the condition. Following a long walk, the patient reports a feeling of numbness and weakness, postero-laterally at the thigh and calf (in the area consistent with the L_5 segment dermatome) of the left lower extremity. She also reports a feeling of her left foot "slapping" the floor, due to lack of control and weakness of dorsal flexion, in the same side.

Other than that, the condition of the patient does not penetrate into her activities of daily living. She lives in an apartment, on the 2^{nd} floor with no elevator access, which poses no challenge to her. Her work can be best described as sedentary and office-based. She undertakes no physical exercise systematically.

Diet, medication and allergies: The patient does not follow any special diet. She is allergic to penicillin, and nothing else. She occasionally uses over-the-counter painkiller medication whenever she feels like it. No other drugs are systematically used.

Psychosocial history: From the time spent with the patient, she appears to be in a good condition psychologically. She appeared to be in a good mood throughout the session and not to withhold information from the physiotherapists willingly. She claimed to have good sleeping patterns.

Substance abuse: The patient is a non-smoker (quit 2 years ago from 10 per day), and does not drink.

Indication for rehabilitation: Pain control, McKenzie exercises, electrotherapy, soft tissue techniques, deep stabilization increase, mobilization.

Differential consideration: After having reviewed the patient's history, her condition appears to be rather anticipated, being an intervertebral disc herniation of the L_5 segment at a chronic stage. The reason for the disturbances that led the subject to seek further physiotherapeutic attention could be issues such as residual reflexive fascia restriction, joint blockage in the lumbar and/or sacral region etc. Additionally, muscular imbalance secondary to the condition can be part of the symptom's causality, and is also often present in most low back pain scenarios, where deep stabilizers are inhibited. In any case, the magnitude of the above factors must be examined precisely.

3.3 Initial Kinesiological examination

Static Postural examination

Anterior observation of the patient's posture showed the left scapula to be depressed and the ipsilateral shoulder internally rotated, compared to the right side. Rounded shoulders were present on both sides.

From a lateral perspective, the patient seems to adopt a kyphotic-lordotic postural pattern, with plantar flexion in the ankle, anterior pelvic tilt, increased thoracic kyphosis and head forward.

Seen from a posterior view, the patient appears to maintain a default head rotation to the left. The thoraco-brachial space was enlarged on the right side, and the right glut rested higher than the left. The left hip was in external rotation.

Dynamic Postural examination

When performing forward flexion, the patient suggested the rise of a feeling of stiffness and "pulling" in the posterolateral aspect of the thigh, as well as -and primarily at- the calf. Apparent prominence of the lumbar erector spinae was present, with that part of the spine remaining flat rather than going into flexion. A 10cm distance from the floor to the fingers of the patient was present at max range.

During extension, the movement occurred almost entirely in the thoraco-lumbar junction. No pain was present, and adequate range of motion was possible.

When lateral flexion was done, there was some restriction present (distance: to left-17cm, to right- 18cm) and roughly symmetrical spinal curvature in both movements.

Gait examination

Abrupt initial contact was constantly performed by the patient, bilaterally. The loading wave of the foot was good, and the step length was roughly symmetrical. The upper extremity synkinesis was almost entirely being performed by the left arm only. The postural pattern assumed during gait matched that described in the postural examination. Tiptoe gait was possible with no problem, as was squat gait; however, drop-foot on the left side was noted during heel gait. While the latter was performed, the patient also complained of hip disturbance.

Inspection

Normal skin color is seen on the patient. Prominence is noted in the erector spinae, particularly those from the middle-thoracic to the thoraco-lumbar level. No apparent deformation of the physiological curvature of the spine is noted in supine position. There is no bilateral discrepancy in the volume or shape of any parts of the lower extremities.

Muscle length testing

Measured by the Thomas test, as described by Kendall et. al., the sartorius and tensor fascia lata of the left hip were found moderately short (grade 1, according to Janda), as was the rectus femoris of the right hip. The gastrocnemius and soleus muscles were both markedly short (grade 2) symmetrically.

Muscle strength testing (according to Kendall et.al., grading scale 0-5)

The tibialis anterior and extensor hallucis longus muscles were suspected to be weak in the affected side due to their innervation by the herniated segment. Both muscles scored 5 in the testing, but when maximal resistance was offered, they proved weaker than the opposite side.

Palpation

Marked restriction of the fascia of the low back was present, from the thoracolumbar to the lumbosacral crossing, in cranial direction primarily, as well as in latero-lateral direction to some degree. Kibler fold was impossible to perform as a result. The erector spinae from the mid-thoracic spine to the thoracolumbar junction were in hypertone, and specifically, more so on the right at the mid-thoracic level, while the left side was in higher tone more caudally until the level of L_1-L_2. Marked hypertone of the quadratus lumborum was detected on the left side, as well as the piriformis of the same side.

Neurological examination

No hypesthesia was present in any part of the lower extremity. All reflexes were normal.

Joint Play examination

The joints of the entire lower extremity were free in all directions bilaterally, as was the sacroiliac joint. Restriction was detected in the springing of the L_2 and L_3 vertebrae. Lateral flexion to the right was restricted in the L_5 segment, and flexion was also very slightly reduced.

