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MAINTAINING BACK FITNESS WITH CORE EXERCISES:  
MULTIMEDIA CD-ROM

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## MAINTAINING BACK FITNESS WITH CORE EXERCISES: MULTIMEDIA CD-ROM

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High level evidence has been presented from effectiveness of therapeutic exercise as a treatment to low back disorders. Studies have also shown that video material motivates patients and increases the learning outcome more than static illustration. This leads to better end results in therapy. The purpose of this thesis was to produce a web browser based multimedia CD-ROM for the use of health care professionals, patients and athletic trainers

Information was gathered from recent professional literature and articles. From this information most essential stabilizing exercises for lumbar spine stability were chosen. Exercises were piloted with semi-professional athletes and were divided to four difficulty categories according to feedback received. Exercises were filmed, edited and constructed to internet web page form. Completed product was piloted with professional.

CD-ROM includes up-to-date information of utilizing stabilizing therapeutic exercises as a therapy implementation with people suffering from low back pain. CD-ROM presents general written information about low back disorders and stability, basic anatomy affecting stability and basic concept of therapeutic exercises. Exercises are presented in Flash video format. This form of multimedia material is user friendly, motivating and economical.

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## 1 INTRODUCTION

Low back disorders are one of the most common reasons for sick leaves in Finland. Obesity and sedentary- or highly loading work are excellent examples of factors predisposing to low back disorders. Even though the numbers have decreased during the last twenty years, 29 380 people were getting disability pension, due to low back disorders, at the end of year 2005. Terveys-2000 research revealed that 10% of male and 11% of female suffer from chronic low back pain. However, there is consistent high, A- level evidence of correctly implemented therapeutic exercise having a positive effect on treating chronic low back disorders. (Suomalainen Lääkärisseura Duodecim, 2007, 11.) Therapeutic exercise has been commonly used term and can be described as systematic, pre-planned exercises intended to reduce and prevent physical impairments and to promote, maintain and restore physical capacity (Kisner & Colby, 2007, 2). Exercises can be comprehensive or very specific. Other terms used in the literature from this form of exercising are for example, medical exercise therapy, physical training, stabilization exercise and physical activity. Term, therapeutic exercise will be used in this context throughout this thesis.

In order to make therapy effective exercises have to be implemented correctly and regularly according to physiotherapists' instructions. Utilization of video material assists remembering the correct way of performing the exercises. Compared to illustration and text, video has been noted to be more efficient way of learning the exercises (Weeks et al., 2002, 72-73). Utilizing of video material has been noticed to increase motivation and facilitate learning process as well (Weeks et al., 2002, 72-73; Miller, Stanley & Moore, 2004, 145-154). Optimizing the learning effects and initiation of self-treatment therapy may be considered have a positive effect on financial aspects of health care as well.

Product of this thesis is electronic multimedia CD-Rom of therapeutic exercises for lumbar spine stabilization. Information in the CD-Rom is up to date and accordant with latest research. It promotes active learning process and provides possibility for individual improvements. It provides feasible and economical way of implementing therapy in modern health care environment.

## 2 PURPOSE AND AIM OF THE STUDY

The aim of the thesis is to provide audiovisual CD-ROM for stabilizing exercises of the low back. Audiovisual material is going to include exercises of different difficulty levels. This material can be used by patients to maximize the learning potential, by professionals to refresh their memories or by anyone who is interested about the exercises to stabilize the low back.

## 3 ANATOMY AND BIOMECHANICS OF THE LOW BACK

Spine is described as complex, multisegmental structure. It has numerous essential functions such as protection, weight bearing and movement of human body (Moore & Petty, 2005, 208). It also functions as a linkage between upper and lower extremities (Hall, 2007, 278). It is a structure consisting of seven cervical vertebrae, twelve thoracic vertebrae and five lumbar vertebrae with intervertebral discs between each segment (Koistinen, 2005, 39).

### 3.1 Anatomy

Body of the vertebrae is a round drum of cancellous bone with trabeculae bounded with cortical bone. Trabecula acts as a support, strengthening the weight bearing ability of the vertebra. Vertebral bodies of the lumbar spine are largest in size, this appears to be related to the high weight bearing demands of the lower region vertebrae. (Moore & Petty, 2005, 209-210.) Intervertebral disc is comprised from three parts; endplate, nucleus pulposus and annulus fibrosus. Endplate is located between the disc and vertebral body. It permits the water and nutrients to pass between disc and cancellous bone of the vertebra. Nucleus pulposus consists of proteoglycan gel. It forms up to 40-60% of the disc. Gel has a high water absorbing ability. Water provides hydrostatic pressure inside disc and pressure provides tension of the annulus fibrosus which aids to separation of vertebral bodies. Annulus fibrosus is a circle shaped, collagen fiber structure, surrounding the nucleus pulposus. It is preventing proteoglycan gel from leaking out. (Moore & Petty, 2005, 210-211.)

Intertransversarii muscle is divided in lateralis and medialis part. Medialis part is considered to be more influential in lumbar spine stability. Muscle originates from an accessory process, mamillary process and mamillo-accessory ligament, which lies between these two processes. Insertion is located in mamillary process of vertebrae below the origin. (Bogduk, 2005, 98-101.) Rotatores originates from transverse process of the vertebrae and attach to spinous process above the origin. Other insertion point is the junction between lamina and transverse process of origin. (Agur & Dalley, 2009, 329.) Multifidus muscle is considered to be very significant stabilizing muscle. Its deep attachments are inferior borders of lamina, mamillary processes and facet joint capsules. Superficially it attaches to spinous processes. (DeRosa & Porterfield, 2007, 52) It expands from sacrum to L1 level (Bogduk, 2005, p. 101).

Erector spinae muscle is consisted of two different muscles, iliocostal lumborum and longissimus thoracis. Superficial part iliocostalis and longissimus attaches up to thoracic spine and deep part of these muscles are attached to lumbar spine area. (DeRosa & Porterfield, 2007, 51; Bogduk, 2005, 103.) Since the length and location of these two muscles they are divided in four parts. Iliocostalis lumborum is divided as iliocostalis lumborum pars lumborum and pars thoracis where as longissimus thoracis is divided in same manner as longissimus thoracis pars lumborum and pars thoracis. (McGill, 2007, 51; Bogduk, 2005, 103.) The lumbar part of both muscles originate from transverse processes, mamillary and accessory of the vertebrae towards the posterior side of sacrum and medial part of iliac crest (McGill, 2007, p.51). Quadratus lumborum originates from anterior surfaces of L1 to L4 transverse processes and expands to ilium and 12<sup>th</sup> rib. It is wide, rectangular shaped muscle that covers major part of lateral side. (Bogduk, 2005, 99.)

