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THE ROLE OF CORE STABILITY IN SURFING

According to a Delphi Panel

Thesis
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KUVAILULEHTI

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Nimeke

Keskivartalon hallinnan rooli surffaamisessa Delphi panelistien mukaan.

Tiivistelmä

Keskivartalon hallinta on ajankohtainen asia fysioterapiassa. Monet tutkijat ovat tutkineet ilmiötä, mutta varsinaista konsensusta sen anatomiasta, tehtävistä tai hyödyistä ei vielä ole. Hyvän keskivartalon hallinnan on todettu vähentävän alaselän kipuja ja suojaavan erityisesti naisurheilijoita alaraajojen vammoilta.

Surffausharrastukseni myötä kiinnostuin keskivartalon hallinnan merkityksestä surffaamisessa. Surffausta on tutkittu vähän, ja tutkimukset ovat keskittyneet lähinnä fysiologisten ominaisuuksien mittaamiseen. Tämän opinnäytetyön tarkoituksena on selvittää, millainen rooli keskivartalon hallinnalla on surffaamisessa.

Tutkimus toteutettiin Delphi-tutkimuksena sähköpostitse. Asiantuntijapaneelilta kysyttiin surffaamiseen ja keskivartalon hallintaan liittyviä kysymyksiä ja vastausten pohjalta luotiin yhteenveto siitä, mikä rooli keskivartalon hallinnalla tutkimukseen osallistuneiden asiantuntijoiden mielestä on surffaamisessa. Tutkimus on suuntaa-antava, sillä varsinaisia mittauksia keskivartalon hallinnan käytöstä surffaamisessa ei toteutettu.

Tulosten perusteella keskivartalon hallinnan rooli surffaamisessa on erityisen tärkeä, sillä keskivartalo osallistuu lähes jokaiseen liikkeeseen. Erityisesti käännöksissä keskivartalon tehtävänä on hallita kehoon kohdistuvia voimia ja toimia raajoille tukevana runkona, jotta distaaliosien on mahdollista toimia taloudellisesti ja tarkasti. Hyvä keskivartalon hallinta tukee rangan linjausta ja näin ennaltaehkäisee ja vähentää vammautumisen riskiä. Surffaajat paneutuvat valmentajien ohjauksella yleisen kunnon kohottamisen lisäksi keskivartalon hallintaan ja voimaan, minkä tarkoituksena on kehittää surffaajan suorituskykyä. Tämän tutkimuksen perusteella keskivartalon hallintaan liittyvät harjoitukset ovat tärkeitä, kun surffaajan suoritusta pyritään kehittämään.

Asiasanat (avainsanat)

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The Role of Core Stability in Surfing According to a Delphi Panel.

Abstract

Core stability has been widely discussed in physiotherapy. Yet, no consensus has been reached on the anatomy, tasks or benefits of core stability. Good core stability has been proven to decrease low-back pain and prevent specifically female athletes' from getting lower extremity injuries.

Surfing has become an extremely popular sport. As a surfer I am intrigued to know what the exact role of core stability in surfing is. There are a limited number of studies on surfing and most of those concentrate on physiological aspects of the surfer. Thus a study was needed to determine the role of core stability in surfing.

This thesis was executed with the Delphi technique via email. The expert panel, consisting of physiotherapists, answered questions related to surfing and the role core stability in surfing. An analysis was made and the results were summarised to generate new information on surfing and core stability from the physiotherapy point of view. The results are to be treated as guidelines as no measurements of the activity of core muscles were recorded.

According to the results the role of core stability in surfing is extreme as it is present in almost all surfing manoeuvres. It is especially important in turns, where it is needed to control and project the forces that act on the body and thus enable the extremities to have a stable base to perform economical and precise movements. Good core stability ensures the correct alignment of the spine, which prevents and decreases the risk for injury. Surfers and their coaches emphasise core stability in addition to general physical and strength exercises to increase the surfer's performance. According to this research, core stability exercises are vital in developing surfing performance.

Subject headings, (keywords)

Core stability, surfing, water sports, balance, motor control, Delphi study

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TABLE OF CONTENTS

1 INTRODUCTION

Surfing began in Polynesia thousands of years ago and eventually made its way to Hawaii and to the rest of the world. From there it has evolved and made its way to a multimillion dollar business. Surfing is described as an intermittent sport activity where the surfer lays prone on a surfboard, paddles to reach the waves to catch them, stand up and do manoeuvres on the wave. The art of surfing evolves constantly. New tricks and manoeuvres are constantly invented as surfers have become more innovative and fearless. Surfboard design has been taken to another level where designers and surfers want to try something that has never been tried before. As competing is getting increasingly demanding, the importance of training is gaining more attention. (Britton 2004; Farley et al 2012, 1889; Méndez-Villanueva at al 2005a, 56-59; Warren 2012, 45, 48, 51.) Once I grew a passion towards this sport I was instantly intrigued by the complexity of the sport and the physical demands to the surfer. It seemed as though surfers are extremely fit, strong and flexible. In search for evidence to support my ideas about surfing, I found that there is an extremely limited amount of scientific information on the subject.

Core stability, also known as lumbo-pelvic stability, is regarded as being an integral part of everyday physiotherapy. It has been shown to prevent back pain. Most training programs and trainers emphasise core control, strength and stability, but it is yet to be proven whether or not these attributes affect performance or are merely protective elements of the spine and internal organs. (Kibler et al 2006, 190; Sharrock et al 2011, 64.) Having surfed myself, I find core stability extremely central in surfing, but there is no scientific proof to support my hypothesis. This study has the potential to increase understanding of surfing and the demands it sets for the surfer, as well as to prove the role of core stability in surfing and further in preventing injuries. It could possibly even encourage trainers to remove useless workouts from training regimes and replace them with more specific exercises that increase the performance of surfers.

The purpose of this study is to be able to explain what kind of role core stability has in surfing. I intend to find out which manoeuvres are the most critical and which core stability improving exercises surfers should do. This is of personal interest to me since I have a passion for the sport, and no previous studies have been conducted in this field. The complex manner of the sport and extreme conditions the surfers face is in-

teresting. I have interviewed professionals using the Delphi technique. It involves interviewing professionals, in this case two individuals, and aims to reach consensus on the presented topic (Hsu et al 2007, 1 – 3; Linstone et al 1975, 5 - 6).

The aims of this thesis are to help physiotherapists and other health professionals working with surfers understand the role of core stability in this specific sport, to deepen the knowledge on surfing, and to develop my own professional skills as a physiotherapist. This study is conducted from a physiotherapy point of view. This information will also be extremely valuable to the ever growing surfing industry and the results from this study will be a needed addition to the scientific evidence on surfing as it is still very scarce.

The thesis begins with an overview on surfing which is followed by a review on previous studies and basic theory on core stability. Finally I present the method and process of the study followed by an analysis of the results and discussion on the entire project.

2 SURFING

Surfing is a sport where lifestyle and culture combine. Surfers have a lifestyle where the respect and understanding of the power of nature is the connective factor between surfers. The act of surfing involves paddling on a surfboard, duck diving, paddling for a wave, standing up, riding the wave and doing special manoeuvres on the wave. After this the same cycle is repeated so many times as there are waves and the surfer has energy and is willing to paddle back out to the point where waves are caught. (Britton 2004; Méndez-Villanueva at al 2005a, 58; Warren 2012, 2 – 3, 5 – 6, 11.)

Unlike core stability, surfing has not been a popular subject for a study. I completed a literature review of which a table can be found in appendix 1. Limited data was available especially about core stability in surfing. Most studies concentrate on physiological aspects of surfing, but none of the studies in the literature review discussed surfing from a physiotherapy point of view. Frank et al (2009, 31) studied the effect of long-term surfing on controlling forces and posture. They found that surfing may affect favourably on a person's balance and muscle control ability. This would suggest that

surfing is a beneficial sport that can increase the quality of life even amongst elderly people. (Frank et al 2009, 31.)

It is clear that research around surfing is increasing, but there are no studies executed from a physiotherapy point of view. This is a tremendous gap as surfing is scientifically proven to be a strenuous sport and so it would be safe to say that physiotherapy is needed for training, prevention and rehabilitation of injuries (Méndez-Villanueva & Bishop 2005a, 55 - 56). In order for this to be as efficient as possible, scientific evidence is needed to understand surfing from a physiotherapist's point of view.

In my profession opinion core stability is a key aspect in surfing as it provides stability, helps produce more effective manoeuvres and could prevent injuries. I find it timely to study core stability as it will gain scientific data that will be publicly available. The research could increase the knowledge of physiotherapists and other professionals working with surfers, and help them make rehabilitation and training more efficient and sport specific.

2.1 History of Surfing

Surfing began in Western Polynesia approximately three thousand years ago when the ancient Polynesians used wooden planks to ride waves to shore with their day's catch of fish. The useful method of transport blended into everyday life as a way to have fun and enjoy the nature. Captain James Cook has recorded a surfing situation already in the 18th century, while he was in Tahiti. As the Polynesians settled to Hawaii they took their knowledge with them and practiced surfing in Hawaii. It is known that they had rituals and carefully selected trees for surfboards. Boards were long (8 – 24 ft). From here, the sport has evolved tremendously into being an extremely popular sport in the whole world. (Britton 2004; Méndez-Villanueva at al 2005a, 56; Warren 11 - 12.)

After some time the popularity of surfing decreased, most likely due to the small number of natives living in Hawaii who knew the sport, until it regained people's interest again in the early 1900's. This is when Hawaii'an Duke Kahanamoku, an Olympic level swimmer at the time, became the "ambassador of surfing". People grew an interest towards surfing around The United States of America and Australia due to

his surfing exhibitions. Boards also developed and became much lighter and easier to manoeuvre. In the 1950's surfing was extremely popular as many people wanted to seek enjoyment after the war. TV-shows, music and movies added attention to surfing. Since then surfing, as a sport, lifestyle and business opportunity, has evolved continuously and has reached a multimillion dollar business status in the world. (Britton 2004; Méndez-Villanueva at al 2005a, 56; Warren 2012, 27, 30 – 32, 51.)

2.2 Equipment

For surfing a surfer needs a surfboard with a fin or fins, a leash, wax, swim wear and according to the current conditions there might be need for sunscreen and a rash vest when sunny, a wetsuit, a hood, gloves and boots, if it is cold (FIGURE 1). Protective gear, like helmets and wrist guards, are becoming more and more common. Some surfers use a tail pad on their board for extra grip for their back foot. As surfing has developed, so have the equipment and accessories. (Extreme Horizon 2013; Warren 2012, 129.)

FIGURE 1. The author surfing in Peniche, Portugal (2012) on a short board and in a full-length wetsuit. Thank you to Lisa Hasselgren for taking the photo.

The design of surfboards has been evolving constantly. Surfers started off with big wooden planks, which then slowly got smaller and along with the industrialisation surfers started using polyurethane or polystyrene for the base which is then covered with fibreglass or epoxy resin. Fibreglass covered boards are the most commonly used. There is a large variety of surfboards used for different conditions or according to skill: longboards, funboards, shortboards, guns, fish, egg and towboards to name a few (FIGURE 2). All the boards come in different shapes and sizes. Custom made surfboards are usually used by more experienced surfers in order for their board to suit their skills, preferences, wave and body type as perfectly as possible. Fins are placed under the surfboard for manoeuvrability and most surfers use a three fin setup, which is called a thruster, but surfers can have one to five fins on a surfboard. (Extreme Horizon 2013; Warren 2012, xxiv – xxv, 11 – 18, 51, 122 - 124.)