Specific tests

The Lasegue and Vele tests were negative. The 3rd level of Rhomberg test was positive.

Movement pattern evaluation

When hip extension was performed, the bilateral activation of the erector spinae preceded that of all other muscles, with the contralateral side being more prominent in both sides tested. The concurrent activation of the hamstrings and gluteus maximus occurred second, followed by contralateral, and then ipsilateral, thoraco-lumbar erector spinae activation. Adequate range of movement was present in the hip.

Trunk flexion was also performed by the patient. Although the movement was initiated through the abdominal muscles as is appropriate, dramatic involvement of the hip flexors occurred following the first 20º of movement, apparent with elevation of lower extremities from the table's surface. Rising to the sitting position was impossible.

Conclusion of initial examination

As expected, there are persistent muscle tone abnormalities around the site of the lesion, as well as persistent reflex changes. Those alone justify the restriction of movement measured in the examination. There appears to be absence of meningeal involvement at the time of examination, and in fact, nerve tension test results were better than expected. Some functionality impairment of tibialis anterior and extensor hallucis longus is present, as well as severe hypertone of the ipsilateral piriformis and quadratus lumborum. The latter hypertonic muscles appear to be fundamental for the residual pain sensation.

3.4 Short and long-term rehabilitation plan

Short-term rehabilitation plan

The short-term plan in this subject's rehabilitation is to abolish any residual symptoms of pain and impaired functionality, so as to render the subject's activities of daily living comfortable. To that end, the fascia of the lower back should be released, and the hypertonic piriformis muscle should be relaxed, as well as the quadratus lumborum muscles.

Long-term rehabilitation plan

The long-term goals of the treatment as a whole would be to shield the patient from future recurrence of similar injury. To that end, the core stability and motor control should be improved, and importantly, movements that typically pose risk for the low back, such as lifting from the floor level, should be re-educated. This means that concurrent postural and SMS training must be performed, and muscle balance should be promoted in general. Before discharged, the patient should be able to perform at any activity that challenges posture and core stability at an acceptable level, while having the ability to carry her bodies- as well as external- weight as she maintains good posture and deep, segmental stability, in challenging situations.

3.5 Therapy progress

Note: The patient performs McKenzie exercises as instructed by the doctor as self-therapy. She also undergoes Träbert current application before every treatment session, at the L_4 placement for 15 minutes, at the electrotherapy department

Session 1 (15/01/2013)

Subjective report: The patient reports minor dull, aching disturbance in the low back region, as well as a stiffness feeling in the posterior hip region. Also, there is a sensation of mild neurogenic at the posterior aspect of the left leg, and especially the calf, exaggerated by bending forward. Patient suggests a 5/10 level of pain to be present.

Assessment: Hypertonic piriformis and slight restriction in internal rotation of the left side compared to the right (Internal rotation: L- 20º, R- 30º). Marked restriction of the fascia in the low back, in cranial and latero-lateral direction. Hypertonic quadrati lumborum, especially on the left side.

Goals: Removal of feeling of stiffness and pain in the region of the low back and hip. Traction of the segment with the herniated disc.

Treatment:

- Fascia release of the lumbar region in cranial direction, in prone lying.
- Fascia release of the lumbar region in latero-lateral direction ("Saw touch"), in prone lying.
- Post-Isometric lumbar traction into flexion, in prone lying, as described by Lewit (9).
- PIR of left Piriformis muscle.

Results: The patient suggested marked improvement in condition. She stated that her low back felt more relaxed and mobile, with the thigh and hip feeling released. The patient now reports a 2/10 pain level.

The mobility of the fascia of the lumbar spine was still suboptimal after the therapy, but there was significant improvement in their condition; the performance of Kibler fold was no longer impossible due to their restricted movement. Improvement of the muscle tone of the erector spinae, quadratus lumborum and piriformis occurred, following the traction and PIR applications. The bending forward movement was performed with normal range, with the fingers touching the floor. Internal rotation was equalized following the treatment, at 30º. The same applies for lateral trunk flexion, with 20cm bilateral motion available in the respective test.

Prognosis: There was immediate positive impact on the patient condition, already from the 1st therapy, both objectively and subjectively. This, along with the fact that the condition of the patient is in chronic stage, sets the stage for a good prognosis with regards to pain management. The concrete rehabilitation, however, rests also on the outcome of the training of posture and core stability; things that have not yet been addressed in treatment. As the patient does not visit the hospital intensively (but rather, only twice a week, and is scheduled for discharge at the 5/2/2013), the eventual result of the treatment will greatly depend on her dedication and skill in performing self-therapy exercises for posture and stability improvement.

Session 2 (17/01/2013)

Subjective report: The patient reports a great improvement in her condition following the first treatment session. Amelioration of pain to a high degree has occurred, chiefly regarding her low back, and secondarily her hip, but it is not abolished (pain level at 3/10). The feeling of stiffness in her postero-lateral lower extremity has also decreased. However, some disturbance persists in her hip, and her feeling of dorsal flexion weakness as well.