External- and internal oblique muscles are often discussed transverse abdominis muscle. These muscles are attached posteriorly to the lateral raphe of the thoracolumbar fascia. (DeRosa & Porterfield, 2007, 50.) and anteriorly to abdominal fascia (McGill, 2007, 59). Rectus abdominis lies within rectus sheath which is attached to the oblique abdominal muscles (DeRosa & Porterfield, 2007, 56-57; McGill, 2007, 56). Psoas major emerges segmentally from the anteromedial side of the lumbar vertebrae and it attaches to the lesser trochanter of the femur (Gibbons, 2007, 96). Latissimus dorsi is considered to be major stabilizer muscle during pulling and lifting

movements. It expands from spinous processes of lumbar spine and continues through lumbodorsal fascia to its insertion at humerus. (McGill, 2007, 54; Willard, 2007, 23-24.) Gluteus maximus is considered to contribute to lumbar stability because its linkage to latissimus dorsi. It links to latissimus dorsi, contralaterally, via thoracolumbar fascia. (DeRosa & Porterfield, 2007, 49.)

Thoracolumbar fascia, also known as lumbodorsal fascia is divided to three layers. The thin anterior layer is originated from the fascia of quadratus lumborum and it is adhering to medial part of transvers processes. (Bogduk, 2005, 110.) The middle layer is located behind the quadratus lumborum, originating from medial part of transverse processes of the lumbar spine. Lateral part is considered to be continuation of aponeurosis of transverses abdominis. The concept of and function of middle layer is still under debate. (Bogduk, 2005, 110.) The posterior layer arises from the spinous processes of the lumbar spine, fusing with middle layer of the thoracolumbar fascia and extending to the lateral border of the iliocostalis lumborum, thus covering the back muscles. Fusion of the layers creates a fairly thick seam which is identified as "lateral raphe". (Bogduk, 2005, 110.)

Posterior layer consists of superficial- and deep lamina (Bogduk, 2005, 111). It is suggested that superficial lamina is continuation to aponeurosis of latissimus dorsi muscle (Vleeming & Stoeckart, 2007, 121; Bogduk, 2005, 111), however it is proposed that it functions also as continuation of aponeurosis in gluteus maximus and a part of external oblique muscles (Vleeming & Stoeckart, 2007, 121). Superficial lamina attaches to supraspinosus ligament and spinous processes above L4 level. Below L4- L5 the lamina crosses the midline and attaches contralaterally to sacrum, iliac crest and posterior superior iliac spine with some fibers blending in to lateral raphe. (Vleeming & Stoeckart, 2007, 121.) Deep lamina originates mainly from the spinous processes and attaches to posterior superior iliac spine, lateral part of erector spinae and blend with lateral raphe (Bogduk, 2005, 111). Some authors suggest that part of the laminae originates from interspinosus ligaments and attaches to iliac crest and lateral raphe (Vleeming & Stoeckart, 2007, 122). Posterior layer of thoracolumbar fascia covers and sheaths the back muscles at the lumbar spine area (Vleeming & Stoeckart, 2007, 121; Bogduk, 2005, 111). Because the several muscle attachments and superficial location, thoracolumbar fascia may play an important role

in spine stabilisation (Vleeming & Stoeckart, 2007, 124). The force produced by attached muscles can provide self-bracing of the lumbar spine through thoracolumbar fascia. Since the deep lamina thoracolumbar fascia covers the erector spinae and multifidus muscle, it is also proposed that activating and increasing cross sectional area of these muscles increase the tension to the thoracolumbar fascia, which provides traction to the fascia and stabilizes the lumbar spine. (Vleeming & Stoeckart, 2007, 123.) In addition to erector spinae and multifidus muscles, latissimus dorsi and gluteus maximus play an important role in the stabilization (Vleeming & Stoeckart, 2007, 123). Abdominal fascial system integrates to the facial network and external- and internal obliques as well as transversus abdominis, through the aponeurosis of these muscles. It also encases the rectus abdominis muscle with a muscle sheath. (McGill, 2007, 56; DeRosa & Porterfield, 2007, 55-56.) It is suggested that abdominal fascia transfers force to the lumbar spine through the connection to the thoracolumbar fascia (McGill, 2007, 56- 59; DeRosa & Porterfield, 2007, 55).

Anterior longitudinal ligament is a band like ligament, which extends anteriorly from the sacrum to the base of the occiput covering the length of the whole spine. It attaches to the periosteum of the vertebrae and to annulus fibrosus of the intervertebral disc. (Willard, 2007, 12-13; Bogduk, 2005, 40-41.) Function of the anterior longitudinal ligament is to prevent the spine from excessive extension (McGill, 2007, 63). Anterior longitudinal ligament loses its elastic and energy-absorbing attributes during a lifetime (Willard, 2007, 12- 13).

Posterior longitudinal ligament is a band like ligament, which extends posteriorly from the base of the occiput to the sacrum. It attaches to the periosteum of the vertebrae and it expands laterally to the annulus fibrosus of the intervertebral discs which give it its saw-like look. (Willard, 2007, 13-15; Bogduk, 2005, 41.) Function of the posterior longitudinal ligament is to prevent the spine from excessive flexion and separation of the posterior ends of the vertebral bodies (McGill, 2007, 63; Bogduk, 2005, 41).

Ligamentum flavum is consisted of 80% of elastin and 20% of collagen providing its elastic capacity (McGill, 2007, 63; Willard, 2007, 6-7; Bogduk, 2005, 42). It is attached between the lower- and upper laminae of consecutive vertebrae (Willard,



2007, 6-7; Bogduk, 2005, 42). Function of ligamentum flavum is considered to form significant portion of the roof of the spinal canal (Willard, 2007, 6-7). Since its elastic properties, ligamentum flavum is also proposed to prevent buckling under the stress of flexion movements (McGill, 2007, 63; Willard, 2007, 6-7).