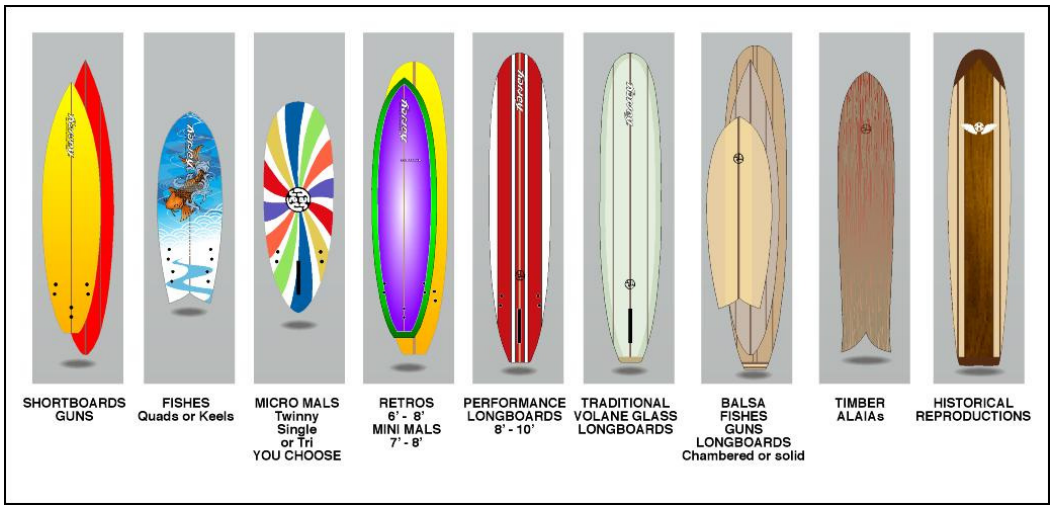

FIGURE 2. A Variety of Surfboards (Harvey Surf-Gallery, 2012)

2.3 Competing

The Association for Surfing Professionals (ASP) organises events with sponsors around the world. There are separate events for women, men, juniors, longboarders and surfers who have not qualified for the women's or men's world tour. (Association of Surfing Professionals 2012b.) The first world championships were held in Australia in 1964 (Méndez-Villanueva & Bishop 2005, 56). In a competition there are heats where two to four surfers surf at the same time for a duration of 20-40 minutes. The aim is to surf waves, which are then judged by the judging panel from the scale 0-10. A two wave total score is calculated of the best scoring waves, which can be a maxi-

mum of 20 points. Judging criteria varies according to the waves, surf break, and the current level of surfing. Judges appreciate and give high scores to surfers who surf a wave to its total potential, linking all the manoeuvres together beautifully and possibly create something new or do an astoundingly hard manoeuvre. (Association of Surfing Professionals 2012a, 20 - 23, 56 - 57.)

Surfing evolves constantly and thus competing is getting increasingly demanding. Hence the specificity of training is gaining more attention. (Anthony 2003; Warren 2012 xxiv – xxv.) Thus I wish to research into the role core stability in surfing.

2.4 Physiological Aspects of Surfing

Surfing is described as a sport that is intermittent and requires excellent aerobic and anaerobic fitness of the surfer. One has to lie on the surfboard, paddle (with just using arms) to the so called line-up, where it is possible to catch waves. To get past the breaking waves on the way, the surfer has to dive under the waves with the board. This is called duck diving. Once in the line-up, surfers look to the horizon to see the incoming swell. Once a wave approaches, the surfer has to paddle into position and catch the wave with strong paddling. Sometimes the surfer might need to gather more speed by kicking while paddling. Once the wave carries the surfer, he or she must stand up quickly (called the pop-up) and then do whatever manoeuvres he or she wants to on the wave. Once the wave has reached the beach or otherwise has ended, the surfer repeats the cycle again as many times that he or she wants to. To be able to repeat the cycle and manage all the actions, it requires endurance, strength, power, stability, balance and co-ordination skills from the surfer. Surfing strains the entire human body and its systems. (Britton 2004; Farley et al 2012, 1889; Méndez-Villanueva at al 2005a, 56-59.)

The basic manoeuvres are turns with differing names, according to the direction or criticalness of the manoeuvre and position of the surfer. For example, a bottom turn is the turn at the bottom of the face of the wave, and layback is a turn where one can see the surfer having to literally lay back to complete the turn. However, the manoeuvres evolve constantly, mostly due to innovative and fearless surfers trying out new tricks like air jumps and turns. (Club of the Waves 2013.)

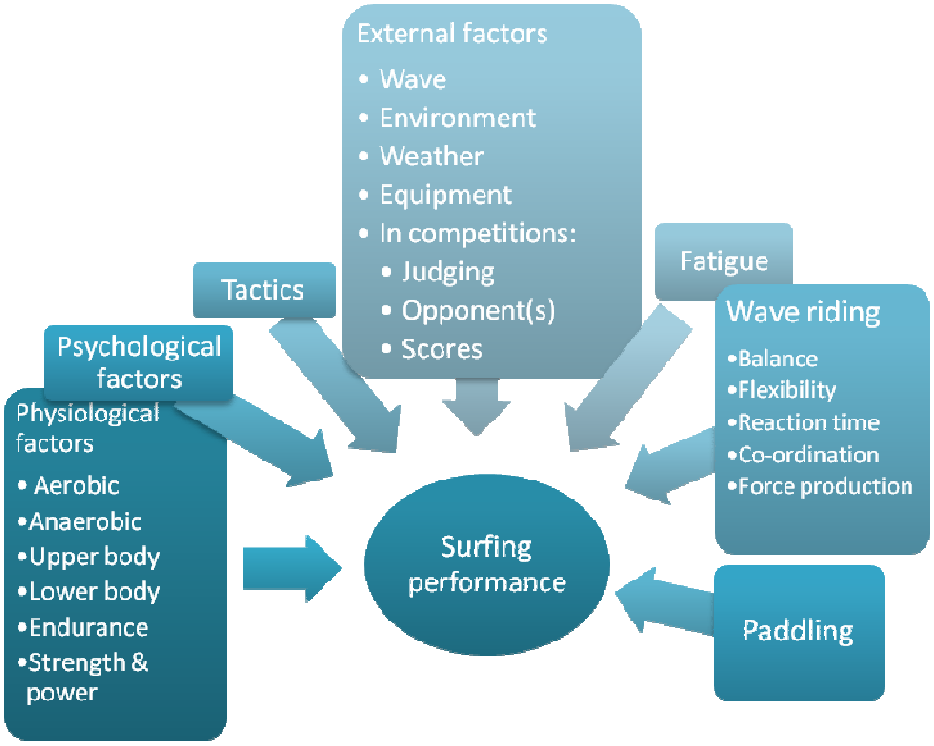

FIGURE 3. A diagram on what surfing requires from the surfer (Modified from Méndez-Villanueva at al 2005a, 59)

Méndez-Villanueva & Bishop (2005a, 55-56) found in their review "Physiological Aspects of Surfboard Riding Performance" that paddling takes up the most time in surfing, surfer's peak oxygen uptake (VO_{2peak}) is higher than amongst athletes with similar tasks, and surfers' heart rate resembles an average intensity workout. Thus surfing strains the cardio-respiratory system of the body. Supporting the idea of upper-body fitness are researches by Méndez-Villanueva et al (2005b, 43) and Farley et al (2012, 2243-2244, 2246) who state that surfers have good upper-body aerobic fitness. Therefore, surfing requires both strength and aerobic fitness. And for these to be most efficient in surfing, core stability is needed, since core stability allows forces to be transferred to the extremities to produce fluid and efficient movements (Hibbs et al 2008, 996-998). Méndez-Villanueva & Bishop (2005a, 64) agree by stating, that surfing seems to "demand a superior level of postural control and whole body fine motor skills". This demands intricate work from the CNS as it is in charge of sending commandments to the rest of the body (Richardson et al 2005, 20). However, there is no scientific proof of the function of core stability in surfing nor any research made on the subject according to the literature review conducted for this thesis.

2.5 Surfing and Postural Control

What I found interesting was that according to Méndez-Villanueva & Bishop (2005a, 59-60) there exists a specific body type that is considered to be most favourable for efficient surfing; short, light-weight surfers tend to have better performance due to a lower centre of gravity and thus better balance. In surfing, postural control is inevitably important and can be very demanding as the base of support varies. In addition to making body adjustments core stability is needed to control movements of the upper extremities in maintaining balance. There are several strategies to be used; the ankle, the hip, the suspensory and the stepping strategy. The strategies activate muscle chains starting from distal to proximal to help in maintaining balance. The ankle strategy is used mostly in anterior-posterior movements where only small adjustments are needed. The hip strategy is taken into use when larger perturbations arise and the base of support is small and variable. Here muscles are recruited first proximally then distally and the core musculature would also be used. The suspensory strategy means lowering one's centre of mass and thus producing a more stable position. Finally, the stepping strategy, i.e. taking a step to maintain balance is used if none of the previous strategies have worked. (Frank et al 2009, 31; Kauranen 2011, 180 -185; Paillard et al 2011, 1619.)

The forces which affect the surfer when surfing are gravity, supporting force, buoyancy, shearing forces, friction and torsional moment. Motions that are caused by these forces are translational and rotational. In addition, the power of the wave and characteristics of water affect surfing. The drag caused by water requires the surfer to have muscle power, to cause torsional moment, in order to execute turns. When the surfer is going straight on the wave the drag does not affect the forward motion strongly since the surfboard is a streamlined piece of equipment and it has been built to best comply with the features of water and to maximise performance. Gravity affects the surfer for example when standing up, keeping oneself upright and in aerial movements. The supporting force is the force that affects the surfer from the surfboard. This together with the buoyancy of the surfboard enables the surfer to surf the wave and to not sink. It also affects the execution of aerial movements and turns. Friction is present between the surfer's feet and the wax that is on the top of the surfboard. It ensures stability for the surfer and a non-slip surface to act from. (Kauranen & Nurkka 2010, 203, 218, 228; Warren 2012, xxiv, 78 – 79.)

3 CORE STABILITY

The core has been widely studied in literature. Regardless of the numerous studies on the matter no consensus has been reached on which structures the core includes, its role in functioning or which exercises are most valuable. Benefits and advantages of good core stability have been recognised, for example the aid it offers in treating lower back pain (LBP). (Hibbs et al 2008, 995-996.) A literature review of researches on the subject is presented in appendix 1.

Although scientists have not been able to agree on a definition for the core or core stability, it is recognised that our **core** includes the structures between our lowest ribs and the pelvis. Kibler et al (2006, 189) and Tse et al (2005) all agree that the core includes the muscles of the trunk and pelvis and are needed in transferring energy to the extremities. Depending on how the core is viewed the definition changes. When observing the core for athletic purposes writers include more parts of the body in the anatomy. Hibbs et al (2008, 996) state that shoulders and knees are included in the core in sports, since they transfer energy and forces to other parts of the body for the required technique to be achieved. Sharrock et al (2011, 64) agree and express that a certain focus should be on the hips, lower back and abdominals whereas Borghuis et al (2008, 894) see the structures of the core to include muscles of the trunk and rather have the hip musculature seen as a mere addition to the functioning of the core.

Core stability, also known as lumbo-pelvic stability, is the basis for functioning of the human body. Stability refers to the ability to have balanced control over the structures of the core, and this requires maintaining a **neutral spine position**, i.e. having the normal curvature of the spine throughout movements, which will be discussed later. The core is a system that supports the spine, protects internal organs and the spine by producing intra-abdominal pressure (IAP), is an important part of maintaining and correcting posture, stability and balance, helps transfer forces to the extremities, and is a part of many kinetic chains. Kinetic chains are chains of muscles activating in a certain order with specific movements (Kibler et al 2006, 189-190; Hyvärinen et al 2010, 3; Richardson et al 2005, 14-19.) Our core helps us control our centre of mass (COM), thus keeping us upright. It also requires work from our central nervous system (CNS). We need to have muscle control to be able to activate the correct mus-

cles at the correct moment to have the needed stability. Core strength and core endurance are integral parts of core stability for the entity to work. (Borghuis et al 2008, 902-903; Filipa et al 2010, 2.)