Assessment: The piriformis of the left side has not relapsed completely, but is in painful hypertone (left internal rotation available was 25º). Restriction in the low back fascia persists, though not in as markedly a way as the in first assessment. There is a fascia restriction in the postero-lateral lower third of the calf. All fascia restrictions are primarily in cranial direction, and secondarily in latero-lateral direction. Springing of the lumbar vertebrae has improved, but is still suboptimal. Painless moderate hypertone of the left quadratus lumborum is present, and the same applies for the erector spinae, in the pattern initially described.

Goals: Residual pain reduction. Mobilization low back and lower calf fascia. Management of muscle tone of left piriformis. Traction of the segment with the herniated disc.

Treatment:

- Fascia release at the restricted region of the calf, in cranial and latero-lateral direction.
- Fascia release of the lumbar region in cranial direction, in prone lying, as described by Lewit.
- Fascia release of the lumbar region in latero-lateral direction ("Saw touch"), in prone lying.
- Post-Isometric lumbar traction into flexion, in prone lying (9).
- PIR of left piriformis.

Results: The enthusiasm of the patient following the treatment was apparent. She reported a more pleasant feeling in her otherwise impaired lower extremity following the treatment, from hip to foot. Her low back also felt looser and pleasantly mobile. No feelings of pain were present at the end of treatment.

The fascias of the calf were successfully mobilized, and those of the lumbar spine gained some further mobility. The springing of the lumbar vertebrae in suboptimal condition improved, more or less to the point of normalization. Muscle tone around the low and mid-thoracic spine is in acceptable condition. Normalization of muscle tone of piriformis occurred, once again normalizing with respect to the contralateral side, at 30º of range of motion and painless palpation. Slight dysfunction of the L5 segment's mobility, in the pattern initially described, persists after 2 treatment sessions. Since the patient responds well to traction and is not in acute stage, a rotatory mobilization and HVLA thrust will be attempted in the next session, if the restriction persists. Additionally, in the next session, corrective exercises and fundamental re-education of lifting and posture will be initiated.

Session 3 (22/01/2013)

Subjective report: Reporting a steady improvement in condition, the patient claims significant gains in functionality to have occurred, especially in daily activities such as prolonged sitting, dish-washing, bending forward etc. She also emphasizes the success of the therapy with respect to her postero-lateral lower extremity pain, as well as its elevation occurring with forward flexion. Still, she claims that there is a "remainder of her condition" occasionally. She suggests a 2-2.5/10 pain level to be present.

Assessment: Further improvement of the muscle tone of all muscles of concern has occurred, more significantly on those around the lumbar spine, and primarily the left lumbar erector spinae. The left piriformis muscle still presents with some discomfort on palpation, and partial restriction of range of motion in the internal rotation of hip is present (25º). The calf fascia has not relapsed. Those of the lower back, however, even though there is progress in their condition, are still significantly restricted.

Importantly, following the usual therapy procedures, the patient was subjected to thumbs test, where the segmental movement of the facet joints of the lumbar spine was assessed. The L_5 segment left facet lagged in forward flexion, and was significantly restricted in lateral flexion to the right.

Goals: Control of the remainder of pain, in the lumbar and hip region. Relaxation of left piriformis. Traction of the segment with the herniated disc. Mobilization of low back fascia. Release of L_5 segment's left facet joint. Core stability improvement. Postural re-education. Lifting mechanics re-education.

Treatment:

- Fascia release of the lumbar region in cranial direction, in prone lying, as described by Lewit.
- Fascia release of the lumbar region in latero-lateral direction ("Saw touch"), in prone lying.
- Post-Isometric lumbar traction into flexion, in prone lying (9).

- Ischemic pressure of left piriformis, in counterstrain position.
- PIR of left piriformis.
- Slow repetitive mobilization of the L_5 segment's left facet joint into rotation (to the right) with flexion, followed by an HVLA thrust, as described by Lewit (9).
- Postural training: Sitting postural exercise, as described by Kendall et.al., and instruction for self-therapy (7).
- Lifting mechanics re-education: Instruction of performance of lifting of objects from elevated platform (knee height), in the principles described by Liebenson (10).
- Instruction of "small-foot" performance in sitting, as described by Janda et.al. in the sensory-motor stimulation concept, and instruction for self-therapy (10).

Results: All treatment approaches and exercises were well-received and painless. The fascia of the patient's low back showed some further gain in mobility following the treatment. The mobilization and thrust successfully released the left facet of the L_5 segment, as confirmed by the subsequent thumbs test, which showed it to move absolutely symmetrically compared to the contralateral facet. The piriformis muscle showed significant gains in its palpation quality (more so than the previous times) and returned the available internal rotation range of movement to 30º, but gained less improvement with regards to produced discomfort when palpated.

The hardest exercise to grasp by the patient was the small-foot performance, which, however, was executed correctly before the treatment session was over. The default lifting mechanism of the patient was markedly dysfunctional and risky for her low back, but she came to terms with back bracing and other fundamental principles of correct lifting fairly quickly and easily. The postural exercise took a lot of concentration by the patient to execute correctly, but she displayed the encouraging signs of understanding when she was executing it suboptimally.

The sensory-motor stimulation is planned to become increasingly harder, as the therapy progresses, and the level from which the lifts will be executed to gradually descend.