Interspinous ligaments are located between the consecutive spinous processes. It comprises of three parts, ventral, middle and dorsal (Bogduk, 2005, 43). It spreads from posterior part of the ridge of the lower spinous anteriorly towards the bottom of upper spinous (Willard, 2007, 7-8; Bogduk, 2005, 43). This arrangement of fibers gives interspinous ligaments fan-like appearance. Interspinous ligament is attached anteriorly to ligamentum flavum and acts as a continuation of this ligament. Posteriorly interspinous ligament attaches to the supraspinous ligament and blend in to it. (Willard, 2007, 7-8.) Function of the interspinous ligament is under discussion. It is suggested that ligament acts as resistance towards forward flexion. (Bogduk, 2005, 43.) However, some authors propose that during forward flexion of the spine, interspinous ligament provides force transmission from thoracolumbar fascia through supraspinous ligament and interspinous ligament to ligamentum flavum, increasing its tension (Willard, 2007, 7-8).

Supraspinous ligament is located posteriorly to the spinous processes, advancing vertically and covering the tips of the spinous processes between consecutive vertebrae (McGill, 2007, 64; Willard, 2007, 8; Bogduk, 2005, 43-44). It extends to L4 in 73% of individuals and is generally missing in L5-S1 (Bogduk, 2005, 44). It is suggested that supraspinous ligament is part of interspinous-supraspinous thoracolumbar ligamentous complex. This complex transmits tension from extremities through thoracolumbar fascia to lumbar vertebral column. (Willard, 2007, 8-9.)

### 3.2 Biomechanics

Hip is the base and control point of basic movement, where lumbar spine functions as lever arm. Function of the hip directs the movement through the lower segments of the lumbar spine towards higher segments and the thoracic- and cervical spine. (Koistinen, 2005, 191.) Spine has curvature features when observing it from sagittal

plane. Thoracic and sacral curves are concave anteriorly where as cervical and lumbar curves are concave posteriorly. Between the ages of 7 and 17 the curvature of lumbar spine can increase approximately 10%. Curvature of the spine allows spine to withstand more load than straight spine. (Hall, 2007, 285.) Six directions of vertebral movement occur in each motion segment. Directions are sagittal rotation and translation, coronal rotation and translation, horizontal rotation and translation. Primary idea of translation is that entire vertebra is shifting to same direction for equal amount. However, rotation is described as entire vertebra moving to same direction but different amount around the fixed point, known as centre of rotation. (Bogduk, 2005, 63.)

Flexion is described as anterior sagittal rotation and translation where as extension as posterior sagittal rotation and translation. Flexion is considered to be the freest movement of the lumbar spine producing up to 10° of anterior sagittal rotation with 2mm of anterior translation per segment. (Moore & Petty, 2005, 223.) Amount of lateral flexion in lumbar spine is approximately 6° and amount of rotation is approximately 2°. Small rotational range of motion is consequence from interlocking properties of articular processes of lumbar vertebrae. (Hall, 2007, 288-289.)

Body weight, tension of muscles and surrounding ligaments, intraabdominal pressure, and external loads are main forces acting on spine. In upright position all of the previous forces contribute to spinal compression. Total-body center of gravity is located anteriorly to spinal column, when standing erect. This contributes to constant forward-bending moment. Forward-bending moment is counteracted by tensing the back extensor muscles. Flexing the trunk increases the torque to lumbar spine, which in turn, contributes to increase in tension of back extensor muscles. (Hall, 2007, 296-297.)

Lumbopelvic rhythm signifies combined movement relations of back, pelvis and lower extremities during the movement pattern. Generally correct progression lumbopelvic rhythm has been described in a flexion of the spine, however it can be applied in all the non-synchronous movements in lumbopelvic area. (Koistinen, 2005, 221.) Wingerden, Vleeming, Kleinrensink and Stoekart (1997) suggest that low back pain alters the lumbopelvic rhythm and normalizing the rhythm could be beneficial

when treating low back pain disorders (Wingerden et al., 1997, 209). Descarreux, Lafond and Cantin (2010) found out similar results. In the research it was suggested that fatigue of erector spinae and hip extensors may alter the lumbopelvic rhythm temporarily. (Descarreux et al, 2010, 1-7)

#### 4 STABILITY

Stability is considered to be co-operation of three different subsystems (Figure 1.). Fundamental passive stability is provided by spinal column, dynamic stability is provided by spinal muscles surrounding the spinal column, evaluation of stability requirements and muscle response is provided by neural components. (Panjabi, 2003, 372; Hodges, 2004, 15.) Dysfunction of one or more of these systems may result to the functional limitation or impairment (Kisner & Colby, 2007, 3).

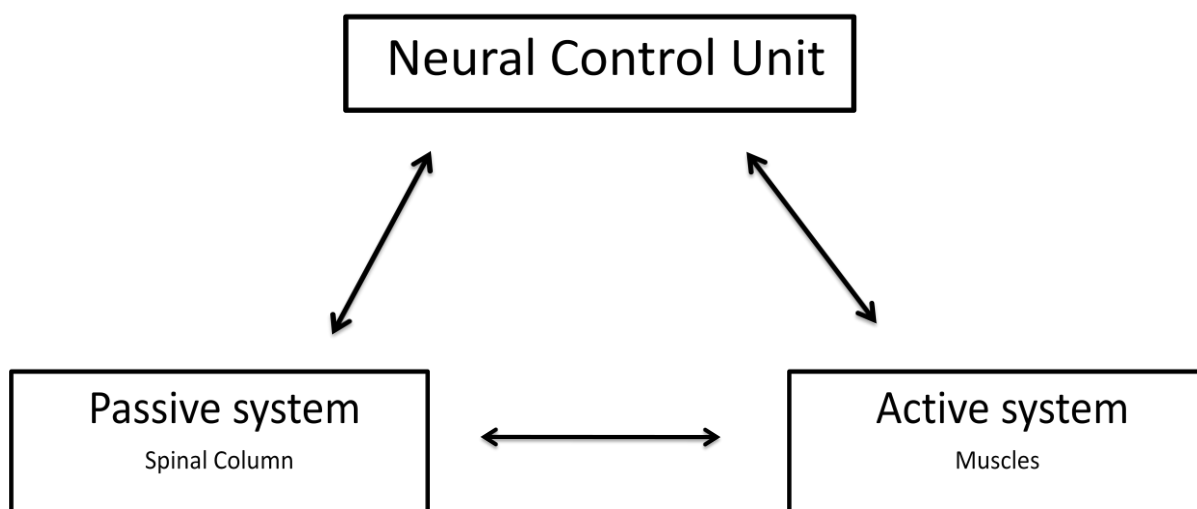


Figure 1: Three subsystems of stability. Modified from Magee, 2007, 392; Hodges, 2004, 16; Panjabi, 2003, 373