Richardson et al (2005, 15-20) use Panjabi's (1992) model of describing the **elements of the core** by dividing the elements into passive, active and neurological control divisions. Most studies accept this grouping. Ligaments, fasciae and bones represent the passive structures. Muscles are the active segment, which Bergmark (1989) separated into local, deep, stabilising short lever muscles and global, superficial, longer trunk moving muscles capable of strong force generation. Finally, the central nervous system CNS is the control segment of the model. All of these three components are needed for core stability to function. (Kibler et al 2006,189; Sharrock et al 2011, 64)

In this study core stability is defined according to Panjabi's (1992) classification, including active (muscles), passive (ligaments, fascia, and bones) and neural components. The neural component is in charge of muscle recruitment, activation and stability strategies. The active component includes the following muscles: the diaphragm, pelvic floor muscles, all abdominal muscles, quadratus lumborum, iliopsoas, erector spinae, multifidi and latissimus dorsi. The deep muscles are local stabilising muscles and the superficial muscles are the global moving muscles. Amongst other ligaments and fascia the thoracolumbar fascia is the most important part of the passive component as it connects the upper body to the lower part of the body. Core stability in this thesis is seen as the basis of functioning, force transferring, supporting and protecting the body and spine. It helps us control our centre of mass (COM) thus keeping us upright and also helps to maintain and correct our posture and balance. (Borghuis et al 2008, 902-903; Filipa et al 2010, 2; Kibler et al 2006, 190 - 191; Richardson et al 2005, 15 - 20.)

Patients of working age, athletes and physically inactive people tend to experience low-back pain. Athletes are also more prone to be affected by lower extremity injuries. (Filipa et al 2010, 2; Hibbs et al 2008, 995-996.) As **core stability is a basis for functioning** it should be included in almost all patient's training programs in order for these possible future injuries, pains and aches to be prevented or decreased. More focus should be on children and youngsters to help build a healthy basis of functioning in an early age, which can be carried through a lifetime. (Hyvärinen et al 2010, 1 - 2.)

3.1 Anatomy of the Core

Bony structures, that are a part of the core, include the spine, vertebrae of the spine, lower ribs and the pelvis. The spine (columna vertebralis) consists of the 7 cervical vertebrae, 12 thoracic vertebrae, 5 lumbar vertebrae, 5 fused vertebrae of the sacrum and 3-5 fused vertebrae of the tailbone (os coccyx). Together they form the spine which has a cervical lordosis, thoracic kyphosis and a lumbar lordosis. (Koistinen et al 2005, 39; Niensted et al 1999, 109.)

Each vertebra has a body (FIGURE 4), two transverse processes, a spinous process, a foramen, where the spinal cord travels and is protected, and many surfaces for ligaments and muscles to attach to and other bony structures to articulate on, for example facet, or apophyseal, joints between two vertebrae. Between the end plates of two vertebrae is a disc, which consists of jelly-like matter on the inside and the outer rings consist of collagen. It works like a shock absorber. (Koistinen et al 2005, 42-43; Niensted et al 1999, 110.) The vertebrae are held together by muscles and ligaments. The pelvis (FIGURE 5) includes the SI-joint (sacro-iliac), sacro-coccygeal joint, pubis symphysis, presacral joint and the hip joints. (Koistinen et al 2005, 156.)

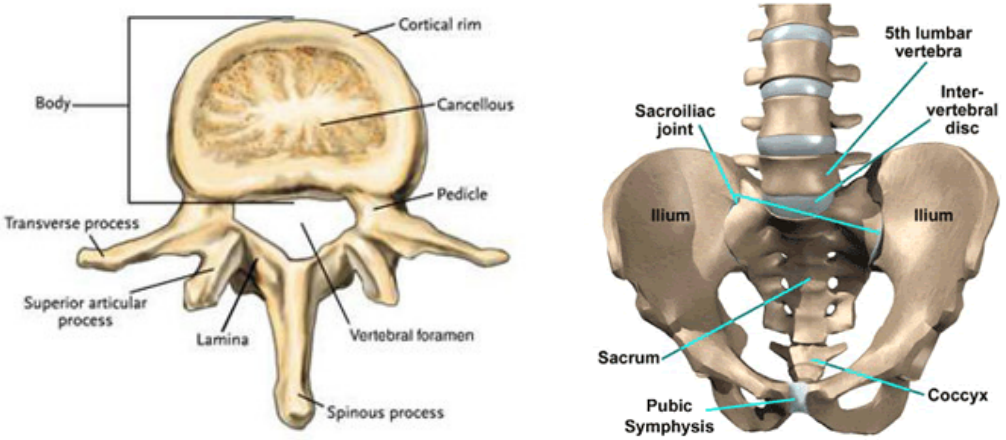

FIGURE 4 & 5. A vertebra (Triangle Disc Care 2012). **Lumbar spine and pelvis** (Active Ortho 2009)

Muscles of the body are divided into **global and local muscles**. Global muscles basically move the body, since they act when external forces affect our balance and they are in charge of creating the body's torque. Local muscles are the deep muscles that

ensure stabilisation of the body and protection of the spine. (Richardson et al 2005, 17-19.) Basically the muscles of the core are like a box with a top, bottom, and sides. The top muscle is the diaphragm, bottom muscles include the pelvic floor muscles and on the sides are the abdominal muscles (FIGURE 6).

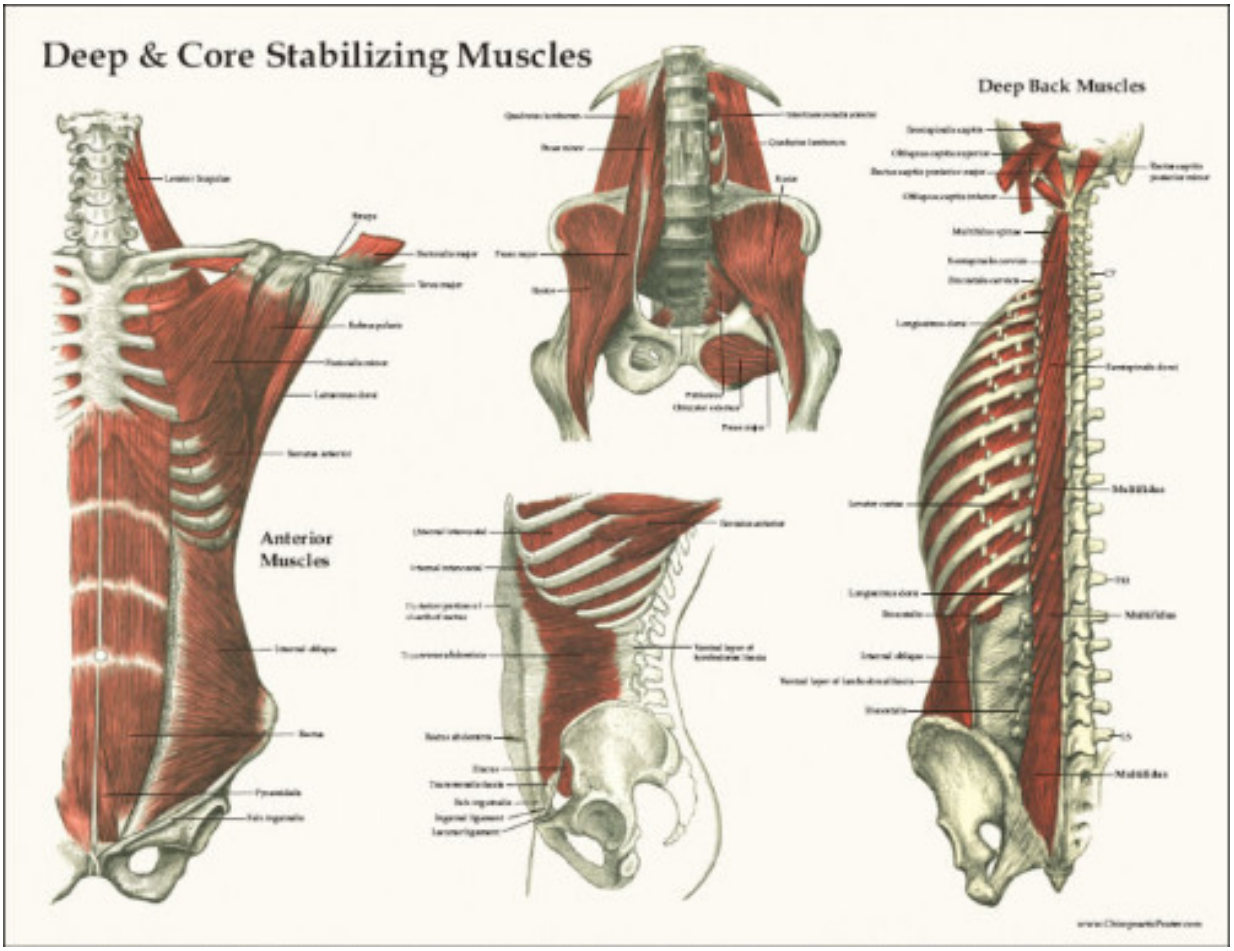

FIGURE 6. Muscles of the core (Cyber wellness center 2012)

According to Kibler et al (2006, 190), the latissimus dorsi, iliopsoas and pelvic floor muscles are included in the core. Latissimus dorsi and the iliopsoas are considered to be superficial (global) muscles and the pelvic floor muscles are deep (local) muscles. (Kibler et al 2006, 190-191.) Detailed anatomical information on the origins, insertions, actions and innervation of the core muscles are in TABLE 1 and 2. In order for the tables to be easier to understand, the muscles are divided into global and local muscles.

Global Core Muscles	Origin	Insertion	Action	Innervation
External oblique	Anterolateral portion of lower 7 ribs.	Linea alba, pubic tubercle and anterior portion of the iliac crest.	Flexion, lateral flexion to same side of the muscle and rotation of the trunk towards the opposite side of the muscle.	Intercostal nerve from nerve root T6-T12.
Rectus abdominus	Xiphoid process and costal cartilages of ribs 5-7.	Pubic bone crest and symphysis pubic.	Flexion and rotation of the trunk.	Intercostal nerve from nerve root T6-T12.
Iliopsoas (m. psoas major & minor and iliacus)	T12, L1-4 and lower ribs. Iliac crest.	Ilium, lesser trochanter of the femur. Psoas major.	Flexion of the hip, anterior tilt of the pelvis.	L1-3 and femoral nerve from nerve roots L1-L3.
Latissimus dorsi	T6-12 and all lumbar and sacral spinous processes	Anterior-superior fossa of the humerus.	Extension and internal rotation of the shoulder, lumbar region stabiliser, extension of the trunk	Thoracodorsal nerve
Erector spinae (includes spinous medial, transverso-spinous medial, spinoustransverso medial, and lateral tracts)	Medial tracts run between spinous and transverse processes of the spine. The lateral tract runs between the iliac crest, transverse processes of the lumbar spine and the lowest ribs.		Extension of the spine, segmental stabilisation	

TABLE 1. The global muscles of the core and their function (Modified from Brumitt, 2012; Koistinen et al 2005, 180-181,215-220; Richardson et al 2005, 36-38)