Session 4 (24/01/2013)

Subjective report: The patient suggest the pain to have disappeared in her low back and hip region, and only residual disturbance to be manifested in the form of occasional numbness in the postero-lateral aspect of the thigh, occurring mostly in excessive (and improper, as it turns out, after her demonstration) bending forward and slight twisting of the trunk.

Assessment: The piriformis muscle has not relapsed in hypertone, and is painless when palpated. The low back fascia mobility is distinctly improved (while still not optimal), and the muscle tone of the erector spinae is almost bilaterally equalized. The quadrati lumborum muscles are bilaterally symmetrical in tone, and painless when palpated. Thumbs testing the facet joint mobility reveals no dysfunction to have reoccurred. Lumbar vertebrae were also normal in springing.

Goals: Mobilization of the fascia of the low back. Traction of the segment with the herniated disc. Core stability improvement. Postural re-education. Lifting mechanics re-education.

Treatment:

- Fascia release of the lumbar region in cranial direction, in prone lying, as described by Lewit.
- Fascia release of the lumbar region in latero-lateral direction ("Saw touch"), in prone lying.
- Post-Isometric lumbar traction into flexion, in prone lying (9).
- Postural training: Sitting postural exercise, as described by Kendall et.al., and instruction for self-therapy (7).
- Lifting mechanics re-education: Instruction of performance of lifting of objects from elevated platform (mid-calf height), in the principles described by Liebenson (10).
- Instruction of "small-foot" performance in standing, as described by Janda et.al. in the sensory-motor stimulation concept. Progression into small step forward, step

forward, and step forward on rocker board. Instruction of self-therapy (small-foot, then step forward) (10).

- Transversus abdominis muscle activation through breathing control, in supine lying with feet on bed, as described by Lewit, and instruction for self-therapy (9).
- Core stability training: conscious transversus abdominis muscle activation in supine lying with feet on bed, deep neck flexor activation, shoulder external rotation, then isokinetic abduction and adduction of hip with stabilized trunk, as described by Richardson et.al (17).

Results: Gains in fascia mobility of the low back were noted. Improvement of the muscle tone discrepancy of the erector spinae occurred following the soft tissue techniques and the lumbar traction. Good activation of the transversus abdominis occurred, and conscious control was possible towards the end of the exercise routines. The lifting mechanics training difficulty progressed with no problems. The postural exercise in sitting was performed in more optimal a manner than the previous time, and the patient showed good understanding of its mechanics. Some difficulty was encountered in the performance of the last exercise, but it was eventually executed in a very good way for a first attempt. Spectacular skill was shown in the sensory-motor stimulation-based exercises.

Session 5 (29/01/2013)

Subjective report: The patient reports no pain or numbness to have occurred at any point in the interval between treatment sessions. She is absolutely functional in her activities of daily living, and reports no sensation of drop-foot to be present, even in prolonged walking. No troubles were encountered in the self-therapy.

Assessment: No hypertone or pain ensued when palpating the piriformis muscle. Very mild lag in the movement of the left facet joint in the L_5 segment was found in the thumbs test. Improvement in the fascia mobility around the low back is obvious; still being slightly restricted, however. Bilateral symmetry of the erector spinae in tone is approximated, but not established yet.

Goals: Mobilization of the fascia of the low back. Traction of the segment with the herniated disc. Core stability improvement. Postural re-education. Lifting mechanics re-education.

Treatment:

- Fascia release of the lumbar region in cranial direction, in prone lying, as described by Lewit.
- Fascia release of the lumbar region in latero-lateral direction ("Saw touch"), in prone lying.
- Post-Isometric lumbar traction into flexion, in prone lying (9).
- Slow repetitive mobilization of the L_5 segment's left facet joint into rotation (to the right) with flexion, followed by an HVLA thrust, as described by Lewit (9).
- Instruction of "small-foot" performance in standing, as described by Janda et.al. in the sensory-motor stimulation concept. Progression into small step forward, step forward, and step forward on rocker board. Instruction of self-therapy (small-foot, then step forward) (10).
- Transversus abdominis muscle activation through breathing control, in supine lying with feet on bed, as described by Lewit, and instruction for self-therapy (9).
- Core stability training: conscious transversus abdominis muscle activation in supine lying with feet on bed, deep neck flexor activation, shoulder external rotation, then isokinetic abduction and adduction of hip with stabilized trunk, as described by Richardson et.al (17).
- Postural training: Sitting postural exercise, as described by Kendall et.al., and instruction for self-therapy (7).
- Lifting mechanics re-education: Instruction of performance of lifting of objects from ground level, in the principles described by Liebenson (10).

Results: Release occurred in the L_5 segment's left facet, equalizing its mobility with that of the right counterpart. Fascia mobility also increased following the treatment. Muscle tone in the erector spinae improved and approximated equalization bilaterally. Better performance occurred in all of the exercised done, and most markedly the conscious transversus abdominis muscle activation, and subsequent core stability challenges. Lifting from ground level was also performed excellently, with no corrections required from the first attempt.

Session 6 (31/01/2013)

Subjective report: Still reporting no symptoms of pain, or other disturbance, to have occurred in a while, the patient claims to have acquired a feeling of safety and confidence with respect to her low back's functionality. She suggests that there is no reminder of her former condition any more, neither in the form of pain, nor manifested as numbness, feeling of instability or foot "slapping" the ground during gait (dorsal flexor weakness). She claims to be regularly practicing her self-therapy exercises, while encountering no troubles with their performance.