#### 4.1 Passive stability

Passive stability is provided by spinal column components such as disks, ligaments and facets (Panjabi, 2003, 372). Passive stability refers to capacity of the spine to withstand the forces of loading (McGill, 2007, 113; Panjabi, 2003, 371). Passive stability can be illustrated with “ball-in-a-bowl” analogy (Figure 2.). Width of the bowl describes the range of motion of the spine and bottom of the bowl describes neutral zone. (McGill, 2007, 114-115; Panjabi, 2003, 373.) Inclination of the sides of the bowl represents joint stiffness (McGill, 2007, 114-115) or spinal stability (Panjabi, 2003, 373). When ball is placed on a bowl it can move without much effort at the bottom of it. This area is called “neutral zone”. In spine neutral zone refers to neutral position of the spine and possible joint laxity. Ball doesn’t need much energy to move around neutral zone, but it requires more effort to climb up the walls of the bowl. Ball rolling out of the bowl indicates displacement or injury of the spine. (McGill, 2007, 114-115; Panjabi, 2003, 373.) It has been measured that osteoligamentous structures of lumbar spine can withstand approximately 90 N of force without buckling (Hodges, 2004, 14). Greater the inclination of the walls and smaller the bottom of the bowl more effort is needed for the ball to roll out of the bowl, hence describing appropriate stability of the spine (McGill, 2007, 114-115; Panjabi, 2003, 373).

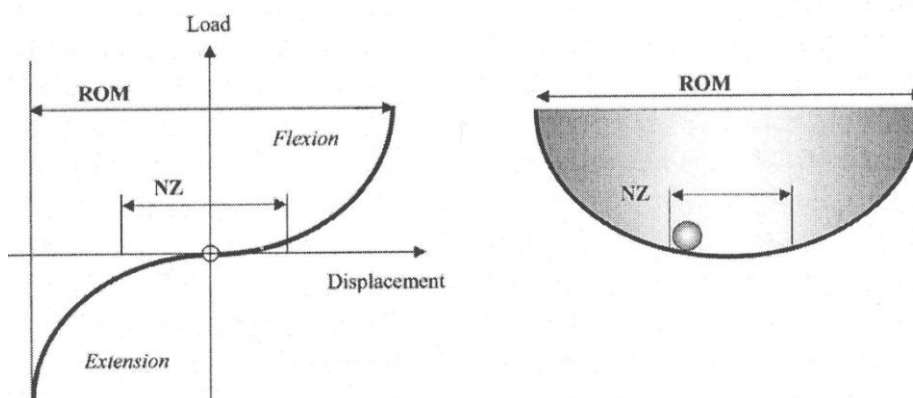


Figure 2. “Ball-in-a-bowl” (Panjabi, 2003, 373)

One factor contributing to passive stability is form closure. When shape of the adjoining articular surfaces is compatible with each other, form closure is achieved. (Koistinen, 2005, 26.) Amount of form closure varies between all joints. When loads

are increased, anatomy of individuals joint will dictate how much added muscle force is needed to stabilize the joint (Lee & Vleeming, 2007, 623).

#### 4.2 Dynamic stability

Dynamic stability plays a significant role in lumbar spine stability. Unstable column can be restabilized to withstand higher loads by supporting it with guy wires. Spinal muscles can be considered as “guy wires” when discussing about spinal stability. (Hodges & Cholewicki, 2007, 489-490; McGill, 2007, 114; Panjabi, 2003, 376.) Measurements reveal that with appropriate dynamic stability and muscle strength spine can withstand loads as high as 1500 N (Panjabi, 2003, 376). If adjoining articular surfaces are poorly compatible, force closure is necessary. Stability can be achieved by external muscle force, which compresses the parts together. (Koistinen, 2005, 27.)

Functional muscle classification is often used to differentiate between varying functions of the muscles contributing to dynamic stability. The first classification of muscle functions is Rood's concept, which divides the muscles in to stabilizing and mobilizing muscles. Stabilizing muscles have postural holding function and eccentric muscle function to decelerate and resist momentum. They have mono- articular segmental attachments. Mobilizing muscles produce movement and acceleration of body segments. They have multi- articular orientation but they lack attachments in every segment between origin and insertion. (Comerford & Mottram, 2001, 16; Gibbons & Comerford, 2001, 24.) Bergmark introduces the concept of local and global stability muscles. Local system consists of deep muscles which are linked to lumbar vertebrae. Role of this system is to provide dynamic stability to the lumbar spine. Global system includes more superficial muscles which are involved in moving the spine and transferring loads between thoracic cage and the pelvis. (Comerford & Mottram, 2001, 16; Richardson, Gwendolen, Hodges, & Hides, 1999, 14.)

Based on these two concepts Comerford and Mottram (2001, 23) are suggesting a new combined approach. Their concept includes local stability muscles, global stability muscles and global mobility muscles (Figure 3.). Function of the local stabilizer muscles is to control the segmental motion and withhold the neutral joint position by increasing muscle stiffness of the local stabilizing muscles. Global stabilizers control the range of motion of the lumbar spine and decelerate the momentum when spine is under low loads. Global mobilizers provide range of motion to the spine and functions partly as a shock absorber. (Comerford & Mottram, 2001, 22.)