Local Core Muscles	Origin	Insertion	Action	Innervation
Transversus abdominus (TrA)	Ribs 6-12, thoracolumbar fascia, iliac crest, inigual ligament.	Linea alba, pubic crest.	Compression of the abdominal wall, stabilisation.	Intercostal nerve from T7-L1
Internal oblique	Thoracolumbar fascia, inigual ligament and anterior surface of iliac crest.	Linea alba and 4 lowest ribs.	Flexion and rotation towards the same side of the muscle. Stabilisation.	Intercostal nerve from nerve root T7-L1.
Diaphragm	Attaches to bodies of the lumbar vertebrae, xiphoid process and costalcartilages	Inhaling and intra-abdominal pressure.	Phrenicus nerve from nerve root C3-C5.	Diaphragm (local)
Quadratus lumborum (local and global)	Lower ribs.	Superior iliac crest.	Open kinetic chain: lateral flexion of the trunk. Lateral stabilisor of the pelvis and lumbar region.	Subcostal, ventral ramus from nerve root T12-L4

Local Core Muscles	Origin	Insertion	Action	Innervation
Pelvic floor muscles: Pubococcygeus Iliococcygeus Ischiococcygeus	 Os pubis, anterior fascia of obturator muscle. Ischiac spine and lumbar fascia. Os ischium, sacrospinal ligament.	 Os coccyx and distal fossa of sacrum. Os coccyx and analococcyx tendon. Os coccyx, sacrum.	Pubococcygeus and iliococcygeus contract the anus and vagina. They aid in continence by pulling in the rectum.The ischiococcygeus tilts the pelvis posteriorly. The pelvic floor muscles aid in exhaling, IAP and they support the internal organs near the hips.	Ventral ramus nerve and pudendalis nerve
Multifidi	The tracts run between vertebras, from the lamina or the spinous process to the transverse process and/or the posterior surface of the sacrum.		Stabilisation, fine motor control of movements, rotation.	Medial dorsal ramus

TABLE 2. The local muscles of the core and their function (Modified from Brumitt, 2012; Koistinen et al 2005, 180-181,215-220; Richardson et al 2005, 36-38)

The fasciae and ligaments of the core (FIGURE 7), include the thoracolumbar fascia, inigual ligament, linea alba, lacunar ligament, iliolumbar fascia, intertransversal ligaments, transversalis fascia, anterior and posterior longitudinal ligaments, ligamentum flavum, interspinosus ligaments and the supraspinosus ligaments. These act as insertion areas for muscles, give support at the last part of movements and aid in maintaining the stability of the spine. (Richardson et al 2005, 16, 31-39.)

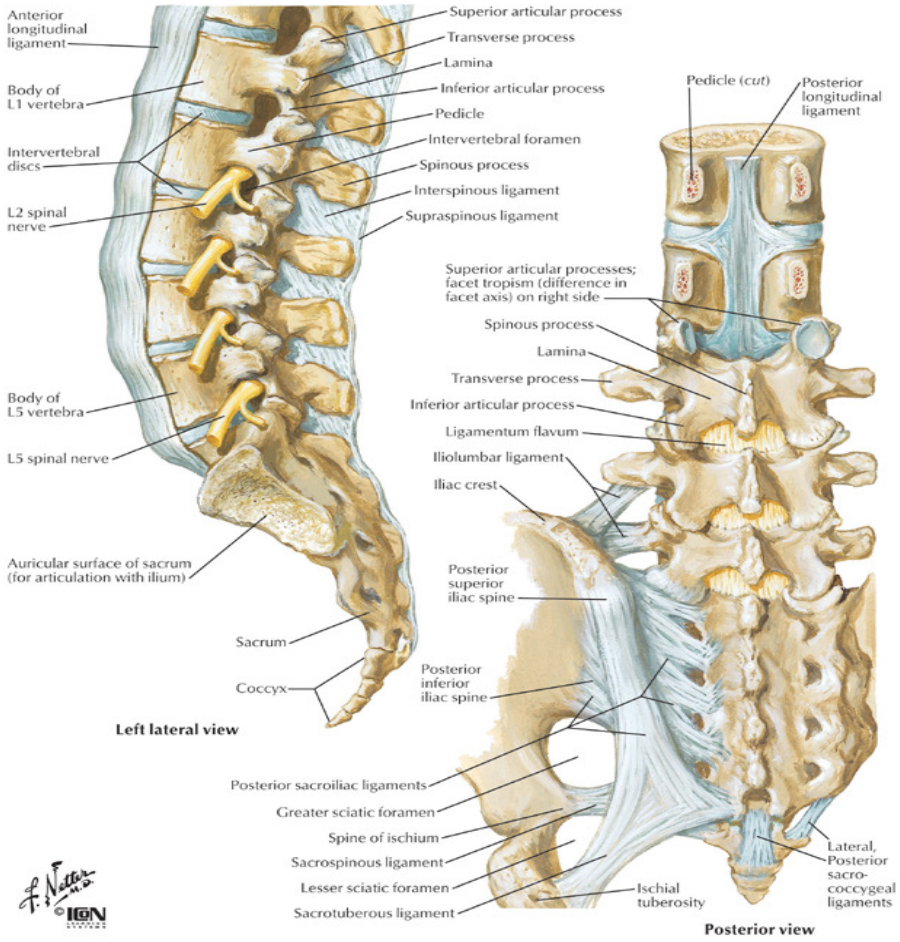

FIGURE 7. Anatomy of the spine. Ligaments related to the core. (Back Pain Guide 2012)

The thoracolumbar fascia has an important role in the functioning of the body since it is a link between the upper and lower extremities and the centre of multiple kinetic chains and partly helps in stabilising the core (Kibler et al 2006, 191). Once the transverse abdominal (TrA) is activated IAP rises and it tightens the thoracolumbar fascia, which is regarded as the most important fascia in core stability (Borghuis et al 2008, 898). According to Richardson et al (2005, 78 - 79) ligaments may also exhibit an ability to control the stability of articulations and co-ordination together with the feedback method of the CNS.

3.2 Core Control

The nervous system consists of the central nervous system (CNS) and the peripheral nervous system. The peripheral nerves receive messages from the alfamotor neurons

in the CNS to ignite and cease movement in muscles by causing a chemical reaction that causes the muscle to contract or rest. The central nervous system (CNS) consists of the brain and the spinal cord. It controls our movements. It calculates the exact time of igniting the movement, when to end it and what muscles to use. (Borghuis et al 2008, 894; Magill 2007, 65, 111; Niensted et al 1999, 544 - 545.) The CNS is constantly evaluating our stability and interior and exterior factors that could affect it. It receives afferent messages for instance from mechanoreceptors, then it must interpret these messages and give commands to use certain strategies to maintain our stability. (Richardson et al 2005, 20.)

When discussing core stability, strategies called **feedforward and feedback** are used. Feedforward refers to the CNS activating needed strategies, built from previous experiences, to act on a foreseen perturbation. The strategy uses visual and vestibular information. Feedback refers to the CNS acting when an unforeseen perturbation has happened. Usually these are quick events where the CNS uses reflexes to maintain stability. (Borghuis et al 2008, 900-901; Richardson et al 2005, 21-25.)

A third strategy to maintain stability is proprioceptic information received from muscles (both agonist and antagonist muscles), which incorporates feedforward and feedback strategies. In the strategy muscle stiffness protects the joints in order to maintain stability. In locomotion all of the strategies are used and could also be used at the same time. The quicker the response is to perturbations, the better is the probability to maintain stability. (Borghuis et al 2008, 900-901; Richardson et al 2005, 21-25.)

In order for us to be able to control our muscles we need to practise and strengthen our nerve paths to work efficiently. For instance, when working on our core, we must first practice to activate the correct muscle(s) correctly and control them. Then we are able to continue strengthening the muscles when the correct recruitment pattern has been achieved. Learning correct muscle recruitment patterns is highlighted for patients with low-back pain or a tendency for lower extremity injuries, since these patterns may be abnormal and thus could be causing pain. (Borghuis et al 2008, 903, 909; Filipa et al 2010, 2; Richardson et al 2005, 178 – 179.)

Muscle recruitment refers to the collaborate activation of muscles to perform a specific function and to stabilise the spine. The patterns differ according to what function

is performed. Muscle recruitment patterns can be exercised by first practicing to activate muscles that are in charge of segmental stability, secondly practicing closed kinetic chain movements where resistance is gradually added to ensure safe and correct movement, and thirdly by practising open kinetic chain movements, where resistance is also added gradually. The evolution of these exercises is pictured in the motor control learning sphere (FIGURE 8). (McGill et al 2003, 353; Paillard et al 2011, 1622; Richardson et al 2005, 176 - 183.)

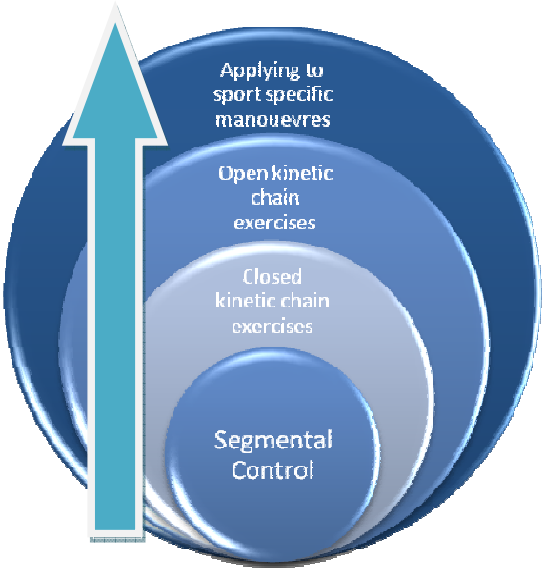

FIGURE 8. Motor control learning sphere. (Modified from Richardson et al 2005, 181)

Segmental control exercises refer to exercises where the athlete is focusing on trying to merely activate certain muscles in a certain segment. **Closed kinetic chain exercises** included movements like the push-up, the plank and squats. In these exercises the moving joints are weight bearing and touching the surface. In **open kinetic chain exercises**, like hip abduction or bicep curls, the moving joint is not weight bearing or in contact with the base. These exercises require more precision and control. An example of applying these exercises to sport specific manoeuvres is of balance training for surfers where vision is impaired and the use of proprioception is emphasised. Examples of other appropriate core stability exercises are abdominal crunches with a twist performed on a gym ball and the plank. (McGill et al 2003, 353; Paillard et al 2011, 1622; Richardson et al 2005, 176 - 183.)

A kinetic chain refers to when the body is working together to produce a certain movement or force in one or more joints. It includes the following components: neural, muscles and fascia. These components activate in a precise sequence to perform a movement. The slightest change in for example the anatomy or function of the ankle may affect the functioning of a whole kinetic chain and could be the reason behind someone's knee pain or low back pain. For instance, postural control requires the whole body to be active or ready to act to maintain stability. (Kibler et al 2006, 189-190; Terveyskirjasto 2012.)

Without neuromuscular control it is possible to end up having an injury, muscle imbalance or incorrect movement patterns, which can affect our functioning, especially in the athletic level. Strength and endurance play a critical role together with muscle control as they are all needed to win forces that act on the body to try and produce instability. (Borghuis et al 2008, 902-904, 908; Filipa et al 2010, 2.) Borghuis et al (2008, 906) state that sometimes elite level of athlete performance and technique might demand altered functioning of muscles and muscle control. They also state that core stability training should concentrate on combining functional exercises for both local and global muscles so the best possible control of posture and alignment is achieved. Good core and muscle control may improve balance and stability, and these can easily be trained with the Swiss ball or on another unsteady surface which offers more efficient core training than a solid surface. (Borghuis et al 2008, 906, 908-910.) Filipa et al (2010, 2) suggest core training should include exercises that focus on controlling the COM since if it is not controlled it may pose a possibility for injury.