Assessment: No relapse of the facet joint's restriction occurred in the L_5 segment. The fascia of the lumbar region display ever more mobility as the therapy progresses, and the muscle tone of the erector spinae and quadratus lumborum muscles is all but equalized bilaterally. The piriformis muscle still remains in normal tone.

Goals: Mobilization of the fascia of the low back. Traction of the segment with the herniated disc. Core stability improvement. Postural re-education. Lifting mechanics re-education.

Treatment:

- Fascia release of the lumbar region in cranial direction, in prone lying, as described by Lewit.
- Fascia release of the lumbar region in latero-lateral direction ("Saw touch"), in prone lying.
- Post-Isometric lumbar traction into flexion, in prone lying (9).
- Instruction of "small-foot" performance in standing, as described by Janda et.al. in the sensory-motor stimulation concept. Progression into small step forward, step

forward, and step forward on rocker board. Instruction of self-therapy (small-foot, then step forward) (10).

- Transversus abdominis muscle activation through breathing control, in supine lying with feet on bed, as described by Lewit, and instruction for self-therapy.
- Core stability training: conscious transversus abdominis muscle activation in supine lying with feet on bed, deep neck flexor activation, shoulder external rotation, then isokinetic abduction and adduction of hip with stabilized trunk, as described by Richardson et.al (17).
- Core stability training: conscious transversus abdominis muscle activation in supine lying with feet on bed, deep neck flexor activation, shoulder external rotation, then isokinetic flexion and extension of hip and knee with stabilized trunk, as described by Richardson et.al (17).
- Core stability & motor control training: latero-lateral shifting of trunk with ipsilateral knee flexion, while standing on BOSU.
- Core stability & motor control training: Semi-squat (up to 45º) on BOSU.
- Postural training: Standing postural exercise, as described by Kendall et.al., and instruction for self-therapy (7).
- Lifting mechanics re-education: Instruction of performance of lifting of objects from ground level, in the principles described by Liebenson (10). Progression to lifting minor weights (5kg ball).

Results: The fascia of the lumbar region gained further mobility, and the muscle tone of the erector spinae and quadratus lumborum improved towards bilateral symmetry. Good performance was achieved in all the exercises. The standing postural exercise, as described by Kendall et.al., will replace that in sitting in the self-therapy exercises. The isokinetic abduction-adduction and flexion-extension with conscious activation of the transversus abdominis muscle and stabilized trunk were challenging for the patient, but successfully performed, with increased levels of control of core muscles and stability compared to previous sessions.

Session 7 (07/02/2013)

Subjective report: The patient's condition of no pain or numbness and increased functionality persisted throughout the interval between sessions. She stated that she currently feels confident in the performance of the self-therapy exercises, as well as activities that would cause discomfort in the past, such as lifting, prolonged sitting etc. The sensation of ankle dorsal flexion weakness is not present. She suggests that she practices the self-therapy regularly.

Assessment: The thumbs test showed all facets of the lumbar spine to move symmetrically. The piriformis muscle was in good tone, and painless; symmetrical internal rotation was present at the hip joint. The low back fascia displayed a steady increase in mobility. The muscle tone of the lumbar and thoracic spine musculature was all but symmetrical bilaterally, and no pain was manifested during the palpation of any point of the area.

Goals: Mobilization of the fascia of the low back. Traction of the segment with the herniated disc. Core stability improvement. Postural re-education. Lifting mechanics re-education.

Treatment:

- Fascia release of the lumbar region in cranial direction, in prone lying, as described by Lewit.
- Fascia release of the lumbar region in latero-lateral direction ("Saw touch"), in prone lying.
- Post-Isometric lumbar traction into flexion, in prone lying (9).
- Instruction of "small-foot" performance in standing, as described by Janda et.al. in the sensory-motor stimulation concept. Progression into small step forward, step forward, and step forward on wobble board. Instruction of self-therapy (small-foot, then step forward) (10).
- Transversus abdominis muscle activation through breathing control, in supine lying with feet on bed, as described by Lewit, and instruction for self-therapy (9).

- Core stability training: conscious transversus abdominis muscle activation in supine lying with feet on bed, deep neck flexor activation, shoulder external rotation, then isokinetic abduction and adduction of hip with stabilized trunk, as described by Richardson et.al (17).
- Core stability training: conscious transversus abdominis muscle activation in supine lying with feet on bed, deep neck flexor activation, shoulder external rotation, then isokinetic flexion and extension of hip and knee with stabilized trunk, as described by Richardson et.al (17).
- Core stability training: conscious transversus abdominis muscle activation in supine lying with feet on bed, deep neck flexor activation, shoulder external rotation, then isokinetic flexion and extension of both shoulders with stabilized trunk, as described by Richardson et.al (17).
- Core stability & motor control training: latero-lateral shifting of trunk with ipsilateral knee flexion, while standing on BOSU.
- Core stability & motor control training: Semi-squat (up to 45º) on BOSU.
- Postural training: Standing postural exercise, as described by Kendall et.al., and instruction for self-therapy (17).
- Lifting mechanics re-education: Instruction of performance of lifting of objects from ground level, in the principles described by Liebenson (10). Progression to lifting minor weights (5kg ball), then lifting from BOSU (from knee height).