Local stabilizer muscles	Global stabilizer muscles
•Multifidus	•Erector spinae
•Rotatores	•Transversus abdominis
•Intertransversarii	•Quadratus lumborum
	Global mobilizers
	•Rectus Abdominis
	•Internal- and external obliques
	•Psoas
	•Latissimus
	•Gluteus Maximus

Figure 3: Muscles of functional muscle classification. Modified from: (Magee, 2007, 395; Comerford & Mottram, 2001, 16)

As a result from the spinosus process attachments, the superficial part of the multifidus produces small amount of extension force (McGill, 2007, 52; DeRosa & Porterfield, 2007, 52). It is also suggested that since the close connection to the spine its main function is ability for corrections and support (McGill, 2007, 52). This is supported by the fact that the muscle contraction of multifidus and erector spinae increases tension to the thoracolumbar fascia, thus providing stability to the spine. It is also noted that people with low back problems, atrophy of multifidus is evident. (DeRosa & Porterfield, 2007, 52.) Role of intertransversarii in stabilization process is

under discussion. Due to its small bulk, it is suggested that muscle acts as “fine tune” of stability process. Alternative, and more specious, suggestion is that due to its close proximity to lumbar vertebral column intertransversarii acts as a proprioceptive transducer. (Bogduk, 2005, 101.) Rotatores provide stability to the vertebrae and assist with local extension and rotary movements (Agur & Dalley, 2009, 329).

As global stabilizer muscles the direction of force produced by erector spinae muscles is directed more posterior-anterior way oblique to the compressive axis of the spine (McGill, 2007, 51-52; DeRosa & Porterfield, 2007, 51). Transversus Abdomini has been suggested to have two different functions, increase of tension to thoracolumbar fascia (DeRosa & Porterfield, 2007, 50; Richardson, 1999, 33) and increase in intra-abdominal pressure (McGill, 2007, 59 DeRosa & Porterfield, 2007, 60; Richardson, 1999, 33). Many authors consider transverses abdominis to be key stabilizer in lumbar spine stability DeRosa & Porterfield, 2007, 59; Gibbons & Comerford, 2001, 25). However, some authors also suggest the opposite, that transversus abdominis doesn't play as significant role as thought (McGill, 2007, 59; Richardson, 1999, 38-39). Due to its attachment points to the lumbar vertebrae quadratus lumborum is reckoned to be stabilizer muscle. Contraction of the muscle does not provide any movement, but contraction is almost entirely isometric. This also indicates towards the stabilizing function of the muscle (McGill, 2007, 61-62; Richardson, 1999, 30). Some authors consider medial part of this muscle to have more stabilizing function than lateral part (Richardson, 1991, 30)

Global mobilizers, a wide discussion is going on about the function of the psoas major as a stabilizing muscle. It is suggested that there psoas major acts as a stabilizing muscle since it can supply compression to the sacroiliac joint. It has also noted that people suffering from low back dysfunctions the segmental cross-sectional area of psoas major has diminished. (Gibbons, 2007, 100-101, Gibbons & Comerford, 2001, 27.) However it has been argued that regardless of its attachments to the lumbar spine it has very little to do with the lumbar spine stability and its main function is primarily the flexion of the hip (McGill, 2007, 60-61; Richardson et al., 1999, 14). This area requires more research (McGill, 2007, 61; Gibbons, 2007, 101). It has been suggested that contraction of rectus abdominis increases the tension of rectus sheath which in-turn increases the tension of the hoop-like structure consisting of abdominal

obliques and rectus abdominis (McGill, 2007, 56; DeRosa & Porterfield, 2007, 56-57), also latissimus dorsi has ability to increase lumbar tension through the lumbodorsal fascia (DeRosa & Porterfield, 2007, 49). Contraction of gluteus maximus increases the tension of thoracolumbar fascia thus providing stabilizing element to the lumbar spine (DeRosa & Porterfield, 2007, 49).

Pelvis provides dynamic platform for spine to function. Regardless to its dynamic attributes platform has to be stable enough, in this case it can function as a base for strong and effective lever arm. Fail of the base and imbalanced function of the muscles contributes to compensation mechanisms. Although compensatory movements might be minimal, countless repetitions render to pain and altered function of surrounding joints. For dynamic stability of pelvis, sufficient power production capacity of a single muscle is not adequate to correct the lack of muscle inhibition, -inactivity or -co-operation. Understanding the function of pelvis as a part of kinetic chain reducing the load of the spine is essential in rehabilitation process. (Koistinen, 2005, 153-155.) Force closure is provided by integrated function of muscles surrounding the joint. Force closure comes in to play when loads are increased. This is important factor in joints such as sacroiliac joint. Due to its wedge shaped form, shock absorption and weight bearing properties force closure must be appropriate in order to provide sufficient stability. (Lee & Vleeming, 2007, 623-624.) Insufficient force closure has been noted to be one factor contributing to pelvic girdle disorders and low back pain. Preceding insufficiency leads to inappropriate load transfer of the pelvic area. (O'Sullivan & Beales, 2007, 93.)

#### 4.3 Control system

Motor control can be defined as central nervous systems ability to regulate and direct the mechanisms essential to movement (Shumway-Cook & Woollacot, 2007, 4). Neural components act as a control unit regulating the stiffness of the muscles according to demands of the load (McGill, 2007, 114). Adequate motor control of the lumbar area has been identified to be paramount contributor to lumbar spine stability (McGill, 2007, 114; Vleeming, 2007, 129; Comerford & Mottram, 2001, 6; Richard-



son et al., 1999, 12). There is consistent evidence that failure of motor control regulating stiffness of the local stabilizing muscles contribute to loss of dynamic stability (Comerford & Mottram, 2001, 22).

The information of needed stabilization is provided through mechanoreceptor signals from the ligamentous tissues of the spine (Panjabi, 2003, 377). Mechanoreceptors are considered to be an important monitor of position, movement, tension and compression. Mechanoreceptors gather information and relay it forwards to the spinal cord. This results to the activation of muscles and reflexes. Proprioception has been defined as an outcome of sensory information collected by mechanoreceptors. Recently it has been suggested that proprioception also includes information from motor pathways together with sensory pathways. (Chmielewski, Hewett, Hurd & Snyder-Mackler, 2007, 375.) It has been also noted that muscle receptors contribute directly to the muscle stiffness. These receptors adjusting stiffness are; Golgi tendon organ which provides feedback about muscle force and muscle spindle monitors the length of the muscle (Chmielewski et al., 2007, 376).