3.3 Biomechanics

Core stability is needed in all three planes of motion and the need for core stability increases in sports as tasks are more demanding than activities of daily living (ADL) tasks (Borghuis et al 2008, 904). In sports, like surfing, when perturbations arise, either from internal (CNS, forces reacting on extremities) or external (surf, waves, unpredicted movements of the surfboard, marine life) factors, they may affect balance and stability. Sport and ADL tasks require the subject to maintain dynamic balance while producing forces. When instability occurs the body tends to compensate by co-contracting muscles which in turn affects the production of forces. (Borghuis et al 2008, 899.)

The main tasks for the core are preventing buckling forces to act on the spine and transferring forces to and from the core. Thus the CNS sends signals to muscles to activate when forces act upon the body and are needed for stabilising the spine. An example is the flexion of the upper extremity: the transverse abdominal muscle (TrA) activates prior to the ignition of the movement and is followed by a certain order of muscle recruitment needed to stabilise the spine during the movement. Constant contraction of the core muscles during motion has not been found to occur. (Hyvärinen et al 2010, 3; Kibler et al 2006, 192; Richardson et al 2005, 21; Vleeming et al 2007, 490 - 491.)

During lifting the core activates together with the back extensor muscles to protect and stabilise the spine from forces acting on it. The need for stabilisation increases in twisting movements and in movements in an upright position. The muscles stabilise the spine together with the fascia and ligaments of the core and back. It is suggested that during lifting the spine should be in a neutral position or slightly straightened. (Vleeming et al 2007, 168 – 169, 172 – 173.)

Kibler et al (2006, 192) present that core activation makes it possible for the distal segments of the body to produce accurate and / or larger forces. For example in a throw the core activates prior to the upper extremity movement to stabilize the body and aids in transferring forces to the upper body and extremity to produce an efficient and strong throw. Kibler et al (2006, 192 - 193) present this as “proximal to distal development of force and motion”. The idea is supported by Myers (2009, 171 – 177) who presents the same function with “functional lines” of the body, i.e. muscle chains that work together to produce a movement. So the core works as a centre of force which allows distal movement with efficiency and accuracy when stable. When stability of the core fails to function appropriately, it can appear as an injury, pain, differing posture or position of the body. (Kibler et al 2006, 192 – 193; Myers 2009, 171 – 177.)

3.4 The Role of Core Stability in Physiotherapy

In physiotherapy core stability is considered to be a key factor in preventing back pain, hip pain and injuries. **Correcting posture, handling perturbations and con-**

trolling movements in general include activating the core. Athletes require good core stability to use kinetic chains efficiently when transferring forces to and from the core. In order to be able to complete activities of daily living (ADL) and athletic movements "it is important to have sufficient strength and stability" and along with that, athletic performance could develop. Controlling movements, transferring forces and performing movements safely are highlighted in order to reduce pain and achieve fluid, economic movements. (Hibbs et al 2008, 995-998; Borghuis et al 2008, 908-909; Filipa et al 2010, 2; Hyvärinen et al 2010, 3 - 4.)

Sharrock et al (2011, 65) differentiate the actions in core stability and state that abdominal muscles control "the position of the spine and pelvis" when the TrA is in charge of increasing intra-abdominal pressure (IAP) and tensions the thoracolumbar fascia. The thoracolumbar fascia is seen as a link between all kinetic chains in the body (Kibler et al 2006, 191). Borghuis et al (2008, 895) agree that **the core is a system that stabilises the body and the spine in static and dynamic functions**, and that it is central to all functional kinetic chains. In general having good core stability is a way to lower the risk of injury and decrease lower back pain. **Good core stability** can increase balance and proprioception, enable faster movements and aid in directing forces to the extremities thus enabling smooth, controlled and effective movements and lessening compensatory movements. (Whyte et al 2009, 104.) Borghuis et al (2008, 897) present a finding by Arokoski et al that "core muscle activity precedes lower extremity muscle activity". It is to say that in order for the lower extremity muscles to function appropriately one must activate the core for core stability to be present when the lower extremity needs to work. Kibler et al (2006, 192) present this as "**proximal stability for distal mobility".**

A neutral spine position has the normal curvatures of the spine: cervical lordosis, thoracic kyphosis and lumbar lordosis. In this position the body can be most economical and efficient, and the position provides stability, protects the lumbar spine and prevents the back extensor muscles from being stretched and thus losing strength. In order to be able to control this position one needs to control the local muscles that give stability and segmental control, and the global muscles that work together with the local muscles. (McGill et al 2003, 356; Richardson et al 2005, 67 – 68, 83.) Keeping this position can prevent low back pain and as the neutral spine position gives stability it may also prevent injuries and pain. In therapeutic exercises especially the activation

of the multifidi and TrA muscles are recognised to be the main focus in treating low back pain. Regarding lumbo-pelvic pain, Richardson et al (2005, 85 – 88) state that activating the TrA and other muscles situated transversely in the pelvic region stabilise the lumbo-pelvic area and protect it from shearing forces and gravity, thus eliminating pain in the area. (Richardson et al 2005, 71, 85 – 88, 94.)

Core stability also aids in controlling balance (Richardson et al 2005, 94). As the core is the centre of force production it needs to be stable and strong in order for other parts of the body to function. Therefore core stability and strength is emphasised with the treatment of knee pain, back pain and even shoulder problems. If one has problems with controlling the hip alignment (i.e. presents the Trendelenburg posture: when standing on one leg the hip drops on the opposite side of the stance leg due to muscle weakness) it may indicate poor core stability. This in addition can have adverse effects on balance. (Kibler et al 2006, 193 – 194; Sharrock et al 2011, 65.)

It is noted that good core stability can prevent injuries, decrease low back pain and generally protect the spine, increase dynamic stability and can possibly improve athletic performance through more effective force transferring and better balance (Borghuis et al 2008, 901; Filipa et al 2010, 5-6; Hibbs et al 2008, 999-1001; Kibler et al 2006, 189, 193). Borghuis et al state that especially females may be prone to injuries in the lower extremities if their core stability is poor. If core stability is poor reflexes may take over in sudden disturbances of stability and could produce an injury as the movement would be compensatory and specified to a certain direction according to the muscle that activates. Decreased proprioception can also cause injuries as it exposes the extremities to larger forces and may also cause misalignments of the body as the neural component's functioning would decrease. (Borghuis et al 2008, 896, 901.)

There are plenty of core exercises, but no efficient evidence-based training program has been developed yet (Borghuis et al 2008, 908). Hibbs et al (2008, 998) state that core training includes exercises for learning motor control and exercises that aim to increase strength. The most popular equipment used in core training is the Swiss ball, balance boards, soft surfaces and BOSU balls. These are used with functional movements that resemble the actual movements or functions in a specific sport or everyday task. (Hibbs et al 2008, 998; Filipa et al 2010, 17.) Body position awareness, muscle recruitment and control should be emphasized in core training. Exercises where pro-

prioception and coordination are challenged are also seen to be efficient. (Borghuis et al 2008, 908-909.) In surfing the following exercises with the Swiss ball are most commonly promoted on internet sites offering exercise tips for surfers: plank and knee tuck, back extension exercise and stretches for the spine (Surf Stronger 2013).

4 RESEARCH PROCESS

For data collection in this thesis I used a technique called the Delphi –technique, also spelled as Delfi or Delfoi. It was invented in the United States in the 1950's. This technique is used to achieve a consensus on a certain matter. It is best used when a matter has to be solved between at least two parties or when no previous data is available on the topic. (eDelfoi 2012; Hsu & Sandford 2007, 1; Linstone et al 1975, 4, 10.) The Delphi technique has three characteristics: anonymity, iteration and feedback. It includes choosing a panel of professionals who are experts in the field to be studied. They are then asked questions in two to three rounds or until mutual consensus has been reached or no new interesting or relevant information is produced. Some references (Hasson et al 2000, 1009; Hsu & Sandford 2007, 1- 3) referred to the use of questionnaires for rounds to receive quantitative data, but nowadays there are multiple modifications of the technique in use. The group and the questions are selected by the researcher(s). All answers from the experts are summarised and sent back anonymously to the professionals to be commented on. Experts are allowed to refine their answers to previous questions after viewing the summary of all responses. A new round of questions will also be sent. Usually a period of two weeks is given to reply to a set of questions. The question for round one is normally a rather open and broad question, that has been chosen after the researcher has familiarised him or herself extremely well with the literature on the matter. Following questions are more detailed. All answers and respondents are anonymous. (eDelfoi 2012; Hasson et al 2000, 1008-1010; Hsu & Sandford 2007, 1 – 3; Linstone et al 1975, 5 - 6.)

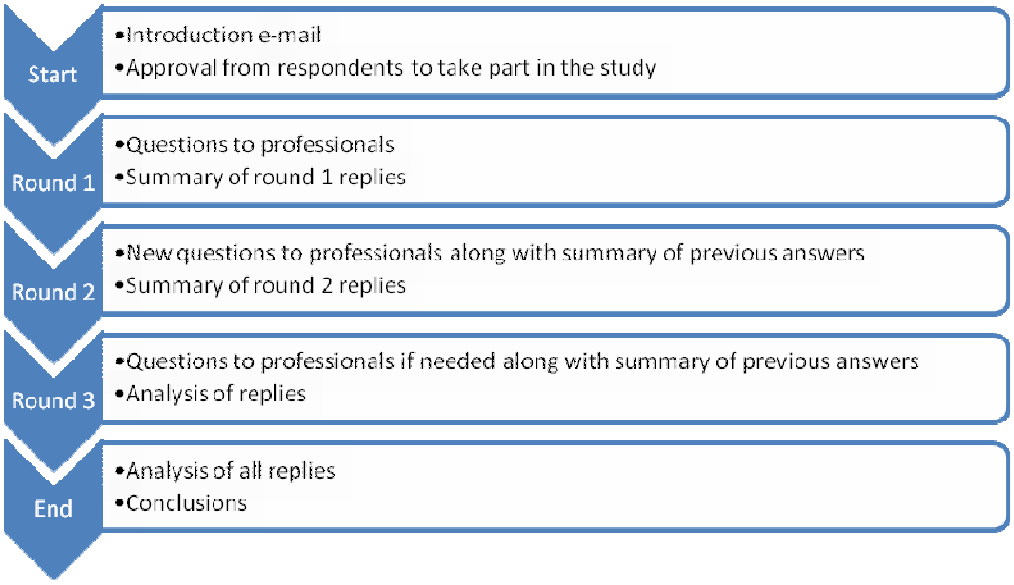

FIGURE 9. Process flow of the Delphi technique (According to Hsu & Sandford 2007, 1 - 5)

When the respondents receive a summary of the previous questions they are able to reflect on their own opinion and comment on other replies. External distractions are eliminated in this method as respondents are able to give their honest opinion on the matter without, for example, peer pressure or stronger and more active counterparts affecting their answer. This gives a fertile ground to finding the best possible consensus. (Hsu & Sandford 2007, 2.)

The Delphi technique represents qualitative research it being a form of interview. A qualitative research aims to describe a natural (usually an intricate) phenomenon, possible causes and effects and professionals' views on the matter. (Shuttleworth, 2008.) As no previous studies have been conducted from this point of view on the topic, and my study questions aim to find out the role of core stability in surfing, it was appropriate to choose a qualitative method for a study in this scale. Hence it is more effective to perform a quantitative research on the topic after main areas of interest and importance have been established for example, related to this study, measurement of the activation and usage of core muscles.

Considering my available resources, and the fact that surfing has not been studied from a physiotherapy point of view, I opted to use this method as it gives a possibility to gain new information of surfing and core stability in a way that both suits my schedule and resources. Even though a quantitative research, like measuring the activ-

ity of surfers' core muscles during a surf session could have been more accurate, but unfortunately it was not possible to perform a study as such in Finland as there is a minimal number of surf days per year, and the surfing conditions in Finland are not compatible with surf conditions elsewhere. Using the Delphi method requires no funds, which was another influencing factor.