Results: Good fascia mobility seems to be established at the patient's lower back, and the muscle tone of the area appears normalized after the therapy. The execution of the exercises went smoothly, as the difficulty progressed. The control of the transversus abdominis muscle is heightened, and the conscious stabilization of the spine was apparent, in the lifting and SMS procedures, as well as in the supine lying and postural exercises. No pain was provoked at any point during the session.

As the patient was discharged after this session, she was subjected into a more extensive kinesiological evaluation, in order to concretely determine the results of the treatments as a whole.

3.6 Final Kinesiological examination

Static Postural examination

From an anterior view, the patient's posture was manifested with more symmetrical shoulders. The height at which the scapulae were resting was approximating symmetry, with the left still being slightly lower. The magnitude of the rounded shoulders was much less, compared to the situation prior to the treatment sessions.

From a lateral perspective, the patient still seems to adopt a kyphotic-lordotic postural pattern, but the extent of dysfunction appears to have gone down markedly. The head-forward position and the anterversion of the pelvis, more than anything else, have seceded to a high degree, as has the plantar flexion of the ankles. Reduction of the formerly increased thoracic kyphosis has also occurred.

The head rotation to the left is still present, but not as markedly as before, as seen from a posterior perspective. From the same angle, the thoraco-brachial space on the right side has approximated the left. The gluts and hips appear symmetrical.

Dynamic Postural examination

When performing forward flexion, the patient suggested no pain, fixed at the lower back or irradiating to the lower extremity, to occur at any point. Some prominence of the lumbar erector spinae was present, but there was an apparently more fluent curve formed throughout the spinal sectors. The patient could easily touch the floor with her fingers.

During extension, the movement occurred primarily in the thoraco-lumbar and lumbar spine, with the thorax more cranially moving to a flat position, rather than extension. No pain was present. Gains in range of motion were noted..

When lateral flexion was done, there was no restriction present (distance: 23cm bilaterally) and symmetrical spinal curvature in both movements. No pain was manifested by the movement in either direction.

Gait examination

Somewhat abrupt initial contact was still performed by the patient bilaterally, but not in as dramatic a manner as before the treatments. The loading wave of the foot was good, and the step length was symmetrical. The upper extremity synkinesis was improved in bilateral symmetry, while the left arm was still moving more markedly. The postural pattern assumed during gait matched the newly described in the latter postural examination. Tiptoe gait was possible with no problem, as was squat and heel gait. No hip disturbances or other symptoms occurred during gait.

Inspection

Normal skin color is seen on the patient. The formerly apparent erector spinae prominence is not present. Physiological spinal curves are seen in supine position. There is symmetry in the volume and shape of the lower extremities.

Muscle length testing

No change in hip flexor length has occurred, in relation to that found in the initial examination. The gastrocnemius and soleus muscles were found moderately short (grade 1) symmetrically.

Muscle strength testing (according to Kendall et.al., grading scale 0-5)

The tibialis anterior and extensor hallucis longus muscles, showing a grade 5 strength previously but less maximal force compared to the healthy extremity, were found bilaterally symmetrical in strength, signifying a significant increase in maximal strength of the affected extremity.

Palpation

Mild restriction of the fascia of the low back was persisting, at the region between L_1 and L_4, in cranial direction. Kibler fold was markedly easier to perform, while some limitation in mobility was still present. The erector spinae from the mid-thoracic spine to the thoracolumbar junction had all but normalized in tone. The bilateral symmetry of the erector spinae has also been restored for the most part; if anything, the left side of the thoracolumbar junction might be slightly hypertonic still. The quadratus lumborum and piriformis muscles were normal.

Joint Play examination

All movements of the lumbar spine were free in all segments. The springing of the formerly restricted lumbar vertebrae was also restored.

Specific tests

The Lasegue and Vele tests were negative. The 3rd level of Rhomberg test was now negative. Thumbs test showed fluent facet joint movement in all of the lumbar and lower thoracic spine.

Movement pattern evaluation

When hip extension was re-evaluated, the erector spinae showed fewer tendencies to over activate, and this time the contralateral erector spinae were activated concurrently with the gluteus maximus. Onward, the hamstrings and ipsilateral erector spinae followed in participation, and eventually the thoracolumbar erector spinae- contralaterally first, and ipsilaterally eventually. Increased stability was apparent in the execution of movement, and the aesthetic result of the motion would definitely be considered improved.

The trunk flexion pattern displayed a more dramatic improvement. The movement was initiated through the abdominal muscles, and the involvement of the hip flexors occurred at about 35-40º of movement this time round; very slight elevation of the lower extremities from the table occurred, however. Trunk flexion was maintained throughout the movement. Rising to the sitting position was now possible with no significant difficulty.