Synchronic function of the control unit is vital in spinal stabilization (McGill, 2007, 114), since the greatest challenge to the system comes from sudden increase in external load (Panjabi, 2003, 376). Inappropriate timing of muscle contraction or the force of the contraction can be harmful to the lumbar spine (Comerford & Mottram, 2001, 3). Timing has been noted to be one of the main problems when discussing about lumbar stability (Hodges et al., 2007, 489). It has been suggested that increase in muscle contraction by 1-3% add to stiffness of motion segments and some authors have also proposed that 25% of maximal voluntary contraction of local muscles provide the sufficient stability to the spine (Comerford & Mottram, 2001, 20). It has also been noted that high external loads require more muscle activity and small external loads less muscle activity (Panjabi, 2003, 376).

Hodges & Moseley (2003) present a group of hypothesis about relations between motor control and pain. One hypothesis is that pain may lead to motor control changes. Changes may appear in excitability at spinal or cortical level, proprioception or specific cortical effects impaired by the pain. Another hypothesis is that fear if pain is the reason for motor control changes. Fear avoidance model leads to altered

movement patterns which in turn may lead to deterioration and disability. It is also noted that there is no certainty of correctness of any of these hypotheses. It remains unclear if pain is consequence of motor control deficit or on the contrary, motor control deficit is consequence of pain. (Hodges & Moseley, 2003, 363-366.)

## 5 THERAPEUTIC EXERCISE

Therapeutic exercises are essential part of the physiotherapy (Smith, Lewis & Prichard, 2005, 93). Therapeutic exercise can be defined as a systematic and planned intervention or performance of physical movements intended to reduce functional impairment, to enhance, maintain and restore physical function and to optimize fitness and overall health status and well-being (Kisner & Colby, 2007, 2; Huber & Wells, 2005, 4). Exercise programs are individualized according to patients or clients needs (Kisner & Colby, 2007, 2). Correctly implemented therapeutic exercise has been noted to have positive impact on pain and functional capacity in sub-acute and chronic cases of low back pain (Hayden, van Tulder, Malmivaara, & Koes, 2010, 11; Suomalainen Lääkäriseura Duodecim, 2007, 11). Exercise therapy can also be recommended to be implemented after treatment period to prevent the recurrence of low back pain (Choi, Verbeek, Wai-San Tam & Jiang, 2010, 16). Functional therapeutic exercise has been noted to increase working days, self-esteem and lifting capacity in chronic nonspecific low back pain (Kool et al., 2005, 861-862).

Oddvar Holten has defined the term “medical exercise training” already in 1968. Holten defines in his article that aim of physiotherapy is to promote and restore clients’ physical and psychological capacity. Chosen exercises have to be justified and reasons for exercising have to be given also to the client. Exercises are tested individually with each client to find out the right dosage and to teach the appropriate way of performing the movement. According to Holten, dosage includes information about number of sets and repetitions, applied resistance with number and time of resting periods. Re-examination has to be carried out in the beginning of every thera-

py session in order to distinguish the trend of therapy and suitability of the exercises. (Holten, 1968, 236-240.)

## 6 LEARNING AND GUIDANCE

In order for therapy to be effective correct performance the exercises are extremely important. Clients are recommended to manage their treatment independently by providing them with home exercise programs. However, these programs are often poorly adhered as clients frequently forget the exercises and fail to comply them. (Miller, Litva, & Gabbay, 2009, 29-30; Smith, Lewis & Prichard, 2005, 93-94.) There is no substitute for practice in learning motor skills, therefore therapist role is to work as a motivator and instructor who inspires the client to practice desired amounts both at the clinic and at home (Wishart, Lee, Ezekiel, Marley & Lehto, 2000, 231). Evidence suggested that motivating interventions lead to improved confidence and health results (Miller et al., 2009, 30).

Concepts of motor learning and recovery of function are often used together although definition is different. Motor learning is often defined as acquisition or modification of new skill (Shumway-Cook & Woollacot, 2007, 23) where as recovery of function is defined as reacquisition of movement skill lost due to injury (Shumway-Cook & Woollacot, 2007, 39) Motor learning has three stages; cognitive, associative and autonomous. Cognitive stage is the first stage of learning process and it starts with the learner comprehending the purpose of the task and requirements of executing it. Learner starts to practice the task, and with therapists feedback, is able to make necessary corrections. In associative stage learner starts to refine the skill. Errors are infrequent and learning focuses on producing regularly correct and efficient movement. Learner may start to explore slight modifications to the skill or to the environment. Feedback from the therapist is more infrequent and corrections occur mostly by learners own consideration. Autonomous stage is the last stage of learning where the skill has become automatic. Learner can perform the skill without concentrating

to the movements and is able to modify or adapt the skill to changing requirements or environments. (Kisner & Colby, 2007, 27.)

Interaction between the client and the therapist can be described as a cognitive process. Therapist provides verbal and non-verbal instructions of desired movements to the client and s/he acts as a problem solver translating the given instructions into action. The ultimate goal of therapy is to instruct the client to reproduce the desired exercises correctly and unattended outside the therapeutic environment. (Wishart et al., 2000, 231.) Research indicates that using videotaped instructions (dynamic modeling) has been proven to be more efficient than face-to-face instructions or illustrations (static modeling). Use of videotaped exercise improved patients' motivation, accuracy of reproducing exercises in self-treatment environment, which in turn improved the efficiency of the therapy. (Miller et al., 2004, 152; Weeks et al., 2002, 71-72.)

Key to successful guidance is to understand the importance of functioning interaction between the client and the physiotherapist. Physiotherapist and client work together as equals. This equality means that participants are committed working towards a common goal. Mutual trust, acceptance and respect have to reign between the participants of therapy process. As therapy progresses role of the client increases and responsibility of therapy moves more to him, simultaneously the role of the physiotherapist decreases and moves towards more passive approach. Therefore therapy methods have to be adapted to changing conditions. (Talvitie, Karppi, Mansikkamäki, 2006, 51-52.)