4.1 Study Questions and Data Collection

My study questions are:

- What is the role of core stability in surfing?
- Which function(s) is it needed most for in surfing?
- What kinds of exercises are beneficial in achieving or maintaining good core stability?

I am interested in finding an answer to these questions as the topic has not been studied before, yet the sport is gaining popularity and surfing is started at a very young age. Thus there can be multiple possibilities for injury, and this study and the data received from it could help physiotherapists and other health professionals prevent injuries, support or rule out the need for core stability exercises in athletes' training regimes and possibly could even enhance athlete's performance.

In this study I wanted the chosen professionals to find consensus on the role of core stability in surfing, and to define in which function it is needed for the most. I sent invitations to take part in the study to a doctor of chiropractic, physiotherapists and an exercise physiologist. I took the respondents' contact information from internet articles and studies on surfing and surfing fitness where they have been as authors or co-authors. Inclusion criteria consisted of the following aspects:

a) A health professional
b) Working with surfers or researching/taking part in surfing
c) Capable of communicating in English via email

Some respondents have not published articles, but have worked with surfers. I found 8 experts of whom I needed at least 3 to commit to taking part in the research. The answers received from the respondents are reliable as the respondents were chosen so

that they have experience on surfing and that they are dealing with surfing or surfers in their profession. All respondents work within health or health related areas. After the required number of question rounds the answers are analysed and conclusions are drawn (Hasson et al 2000, 1010; Hsu & Sandford 2007, 3 - 4). Questions for the panel and their summaries are exhibited in appendix 5.

The letter for approval was sent to nine (9) participants in November 2012 via email. Two email addresses did not work. I received one refusal to participate in the study and five acceptances. A minimum of 3 respondents was needed for this study, and in order to reach this goal, I took part in the study. When the approval was received, from 5 respondents, I began the first round and sent detailed information on the study and what is to be expected of the respondents. This was done as it has been noticed to have an effect on the response rate (Hasson et al 2000, 1011) (Appendix 6). Two weeks were given for replying, after which I sent a reminder to all the respondents about replying as I had received one response. After receiving two replies I analysed the answers, reflecting them on my theoretical knowledge and knowledge acquired by experience on the matter, and sent a synthesis of the responses back to the panel with a new set of questions –based on their previous answers – on the 25th of January. Again I gave two weeks' time to answer the questions, analysed the two answers received and sent a new set of questions along with a summary of the previous answers. The analysis of the final round answers begun in February 2013. The study took place in December 2012 to February 2013 in Finland and partly in Australia. All research questions were sent to respondents by email so the actual environment in which the study was conducted is not an essential factor.

The first round of questions included defining core stability according to this thesis so I ensured that all participants are communicating and discussing the same structures and functions, since the concept still has very diverse definitions. That is, core stability includes active, passive and neural components as presented in this thesis. The neural component is in charge of muscle recruitment, activation and stability strategies. Core stability is the basis of functioning, force transferring and supporting and protecting the body and spine. (Kibler et al 2006, 189-190; Hyvärinen et al 2010, 3; Richardson et al 2005, 14-19.) The letter sent to the participants on the first round is presented in appendix 6. **The second round** of questions included a summary of round one to the respondents for commenting and new detailed questions that are also

presented in appendix 7. **The third round** of questions included a summary of round two, and a new set of questions presented in appendix 8.

4.2 Data Analysis

The method used to analyse the data after reaching consensus, is a qualitative content analysis (KvaliMOTV 2006). With this method I am able to gather all the information together and form a concise summary of what has been discussed and to highlight the end result with the facts presented by the experts. I should also be able to form concepts that can be applied into everyday physiotherapy or training. According to Hasson et al (2000, 1011) data analysis is "the discovery of opinions; the process of determining the most important issues; and managing opinions".

Coding, for example colour-coding the data, has been recognised as an effective way of reading through the data and finding similarities. It also shows which areas were spoken of the most. (Hasson et al 2000, 1012; KvaliMOTV 2006.) According to Tuomi & Sarajärvi (2011, 94) grouping replies, or in other words putting similar replies together, makes data analysis easier and more structured. Analysis of the received data was based on the study questions, that is, I searched for an answer to my study questions in the data received. I also presented matters that were agreed on and were carried throughout the interviews. I will present the similarities, differences and the topic that brought on the most discussion amongst the respondents. In figure 10 is a diagram clarifying the data analysis process.

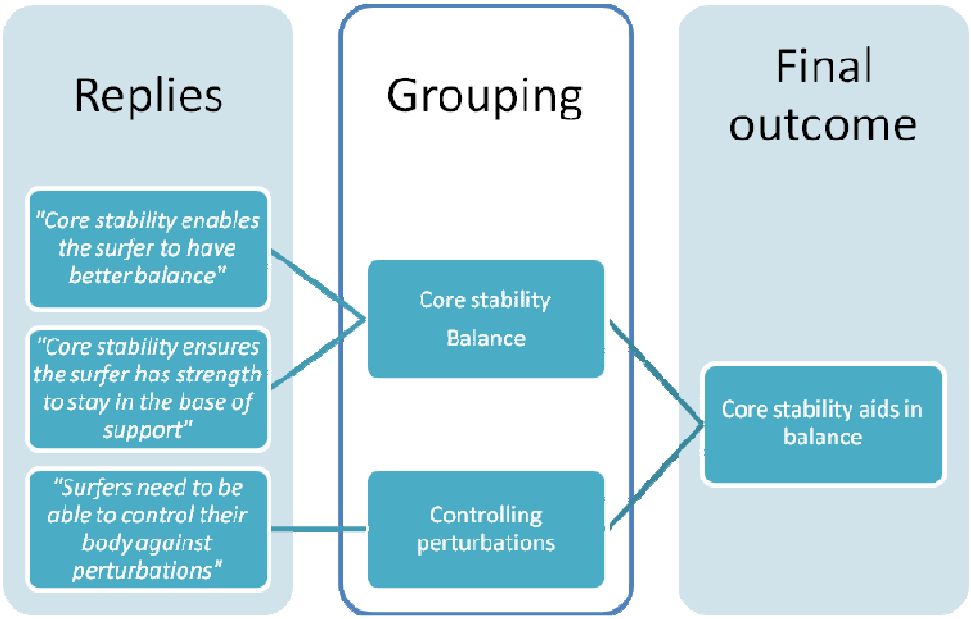

FIGURE 10. Example of the process of data analysis (Modified from Tuomi & Sarajärvi 2011, 94)

4.3 Reliability and Ethics

The Delphi-technique is considered to be an effective way of receiving information on a subject that does not have evidence-based material yet available. It is flexible and rather easy to apply, but it does present some problems. The method can take up a lot of time, experts' opinions might change on the course of the study even though most distractions are eliminated and they might not even reply after the first round. The respondents can also be from very different backgrounds, making it hard to reach consensus on an elaborate matter, but a group presents a lesser likelihood to produce incorrect or specious results. The results could vary if a different group of respondents would have taken part in the study. (Hsu & Sandford 2007, 1, 3 - 4.) The problem in this study could have been that the panel would have consisted of surfers only, thus the physiotherapy view on the matter might not have been the focus point. However, as I chose the panel to include physiotherapists, I ensured that the professional view on the matter was combined with the surfers' views through experience. Another problem arising through having surfers take part in this study is that they are the subject of research and the result can affect their life and work.

The data analysis depends on the researcher's devotion to the study also as the researcher needs to prepare the study well, and to process and see through all disputes

and disagreements to form valid concepts. For the eventual analysis to be valid and reliable I shall not discriminate any opinions stated by the respondents as it should be up to the panel to decide which concepts are carried through the entire study. Considering my resources for the study and participation rate, the results are to be taken as guidelines as a larger number of participants would be needed to form reliable new concepts that could be generalised. (Hasson et al 2000, 1010, 1012; Hsu & Sandford 2007, 5; Linstone et al 1975, 6.) That is to say, results from the Delphi technique are safe to be taken as guidelines and not as the absolute truth in this study. For a study to be reliable it should be possible for anyone to repeat the study and receive identical results with the original study. This is mainly applied with quantitative studies. (Shuttleworth 2008; Virtuaali ammattikorkeakoulu 2012a).

According to the National Advisory Board on Research Ethics in Finland (2002), research must be accurate, honest, ethically correct, public, promptly planned, and it must respect others' work and the participants of the study. This method is therefore ethically correct as it is publicly available, respects others and their work, and it is conducted in a prompt and honest manner. It also gives respondents the possibility to choose whether they want to participate, all their information is kept anonymous and classified from others. The method is ethically safe as no data is revealed to the respondents that could damage them physically, mentally or financially. No research proposal was needed for this study since the Delphi method requires only individuals to answer presented questions. A letter of approval was sent to all participants to be sure that all respondents took part in the study voluntarily.

The research questions and topic are of such manner that they are ethically correct. All respondents received the same questions and all replies were handled anonymously and analysed equally. Collection of this data does not harm any human being. (Virtuaali ammattikorkeakoulu 2012b.) I collected and analysed the data in this study according to the above mentioned guidelines.

5 RESULTS

The results of this study are presented in the order that the data was received so that the nature of the discussion can easily be seen. The results are based on two physiotherapists' replies of which one surfs and the other one has been working with surfers.

Both of them have been working and developing their skills in musculoskeletal and sports physiotherapy for some years. I joined the panel by reflecting on the respondents' answers with my professional views acquired by my work on this thesis and experience-based knowledge on surfing. For each round I have presented the anticipated answer according to the theoretical framework and my professional view and experience on surfing. I have also chosen quotes from the original replies to highlight certain areas of interest. With this theoretically correct answer and the responses received from the professionals I formed syntheses were sent to the respondents to be commented on.

The first round question was: what is the role of core stability in surfing?
According to my professional view and experience I would define the role of core stability as something which ensures that the needed balance is gained during paddling, pop-up, standing and doing manoeuvres on the surfboard. It acts as the centre of strength and enables the other parts of the body to work efficiently and safely, i.e. causing no injuries. The responses received from the experts highlighted similar topics. The main topics that were discussed were:

QUESTION	ANSWERS
What is the role of core stability in surfing?	Stability Injury prevention Enabling extremities to work efficiently Structural alignment Force projection Balance

TABLE 2. Question and answers to round one

"...surfers are able to function in a co-ordinated fashion without overloading their central and peripheral joints...the spine to be supported as to reduce injury and increase sustainability."

"...maintain structural alignment...initiates movements... allowing the upper and lower limbs to have a stable base to move from."

As these responses mainly discussed different areas of core stability and which functions it has, my follow-up questions that I had planned earlier seemed fitting. I intended to find out more about which specific manoeuvres require core stability and how core stability is used during surfing. These questions were designed to have the experts reflect on the topic and give more in depth answers.

The second round questions were:

a) Which surfing manoeuvres require core stability?
b) Which of those manoeuvres are the most critical and why?
c) How is core stability used in these manoeuvres?

According to the theoretical framework and my experience in surfing it seems as paddling and turns require core stability. (Méndez-Villanueva & Bishop, 2005a, 55-56). Also the pop-up phase requires core stability and the control and strength to stay within the base of support. Regarding force projection core stability is a key factor as it enables the extremities to work efficiently and prevents injuries from occurring as the strength basis is within the core. I have noticed a correlation with poor core stability and knee pain. Thus I think the most critical manoeuvre would be a strong turn where body alignment and force projection play an integral role.

TABLE 3 presents the responses received from the panel to questions of the second round.