Overall therapy effect

Item tested	Initial examination	Final examination
Gastrocnemius & Soleus muscle length	Bilateral shortness, grade 2	Bilateral shortness, grade 1
Tibialis anterior & Extensor hallucis longus muscle strength	Bilateral grade 5, maximal strength less on the left side	Bilateral grade 5, maximal strength symmetrical
Rhomberg test	Rhomberg 3 positive	Negative
Active trunk flexion	Painful at posterolateral left leg, 10cm fingers distance from floor. Restricted lumbar mobility.	Painless, floor touched with fingers. Lumbar mobility improved, curve more fluent.
Active trunk extension	Movement almost entirely in Th-L junction. Adequate ROM available.	Majority of movement in Th-L and L spine. Some mobility of the thorax was noted. ROM increased.
Active trunk lateral flexion	Left: 17cm Right: 18cm	Left: 23cm Right: 23cm
Gait	Abrupt initial contact. Only left upper extremity synkinesis present. Heel gait impossible and painful.	Improved initial contact (still suboptimal). Symmetrical upper extremity synkinesis. Heel gait possible and painless
Posture	Markedly kyphotic-lordotic pattern. Obviously rounded shoulders, left internally rotated and scapula more depressed. Head forward and rotated to the left. Thoracic kyphosis. Anterior pelvic tilt. Ankle plantar flexion. Left glutei lower, left hip external rotation. Thoraco-brachial space enlarged on the right.	Not as dramatic kyphotic-lordotic pattern. Less rounded shoulders, more symmetrical height (left still lower). Head less forward and rotated. Less anterior pelvic tilt and plantar flexion of ankle. Reduced kyphosis of thoracic spine. Symmetrical hips and glutei. Symmetry of thoraco-brachial space bilaterally was approximated.

Table 1: Overall effect of therapy, as illustrated by the examination findings before and after the treatment sessions.

Inspection	Marked erector spinae prominence, from mid-thoracic to Th-L level.	Prominence absent
Palpation	Dramatic restriction of low back fascia (Th-L to L-S junctions) in cranial and latero-lateral direction- Kibler fold impossible. Erector spinae hypertone (more to right in mid-thoracic level, more to left caudally up to L_1- L_2). Marked hypertone of left piriformis and quadratus lumborum muscles.	Mild fascia restriction in cranial direction around the L_4 level- Kibler fold performed easily, some limitation still present. Very small residual hypertone of the erector spinae found, and bilateral symmetry was approximated to a high degree. Quadratus lumborum and piriformis muscles were found in eutone.
Joint play	Springing restriction of the L_2 and L_3 vertebrae. Lateral flexion restriction in the L_5 segment, as well as flexion slightly	All restrictions abolished
Hip extension pattern	Bilateral lumbar erector spinae (more contralaterally)- hamstrings and gluteus maximus- contralateral Th-L erector spinae- Ipsilateral Th-L erector spinae activation pattern.	Gluteus maximus and contralateral lumbar erector spinae- hamstrings and ipsilateral lumbar erector spinae- contralateral Th-L erector spinae- Ipsilateral Th-L erector spinae activation pattern. Increased fluency and stability.
Trunk flexion pattern	Initiated at abdominal muscles. Marked hip flexor activation at 20° of movement. Lower extremity elevation. Rising to sitting impossible.	Initiated at abdominal muscles. Moderate hip flexor activation at 35°-40° of movement. Very slight elevation of lower extremities occurred. Rising to sitting possible.

Table 1 (continued): Overall effect of therapy, as illustrated by the examination findings before and after the treatment sessions.

Conclusion of final examination

At the point of discharge, the patient has displayed improvement in objective as well as subjective factors characteristic of her former condition.

Specifically, the trunk mobility, expressed in measurable range of movement in flexion, extension and lateral flexion, has increased, but also approximated bilateral symmetry. The fluency of movement transition among different segments has also improved. Additionally, the muscle tone around the trunk and hip has improved markedly, as has the possibility of execution of movements like heel gait (which was impossible prior to the treatment), trunk flexion and hip extension. All of the above depict an increased level of balance between tonic and phasic, as well as bilateral, muscle tone, to have been achieved.

The aforementioned muscle tone control, in combination with the improvement of the fascia mobility of the low back and increased core stability, have brought about the alleviation of the patient. From a very early stage in the therapy, pain and radicular symptoms showed an excellent response to the combination of techniques applied. Hip, lower extremity and low back disturbance have disappeared, segmental movement in the lumbar spine has been restored and posture has also shown improvement.

Finally, and perhaps most importantly, significant increase has occurred in the performance and understanding of the correct mechanics of lifting and posture. The integration of core stability and limb movement, which requires not only deep musculature activity, but also spatial orientation and understanding of one's own body, has increased dramatically on this patient.

4 Conclusion

Evaluating the therapeutic approach as a whole (including the electrotherapy and McKenzie method applications) in retrospect, it can be said that there was a successful attempt to consciously address the issues that the patient was facing (pain, soft tissue restrictions, joint dysfunctions, faulty movement stereotypes), in both analytical and integrative manners, where applicable, to the best of my ability.