## 7 TOOL

The product of this thesis is web browser based CD-ROM about therapeutic stabilization exercises for lumbar spine. At the times of ongoing development of technology based services need for electronic rehabilitation tools is well-grounded. Computer can be found almost from every household. Electronic rehabilitation instructions can be accessed from everywhere and at any time. This enables the client to do the exer-

cises at the best suited time. Video format promotes the motivation and learning outcomes which in turn provide better rehabilitation result compared to, widely used, static illustrations (Miller, Litva, Gabbay, 2009, 29-35). Tool can be used, for example, by individuals going through rehabilitation process, by professionals to support teaching outcomes and by sports clubs to develop their coaching to more injury prevention based training.

## 8 THESIS PROCESS

The purpose of the thesis was to produce web browser based multimedia CD-ROM about therapeutic stabilization exercises of lumbar spine. CD-ROM contains information about the anatomy of the low back, factors contributing to stability and video about the exercises. Target group is health care professionals, physiotherapists, doctors, physiotherapy students, athlete trainers, athletes and ordinary people who can benefit from stabilizing therapeutic exercises of the lower back.

### 8.1 Literature review

Databases used to research the relevant material were: Science Direct, PubMed, EBSCO and PEDro. Since therapeutic exercise has various synonyms, many different word combinations were used. The problem that occurred because of inclusion of several search words was the huge amount of articles returned. In order to discover all the relevant material, browsing through abstracts was necessary. However, one definition made in the beginning was that articles published before year 2000 were not included in the search. Many relevant authors were also used as search criteria. Focus of included articles was mostly on definitions of stability, intervention procedures for low back disorders, comparison of treatment results in low back pain using different approaches and anatomy of lumbar spine area. EMG and muscle force production measurements and analyses of certain muscle groups when performing certain movements were generally ignored. Resources available at the library of Satakunta University of applied sciences were essential for acquiring information. The

huge amount of information available from this subject was not surprising, there has been a huge discussion going on for the past ten to fifteen years about the stability of lumbar spine. This has led various authors to tackle the problem from their own perspective.

## 8.2 Implementation of WWW-pages

CD-ROM was created by using the WWW-pages as a user interface. This enables browsing of the material through standard web browsers which can be found from every computer using the most common operating systems. This way everybody who have access to a computer can use and browse through the CD-ROM. Process started from planning of the user interface layout, page layout, color scheme, page structure directory and material to be added to the pages. For the actual implementation and coding professional assistance was acquired. Software used for making the pages was Adobe Dreamwaver.

Visual layout of the page is important since it produces the first impression for the user. Visual layout contributes also to usability of the pages. (Keränen, Lamberg & Penttinen, 2003, 43.) Layout used in the pages is fairly simple and color scheme neutral and light. Color scheme also correlates with the logo of the product. Since the product is meant for field of healthcare colors should not be too aggressive and abrasive in order to prevent wrong associations. Layout and user interface for the pages is fairly simple. Amount of navigation links has been kept to minimum and information is clearly distributed and illustrated throughout the pages. Main part of the product is the video of the exercises in the WWW-pages. Flash file format was used in the videos. Flash format is light and feasible, but it provides sufficient picture quality for present-day standards. Flash format is also universally used video file format. Web pages were tested on several different web browsers to ensure workable and cohesive usability regardless of the browser used.

### 8.3 Filming and editing

Logical manuscript was formulated before the beginning of the filming. Purpose of this was to ensure smooth progress of the filming. Manuscript included information about technique of the movement, equipment required during the shot and angle of view. Space used for filming was located in 24/7-access gym of Satakunta University of applied sciences. Reason for choosing this location was sufficient environment, equipments and lighting. Space was also possible to be reserved so filming could proceed as planned without any outside interference. Camera and tripod was provided by the university. Model was Antti Laurila and video photographer Anu Leppänen. Filming lasted approximately four days.

Software used for editing was Pinnacle 14 HD. Raw material was transferred to the computer as AVI file format (Audio Video Interleave). Material was edited to desired array and length. Audio was muted and fade-ins and –outs were added to the video. For some exercises also zoom-ins and multi-angle of views were utilized. Edited video material was converted to Flash file format, in order to ensure feasibility with the web environment. Conversion of video file format also made video files smaller, thus making pages lighter and shortening the loading times.

### 8.4 Piloting

Product was piloted with two physiotherapists working in Pori area. One is physiotherapy entrepreneur and the other is physiotherapist of local, Finnish championship level, ice hockey team. Piloting was done to receive information about usability of the interface, propriety of exercises and demand for product of this kind. Questionnaire was given in paper to the physiotherapists with the unfinished product and feedback was received via phone call. Feedback was constructive. Exercises were well shot and served the purpose. They were well divided. Videos were clear and exercises were shown in proper speed. Theory part could have been stronger, including deeper information about the anatomy. All in all feedback was good and there would be place for this kind of product.

## 9 DISCUSSION

The aim of this thesis was to produce multimedia CD-ROM about therapeutic exercises in maintaining low back fitness. I got the idea from my tutor teacher who suggested that I would do a multimedia tool used for teaching. Going through the previously done theses I found out that there has been couple similar kind of thesis done in our University. First I intended to do the thesis with co-student, however because of schedule problems we decided to do individual works. I started to think of the idea for the first time in autumn of 2009. First idea was just to produce multimedia rehabilitation package what can be used also for teaching purposes. In the spring of 2010 I started to narrow the topic. I was thinking that what topic would serve me the most in my future occupation. I concluded in low back, since it is one of the most common reasons for physiotherapy visits. I was going through literature trying to find out suitable low back diagnosis for my thesis, but nothing seemed to fit my standards. I also wanted to incorporate to my thesis the element of therapeutic exercise. Treatment implementations of diagnosis were vast so I was frustrated and thinking about that I have bitten of more than I can chew. After a discussion with my tutor teacher we concluded that I would not concentrate on one specific low back diagnosis, but I would look more deeply in to the concept of therapeutic exercise as means of maintaining low back fitness. There is high-level evidence on efficiency of therapeutic exercise when treating non-specific sub-acute and chronic low back disorder (Suomalainen Lääkäriseura Duodecim, 2007, 11).