QUESTION	**ANSWERS**
Which surfing manoeuvres require core stability?	All manoeuvres are critical Core stability ensures structural alignments thus avoiding injury
Which of those manoeuvres are the most critical and why?	Big turns are the most critical regarding core stability The pop-up is a critical manoeuvre
How is core stability used in these manoeuvres?	The need of core stability in contralateral movements Force transferring from core to extremities

TABLE 3. Questions and answers to round two

"all surfing manoevres!... standing up and big turns like reos, cutbacks etc where a lot of force is put through the spine while it is in a flexed position…the core holds the spine in correct structural alignment during these manoevres to avoid any injury to discs…"

"…the core muscles are vital for postural control …Even for something as seemingly easy as paddling the core is utilised to co-ordinate contralateral arm and leg motion as to ensure correct propulsion."

"…the core is pivotal in in both force transferal from the legs to the trunk and upper body to create the power to stand…It must also stabilise the vertebral column as to create a solid base upon which the surfer can create movement."

In order to be able to answer my last study question I conducted a third and final round. The questions for **the third round** were:

a) How can good core stability prevent injuries from occurring while surfing?
b) What exercises do you suggest surfers should do in order to improve their core stability? Why?

Question A was answered in round two so that was not sent to the respondents. Question B was rephrased from the original form presented in appendix 8. According to the theoretical framework and my own professional knowledge on the matter core stability ensures adequate and essential stiffness in the spine to protect it from forces acting on it (Hyvärinen et al 2010, 3; Kibler et al 2006, 192; Richardson et al 2005, 21; Vleeming et al 2007, 490 - 491). Thus it also ensures good alignment of the body and enables the global muscles to project larger forces safely and efficiently from the core to the extremities. Examples on how to develop core stability amongst surfers includes exercises with the Swiss ball, BOSU ball and other equipment that can be used to develop proprioception, balance and strength. Some good examples of exercises include the plank, balance exercises, pilates and yoga poses. The topics discussed during the third round are presented in TABLE 4.

QUESTIONS	ANSWERS
How can good core stability prevent injuries from occurring while surfing?	Answered in round two.
What exercises do you suggest surfers should do in order to improve their core stability? Why?	Postural control Lower extremity strength Functional training Twisting/rotating movements Contralateral movements Sport specific exercises

TABLE 4. Questions and answers to round three

"Surfers should work on core stability in postures and with forces that mimick those they experience surfing…might include those with twisting…"

"Rotational control exercises stressing contralateral body parts are essential when training surfers."

"As the motion of the water takes you forward yet turns require a rotational axis, training in one plane of motion will not transfer over the required skills"

With these results we can conclude that surfing is a complex sport where core stability is needed for stabilisation to ensure proper alignment of the body and to prevent injuries. It also affects surfing performance by enabling the extremities to work efficiently to perform precise movements. Core stability should thus be exercised by doing functional training where the movements are similar to the movement when surfing. An example would be a weighted squat with a twist.

6 DISCUSSION

According to the results of my study core stability is seen as an integral part of surfing. It is required to perform manoeuvres and to protect the body, especially the spine, from injury by stabilisation. Also an important function for core stability is to stabilise the core to enable precise movement of the extremities. This is needed in the completion of surfing manoeuvres. Exercises that surfers should work on include rotational movements, control exercises and especially exercises where contralateral movements

are focused on. These results correlate with the theoretical framework of this study. The same key areas were discussed in theory as in my study: using core stability to stabilise proximal areas and so enable distal movement, force projection and prevent injuries. Core stability training was also linked to sport or task specific exercises in both discussions. Whether other exercises or muscles can produce the same effect is still unclear.

The respondents discussed structural alignment which is presented in the theory chapter as stabilisation, segmental stability or protection of the spine. Several researches highlighted the importance of segmental stabilisation of the core in injury prevention. It was also discussed as the essential activation needed before commencing a movement in order to protect the spine, but also to ensure effective force transferring. (Borghuis et al 2008, 903, 909; Filipa et al 2010, 2; Richardson et al 2005, 178 – 179.) Force transferring from the core to the extremities, or as Kibler et al (2006, 192) stated "proximal stability for distal mobility", was seen as a central role of core stability in surfing. Respondents stated that this enables the surfer to maintain balance, produce strong turns and to have correct structural alignment while surfing.

Regarding **core stability exercises**, the panel agreed that functional training is most effective and the key to improving core stability. Borghuis et al (2008, 906, 908-910) presented similar ideas of core stability training where postural control, structural alignment and thus balance and stability are emphasised. Whether these exercises have an effect on preventing injuries is still unclear as the cause and effect between these exercises, core stability and injuries has not been presented regarding surfing. As similar exercises do have a decreasing effect on low-back pain it could be that these exercises may protect surfers from surf induced injuries. (Hibbs et al 2008, 995-996.)

Having gained all this information I have been able to answer my study questions and thus have reached my goal. I would have liked to be able to answer the questions in more depth, but this would have needed a larger group of professionals in the panel and more time to create an easier way for the respondents to answer, for example a multiple-choice questionnaire together with open questions.

The results are reliable, but not to be used for generalisation. I feel this study has not produced new information regarding surfing, but it has rather gathered the theory

basis on surfing and this is connected to the activity into an easy read format. Previously it was hard to find information on surfing and none of those articles discussed surfing from physiotherapy point of view, but now it is easily accessible in one study. More research needs to be done before this information can be used to describe surfing and surfers in general. However, hopefully the results can act as a guide for physiotherapists working with surfers and for individuals who are interested in developing their surfing skills. The results can help physiotherapists in structuring therapy sessions with surfers by presenting the critical functions that need to be worked on. I also hope the information will reach the surfing industry and increase the understanding of the role of core stability in surfing.

The actual study commenced in November 2012 by sending the first email to ask for respondents' consent to participate in the study. From here it took some time to gather the panel so that the first round could begin. Motivating respondents to answer seems to be most critical in studies like these. However, even with using the Delphi technique the results seemed to correlate with the previous studies executed on the subject of surfing. Reminding the respondents to answer the given questions was somewhat frustrating. Half way through the study I was pondering if I should have used a public questionnaire instead to gain all this information. However, the study was interesting, I gained information regarding surfing and I feel successful after completing this study. It gained supporting information for the role of core stability in surfing. Another problem I faced during the study was the fact that the first round was sent in December just before the holiday season began. Hence timing with the beginning of the study was bad as all respondents were on holiday and it took over a month to receive the needed three answers. If I were to repeat the study I would make sure the study would be executed outside of the holiday season, respondents would be truly committed to the study and would have enough time to answer all questions. Structuring the questions sent to the experts was challenging and I feel I should have spent more time thinking about the questions so that I would be able to answer my study questions in depth.

I started writing this thesis in September 2012. After deciding on the topic I had clear ambitions on how to continue with the process. However, writing the theory proved to be harder than I expected it to be. The scarce scientific or evidence-based information on surfing was astounding. Because of this I had to apply most of the data from other

areas of research to fit into my framework. On the other hand the abundance of information on core stability and what it consisted of was a different kind of shock. It was arduous to critically choose which articles to include in my thesis. I think this was one of the most educational sections of this process. Comments from my opponent and instructors were crucial in this part. Through the process I have greatly developed my professional skills regarding physiotherapy by understanding the connections of different areas required in human body functioning and by being able to apply these to my everyday work. I feel like I am an expert on core stability, which is a merit that will surely help me on my professional path.

Suggestions for further research includes whether surfers have a higher level of muscle control compared to other athletes or non-surfers or to complete a quantitative research where muscle activity during surfing is measured to establish the importance of core stability/activity in surfing. This could also assist in understanding which muscles are used in surfing and thus training can be developed further.

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APPENDIX 1.

TABLE 1. Literature Review Findings

Article Info	Theme for Study	Method	Main Findings	Importance for my Thesis
Méndez-Villanueva, A; Perez-Landaluce, J; Bishop, D; Fernandez-García, B; Ortolano, R; Leibar, X; Terrados, N 2005. Upper body aerobic fitness comparison between two groups of competitive surfboard riders. WWW-document: http://ac.els-cdn.com/S1440244005800234/1-s2.0-S1440244005800234-main.pdf?_tid=29c94d36-0bbd-11e2-8c41-00000aab0f6b&acdnat=1349091965_496d73841614ff62e2d04757b23f9022. Read 1.10.2012. No update information.	To define whether upper body aerobic fitness contributes to surfing performance. The characteristics were evaluated and compared between two different performance levels.	13 surfers from two different performance levels were divided into two groups according to their ranking. Data was collected for 3 months and at the end of the competitive season. Peak oxygen uptake, peak power output, exercise intensity and lactate levels were studied, using a paddling test on land.	Upper body fitness was better amongst better surfers and their lactate threshold was higher than surfers that were ranked lower (according to performance).	This article gives a reference for describing surfing and it also gives evidence on what sort of fitness surfing requires from the surfer.
Frank,Martin; Zhou,Shi; Bezerra, Pedro; Crowley, Zachary 2009. Effects of Long-Term Recreational Surfing on Control of Force and Posture in Older Surfers: A Preliminary	To study whether surfing has long-term effects on neuromuscular function.	11 surfers and 11 non-surfers were compared according to maximal isometric voluntary contraction force (MVC), rate of force	The surfers exhibited less postural sway when standing on a soft surface blind folded, they had less muscle force fluctuations in	The study focuses on what effect surfing may have on a person's functioning, mainly balance. This is important as these actions

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Article Info	Theme for Study	Method	Main Findings	Importance for my Thesis
Investigation. WWW-document: http://ac.els-cdn.com/S1440244005800234/1-s2.0-S1440244005800234-main.pdf?_tid=29c94d36-0bbd-11e2-8c41-00000aab0f6b&acdnat=1349091965_496d73841614ff62e2d04757b23f9022. Read 1.10.2012.		development, muscle force production steadiness, joint position sense, and body sway in standing on different surfaces and conditions.	the steadiness test. According to this study's results surfing could help maintain and/or improve neuromuscular function and thus would help improve quality of life.	are associated with core stability.
Méndez-Villanueva, A; Bishop, D 2005. Physiological Aspects of Surfboard riding Performance. Sports Medicine: 35(1):55-70.	This was a review of all the aspects required in surfing.	Literature review of different studies from the surfer specific field.	Little is known about surfing. It requires aerobic and anaerobic fitness, endurance, strength, power, balance, co-ordination. Surfers have been proven to have above average results from testing the above characteristics. Abdominal muscles strength was lower compared to other athletes.	This article gives support for describing surfing, its demands, history, competing and much more. It discusses surfing from different point of views so it is possible for me to apply information from this article to my thesis.

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Article Info	Theme for Study	Method	Main Findings	Importance for my Thesis
Farley, Oliver R.L.; Harris, Nigel K.; Kilding, Andrew E. 2012. Physiological Demands of Competitive Surfing. Journal of Strength and Conditioning Research. 26(7)/1887–1896. National Strength and Conditioning Association.	Analysing the performance of competing surfers in order to understand what surfer-specific training should include.	12 surfers competing on a national level were monitored with heart rate and global positioning system during two competitions. Their performance was videoed.	The researchers found, that the greatest time during surfing was spent paddling, and that 60% of the time surfing the surfers had a heart rate between 56% and 74% of their maximum heart rate. The results indicate that surfing is an intermittent activity with high-intensity bouts and relatively short recovery periods. It also includes low-intensity paddling with sporadic breath holding (during duck dives).	This article gives another reference for describing surfing, what it demands from the surfer and also gives apt suggestions on how to apply the findings in practice.
Farley, Oliver R.L.; Harris, Nigel K.; Kilding, Andrew E. 2012. Anaerobic and Aerobic Fitness Profiling of Competitive Surfers. Journal of Strength and Conditioning Research. 26(8)/2243-2248.	Measuring and analysing the aerobic fitness and anaerobic power characteristics of surfers and find the correlations of these with surfing performance.	A modified kayak ergometer test was used to measure the peak oxygen uptake, maximal power output, heart rate, and expired and ventilated gases were ana-	Season ranking correlated with relative anaerobic peak power. No other significant correlations were found, but researchers say that aerobic capacity is	The study gives more evidence on physiological aspects of surfing. It also gives support for describing surfing.