All techniques were well-tolerated by the patient, and in fact no discomfort was provoked during any activity (non-examination-related) throughout the entire time available with her. The soft tissue techniques, and specifically the fascia mobilizations of the low back, along with the post-isometric lumbar traction into flexion, were those that were the most enjoyably received for the patient. In my opinion, however, the most important parameters for the long-term management of the patient's condition were those exercises that facilitate deep stabilization and good posture in various movements, and especially with regards to lifting mechanics. It is the prompt success of the transversus abdominis muscle activation, as well as lifting mechanics and postural correction, that make me optimistic for the eventual therapeutic outcome.

It can be argued that there are many alternative approaches to the management of the condition discussed in this paper. For instance, one could apply techniques grounded on the PNF or Vojta's concepts to facilitate more optimal abdominal musculature activation patterns, or follow different author's approaches in muscular relaxation or joint mobilization. A significant factor in deciding which available method to apply was my familiarity with them, both in a personal and academic context. Also, therapeutic approaches that are, more or less, "hernia-specific", such as the McKenzie extension performance or lumbar traction, were included in the applied treatment repertoire, and I believe that being concerned with whether to apply, for instance, lumbar traction as described by one author over the other is a secondary concern. Finally, an important parameter leading me away from changing my therapeutic approach with respect to specific techniques was the immediate effect that the aforementioned techniques had as they were being applied.

Summary

Overall, I am satisfied with the progress of the patient's condition through the past 7 physiotherapeutic sessions. She is pain-free, functional and safe when participating in her activities of daily living. However, the nature of the condition is degenerative, and it is mostly up to her to continue practicing the self- therapy exercises in order to achieve an optimal postural pattern and core stability standard, if she is to sustain her back's newly acquired condition.

I was pleased to see the theoretical knowledge I have acquired in practice, working to benefit a real patient. Moreover, I was happy to have a chance to prove to myself, and my patient, that I can participate and make a difference within a rehabilitation endeavor as a professional of physiotherapy, the the context of which appears to be a cornerstone in pain management and social reintegration of many patients.

I would also like to extend my gratitude to my patient, who gave me a sincere opportunity to win her trust as a healthcare professional, and did not merely see me as a student. Her belief and appreciation of my work functioned as a huge motivational force for my bachelor praxis, and her positive outlook of the fact that an intern student would work with her is what made this whole procedure so positive and rewarding. One could not have asked for a better case study patient.

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6 Attachments

INFORMOVANÝ SOUHLAS

V souladu se Zákonem o péci o zdraví lidu (§ 23 odst. 2 zákonac.20/1966Sb.) a Úmluvou o lidských právech a biomedicíne c. 96/2001, Vás žádám o souhlas
k vyšetrení a následné terapii. Dále Vás žádám o souhlas k nahlížení doVaší dokumentace osobou získávající zpusobilost k výkonu zdravotnického povolání v rámci
praktické výuky a s uverejnením výsledku terapie v rámci bakalárské práce na FTVS UK. Osobní data v této studii nebudou uvedena.

Dnešního dne jsem byla odborným pracovníkem poucena o plánovaném vyšetrení a následné terapii. Prohlašuji a svým dále uvedeným vlastnorucním podpisem potvrzuji, že odborný pracovník, který mi poskytl poucení, mi osobne vysvetlil vše, co je obsahem tohoto písemného informovaného souhlasu, a mela jsem možnost klást mu otázky, na které mi rádne odpovedel. Prohlašuji, že jsem shora uvedenému poucení plne porozumela a výslovne souhlasím s provedením vyšetrení a následnou terapií. Souhlasím s nahlížením níže jmenované osoby do mé dokumentace a s uverejnením výsledku terapie v rámci studie.

Datum:...

Osoba, která provedla poucení:...

Podpis osoby, která provedla poucení:.......................................

Vlastnorucní podpis pacienta /tky:.......................................

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Application for Ethics Board Review

of the undergraduate research, involving human subjects

Project title: Case study of a patient with the diagnosis of Intervertebral Disc Herniation with Radiculopathy.

Nature of the research project: Bachelor Thesis

Author (chief investigator): Nikolaos Rogdakis

Supervisor (in case of student research): PhDr. Tereza Novakova, PhD.

Research project description: Case study of a patient with the diagnosis of Herniation of the L_5 Intervertebral Disc with radiculopathy will be conducted under the expert supervision of an experienced physiotherapist at ústřední vojenská nemocnice.
Guaranteed safety to be judged by experts: No invasive methods will be used.
Ethical aspects of the research: Personal data obtained during the investigation will not be published.
Informed consent (attached)

Date: 24. 1. 2013

Author's signature:

Faculty of Physical Education and Sport, Charles University in Prague
ETHICS BOARD REVIEW

Ethics Board members: Doc. MUDr. Staša Bartůňková, CSc.
Prof. Ing. Václav Bunc, CSc.
Prof. PhDr. Pavel Slepička, DrSc.
Doc. MUDr. Jan Heller, CSc.

The Ethics Board at the Faculty of Physical Education and Sport, Charles University, approved the research project.

Approval number: 046/2013

Date: 29. 1. 2013

The Ethics Board at the Faculty of Physical Education and Sport, Charles University, reviewed the submitted research project and **found no contradictions with valid principles**, regulations and international guidelines for biomedical research involving human subjects.

The chief investigator of the project met the necessary requirements for receiving the Ethics Board approval.

Official school stamp

Signature, REB Chairman

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