In the spring of 2010 I started to gather information of therapeutic exercises in low back problems through literature search from various databases. I was searching the relevant articles and books. In the spring I also did a plan for the progression of the thesis. Actual writing did not commence before the autumn of 2010. This was due to my clinical practice periods in various locations around the world. After my return back to Finland I started to write my thesis. I read through the previously done thesis in order to prevent doing the same mistakes and trying to hasten up the process. I started the writing from subjects that do not change over time, such as anatomy, and does not require extensive literature research. At the same time I was searching for the most up-to-date information about correlation between low back pain and results



of therapeutic exercise as a treatment. The writing process, in its entirety, progressed stunningly well.

As I was writing, I started to think about the exercises for the CD-ROM. I searched various sources for ideas. Internet proved to be irreplaceable source of information regarding the exercises. I browsed through several reliable rehabilitation and athletic training web sites to find some ideas and exercises for my thesis. I picked the ones I felt were most suitable and I piloted them several times with judokas of local judo club. I received a large amount of valuable information about efficiency and difficulty level of the exercises. I constructed a framework about the exercises and divided them in four levels according to their difficulty. I recognize that some of the exercises were chosen from sources concentrated more on promoting athletic performance rather than injury rehabilitation. In my opinion this is not a problem since both originate from same anatomical and physiological background and strive towards common goal, promoting performance capacity. The piloting of the exercises was carried out with very active persons and semi-professional athletes. This might not be entirely according to realities of clinical practice since physiotherapists nowadays might be dealing with numerous sedentary clients. However, exercises in the CD-ROM vary from easy to very difficult. Here I am emphasizing the responsibility of the physiotherapist to implement the therapy according to every individual's needs. One group of clients may reach their aim of sufficient low back fitness, coping with activities of daily living, with easier exercises. Whereas, another group requires more challenging exercises when, for instance, returning to their sport.

After selecting and dividing the exercises, manuscript was produced to hasten up the filming process. Manuscript included information about how the exercises is performed, equipment needed for the exercise and angle of view. Completing the manuscript took approximately one day. I researched the previously done thesis in order to find good location with sufficient lighting and suitable surroundings. 24/7 gym of the University filled the requirements. Added to this, the university provided a digital video camera and a tripod to my disposal. I acted as a model in the video and I had outside help filming. Exercises were filmed mute and against simplified background, to eliminate any disturbances and to maximize focus to the exercise.

For implementation and design of WWW-pages and CD-ROM covers, professional help was hired. It helped compiling the product considerably. Reason for choosing the WWW- pages made with HTML- language (HyperText Markup Language) was that it is easily modifiable. It also serves well for the future, since there is potential for expanding the product to internet based service. Attractive visual appearance created by professional designer affects on the credibility and marketability of the product.

Product includes general written information about low back pain, anatomy of the low back and use of exercise as a form of therapy. Introduction “tab” (internet synonym to interleaf) of the CD-ROM provides information about occurrence and prevalence of low back pain. Also concept of stability is described briefly. Anatomy tab discusses about bony structures, muscles and nervous system involved providing stability. Besides video material, exercise tab includes short description about therapeutic exercise and results of implementing it as therapy approach in low back disorders. In this tab I decided not to include any specific therapy guidelines to the product, since it might vary greatly between different cases. When prescribing the exercises, amount and dosage, it should occur with case-specific manner. When using this product, health care professionals should always be consulted, if user is not professional himself.

Piloting proved out to be one of the weaknesses of this thesis. Since the late completion of the product, reaching the people piloting and delivering the product to them did not go according to plan. It was difficult to find appropriate time to meet these busy people in few days notice. In the end I was able to reach two health care professionals who had time to get acquainted with the product and provide some feedback from it. I enclosed a feedback form (Appendix 1.) with the CD-ROM and they provided the feedback via e-mail. Intention was to include more health care professionals and some athletic coaches to the piloting. I would have got valuable information also from using the product as tool for injury prevention. Feedback received from piloting was constructive and motivating. Exercises were purposeful and well divided. Weakness was the written part of the product. It should be more strong and deeper.

Strength of the thesis is that it is intended for wide variety of users. Besides health care professionals and patients, this thesis can be used by teachers in university physiotherapy teaching or by students as a support of learning in a field of therapeutic exercise. From injury prevention point of view, athletic clubs may incorporate exercises and ideas presented in this thesis to their training programs. In order for athlete to excel, s/he has to be healthy and able to train rigorously throughout the year. This product may provide athlete with valuable information about exercises strengthening and promoting the function of pelvis and core.

Within the field of health care trend of shifting the responsibility of therapy to the client is increasing constantly. The goal is unload the pressure of health care organization and make it economically more beneficial. The role of the therapist is to act mainly as a consultant prescribing the exercises and teaching it to the client. Responsibility of client is to commit to therapy and implement it according to therapist prescription. Motivating the patient to commit to the therapy and follow the prescription given by therapist is often difficult. However, this motivation may be decisive factor for success of therapy. Utilizing video filmed exercises has been studied to increase this motivation (Weeks & al., 2002, 65- 73). Technological development have made possible for majority of people to access services such as this individually. This possibility promotes the commitment for individuality, motivation and economical feasibility of therapy process. For this reason it is justifiable to produce products based on using video and opportunities of information technology. In the future, service application offering therapy implementations accessible from your mobile phone could be developable and profitable.

For the future there is various ways to develop this product. Content can expand to go deeper in to the exercises, coming up with new ways to challenge and develop lumbar spine stability or it can be changed to deal with stability of shoulder girdle. Due to fast development of technology, the product has to develop as well. Next step could be internet based service providing similar information and further in the future a service application offering therapy implementations accessible from your smartphone.

During the thesis process I have acquired huge amount of information concerning therapeutic exercise, stability and low back disorders. At the same time I developed a hunger to seek more information and improve my skills. I also improved my computing skills creating multimedia systems and I realized the potential of utilizing technology with good old face-to-face therapy to reach the maximal therapy results. I am positive that this information will help me greatly in my future occupation.

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## APPENDIX 1

### Kysely/Palaute

1. Onko CD:tä mielestäsi selkeä käyttää?
2. Ovatko harjoitteet mielestäsi tarkoituksen mukaisia?
3. Onko harjoitteet jaoteltu oikein?
4. Onko tällaiselle tuotteelle mielestäsi tarvetta/käyttöä?