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Article Info	Theme for Study	Method	Main Findings	Importance for my Thesis
National Strength and Conditioning Association.		lysed by a metabolic analyser. A correlation analysis was used to analyse data, and season rankings were used to find correlations with surfing performance.	still important concerning surfing performance, as surfing is described to be an intermittent sport with high fitness level aerobic bursts.	
Sharrock, Chris, Cropper, Jarrod, Mostad, Joel, Johnson, Matt & Malone, Terry 2011. A Pilot Study of Core Stability and Athletic Performance: is there a relationship? WWW-document: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3109894/pdf/ijspt-06-063.pdf. The International Journal of Sports Physical Therapy. Volume 6, Number 2, June 2011, Pages 63-74. Read 16.10.2012.	To determine whether a correlation between core stability and athletic performance exists.	35 college students volunteered to take part in the study. A double leg lowering (DLL) test was used to measure core stability and it was compared with athletic performance test results from the T-test, vertical jump, medicine ball throw and a forty yard dash.	A significant, but weak negative correlation was found between core stability and the medicine ball throw test. Males represented better results in the core stability test compared to females.	As I am studying the importance of core stability in surfing this article gives a possibility to apply some of the findings into surfing. It also discusses core stability in general so it is a good reference for my thesis.
Filipa, Alyson, Byrnes, Robin, Paterno, Mark V., Myers, Gregory D., Hewett, Timothy E. 2010. Neuromuscular Training Improves Performance on the Star Excursion Balance	Researchers wanted to determine whether the SETB test results improved in female soccer players after taking part in	20 female soccer players completed the SEBT pre- and post- training. 13 subjects took part in a training group and 7 subjects in a	SEBT results improved significantly with subjects who took part in the NMTP. Anterior direction reach showed no differ-	This article discusses core stability amongst young female athletes and gives a point of view on what exercises may improve core

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Article Info	Theme for Study	Method	Main Findings	Importance for my Thesis
Test in Young Female Athletes. WWW-document: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3439814/pdf/nihms399121.pdf. Journal of Orthopaedic & Sports Physical Therapy. September 2010. 40(9): 551-558.	an 8 week neuromuscular training program concentrating on core stability and lower extremity strength.	control group that did not receive NMTP.	ence. NMTP could prevent injury in lower extremities. Core stability could also influence stability of the lower extremities in fast athletic manoeuvres.	stability.
Hibbs, Angela E., Thompson, Kevin G., French, Duncan, Wrigley, Allan, Spears, Iain 2008. Optimizing Performance by Improving Core Stability and Core Strength. Sports Medicine 2008; 38(12):995-1008.	The writers of the article review studies on core stability and strength and how core training programs have affected athletic performance.	The writers compare studies on the effectiveness of core training on athletes' performance with findings from literature.	Definitions of the core are multiple, usually depending on how it is viewed (domestic vs. athletics). Currently there isn't a global definition for the core, what core stability or strength is and how these can be exercised. Many valuable choices are available.	This study gives important views on the basic knowledge about the core, what it includes and how it is viewed. It is possible to apply information from this article to surfing as the writers had a rather unanimous view on what role core stability has in athletic performance regardless of varying study results. The writers also suggest numerous exercises for the core, core stability, strength endurance and motor con-

APPENDIX 1.

Article Info	Theme for Study	Method	Main Findings	Importance for my Thesis
				trol.
Kibler, Ben W., Press, Joel, Sciascia, Aaron 2006. The Role of Core Stability in Athletic Function. Sports Medicine 2006;36(3): 189-198	This is an opinion on core stability, where a definition of core stability is given. Also the anatomy, physiology, functioning and dysfunction, along with views on rehabilitation and clinical evaluation of core stability are discussed.	The writers combine evidence from literature, studies and work experience to explain to the reader what core stability is and how it could be assessed and exercised.	The core is an integral part of all functioning as it affects both lower and upper extremities' power, speed and accuracy. It should be emphasized with a functional view when rehabilitating injuries.	This article discusses core stability and is important for my study as these findings can be applied to it. It describes the different segments of core stability and is an excellent reference for comparing and describing current knowledge about core stability.
Borghuis, Jan, Hof, At L., Lemmink, Koen A.P.M. 2008. The Importance of Sensory-Motor Control in Providing Core Stability: Implications for Measurement and Training. Sports Medicine 2008: 38(11): 893-916.	This is a review article that gathers information about core stability from several points of views: anatomy, athleticism, injuries, neuromuscular control, balance, training and measuring core stability.	The authors have reviewed articles written about core stability and formed a concise article on the matter.	The definition for core stability varies. The core provides stability for the body against forces acting upon it. Muscles must work together to form a working segment together with the CNS. Correct activation time and order is vital for core stability to work. Poor core stability	The article gives profound information on core stability and is also one of the few that handle the importance of controlling the muscles and in what order they are activated.

APPENDIX 1.

Article Info	Theme for Study	Method	Main Findings	Importance for my Thesis
			may influence the onset of certain injuries, like low-back pain or knee injuries. Balance and core stability improve by functional exercises where the pro-prioceptive system is chal-lenged.	

The search criteria included studies to the literature review with the following requirements: studies that handled the sport of surfing or similar, answered one or all of the study questions, had evidence-based research and had to have a free full text available.

I searched for studies on surfing in online databases to understand the scope of research produced on this topic. I used the PubMed and ScienceDirect databases, and planned using the following keywords: surfing, surfboard riding, sports, core stability, motor control, motor learning, balance, strength, endurance, bodyboarding, snowboarding, windsurfing. Since the word "surfing" has multiple meanings that do not always relate to the actual sport, I found it more effective to use a search sentence "surfing AND sports", so the results would end up consisting of studies on the act of surfing waves.

Science direct found 1 406 articles with the search words "surfing AND sports", thus I needed refine the results by using the databases own tools. I chose the limitations that the results must be under the topics sports, physical activity, sport medicine, New Zealand and athlete. This limited the results

to 86 articles. None of the articles met the search criteria. Next I used “surfboard riding” as my key search word. The database found 75 articles of which 2 studies met the search criteria and were chosen to the literature review.

PubMed database found 20 articles with the search words “surfing AND performance”. Of these articles 10 handled the study topic and three studies met the criteria and were chosen for the literature review. I also used to words “surfing AND stability” and found one study that was accepted to the literature review since I found it had important value for this study.

To find more information concerning core stability I conducted a general search on core stability not relating to surfing. I used the PubMed and Academic Search Elite database as they proved to be the most lucrative of all my options. I searched on Academic Search Elite with keywords “core stability” and accepted only free full text articles. The database found 95 articles and of those, two articles met the search criteria. On the PubMed database I used search words “core stability sport”, also accepting only free full text articles, and found 14 articles of which two met the search criteria.

Further into my research on core stability I felt as though I did not have enough information on core stability and motor control. I searched Academic Search Elite database for “core AND motor” and limited my search to articles between years 2005 and 2012, full text and academic journals. 258 articles were found and one of these fulfilled the search criteria. I search both Academic Search Elite and CINAHL databases for “core AND anatomy AND balance”. 7 articles were found of which one met the search criteria. From this article I also found another useful article via the references (McGill 2010) which I found free in Google Scholar.

APPENDIX 2(1).

Letter to the panelists to ask for consent

Dear receiver,

I am a surfer and a physiotherapy student from the Mikkeli University of Applied Sciences in Savonlinna, Finland. I am currently writing my bachelor's thesis and would like to ask if you are willing to participate in my research.

The topic of my thesis is "The Importance and Role of Core Stability in Surfing". I am trying to find new scientific information on core stability and surfing. No previous studies have been performed on this topic or from a physiotherapy point of view, though both core stability and surfing have been studied. My research is performed by the Delphi technique where I ask questions about core stability and surfing from a panel, which I would like you to be a part of, and analyse all the answers from the panel to form new concepts. The special characteristics of this technique are anonymity, iteration and feedback. All respondents' answers will stay anonymous, questions rounds are repeated two to three times and every time you will receive a summary of all answers to previous questions and you may refine or change your answer and/or opinion on a matter.

Would you like to help me perform this study by being a part of the panel? I would send two to three sets of questions, each several weeks apart, which I would like you to answer according to your own professional view and knowledge on the matter. It would be best if you can commit to replying to all emails and questions so that the best consensus is reached on the matter.

This study would be an important addition to scientific knowledge on core stability and surfing. It would help professionals work with athletes and it could also develop surfing, athletic training and surfers' performance.

I am hoping to hear from you soon!

Best regards,

Liisa Airaksinen
Physiotherapy student and passionate surfer

APPENDIX 3(1).

Questions sent to participants

First round:

Question 1: what is the role of core stability in surfing?

This question is broad and open so all participants can focus on what they see is important. No studies have been completed on this topic either, so I am hoping to bring new valuable information to use. From here we continue into more detailed and more focused questions.

Second round:

Question 2:

a) Which surfing manoeuvres require core stability?

b) Which of those manoeuvres are the most critical and why?

c) How is core stability used in these manoeuvres?

These questions aim to break down the big concept of core stability into smaller pieces, and hopefully give a view on what functions are seen as being most important or most challenging regarding core stability. Even though there are studies on surfing, none of those have focused on discussing different manoeuvres or the (probable) need of core stability to perform them. If other areas of focus arise from the respondents' previous answers these questions may be modified to suit the discussion better.

Third round:

Question 3

a) How can good core stability prevent surfing injuries from occurring?

b) What exercises do you suggest to improve core stability amongst surfers?

These questions aim to correlate with the questions in round 2. These answers could bring valuable information to professionals on what strategies should be used to ensure excellent core stability amongst surfers and thus prevent injuries.

APPENDIX 4(1).

First round email and reminder

Dear receiver,

Thank you for taking part in my study!

I will send two to three rounds of questions that I would like you to answer to according to your own professional view on the matter. For each round you have two weeks time to answer. On the second and third rounds I will present answers to the previous questions for you to comment on. If you like you may refine or change your answer to the previous questions once you have read other respondents' answers. To make the discussion easier I have shortly defined core stability for you below.

In this study core stability includes active (muscles), passive (ligaments, fascia, bones) and neural components. The neural component is in charge of muscle recruitment, activation and stability strategies. The active component includes the following muscles: the diaphragm, pelvic floor muscles, all abdominal muscles, quadratus lumborum, iliopsoas, erector spinae, multifidi and latissimus dorsi. The deep muscles are local stabilising muscles and the superficial muscles are the global moving muscles. Amongst other ligaments and fascia the thoracolumbar fascia is the most important part of the passive component as it connects the upper body to the lower part of the body. Core stability is the basis of functioning, force transferring, supporting and protecting the body and spine. It helps us control our centre of mass (COM) thus keeping us upright and also helps to maintain and correct our posture and balance.

First round:

Question 1: what is the role of core stability in surfing?

If you have any questions regarding the study please do not hesitate to ask.

Merry Christmas and a happy new year!

Sincerely yours,
Liisa Airaksinen

Dear all,

I hope you had a good Christmas and New Year's. I understand that everyone has been on holiday and thus not been able to answer the first round in the given time. If possible I would appreciate if you could give your answers by the end of this week.

I wish you all the best for the year 2013!

Best regards,
Liisa Airaksinen

APPENDIX 5(1).

Second round email

Dear receiver,

Thank you for your response to the first round. If you missed out on replying to my first email that's fine, you may comment on the summary of the answers presented below. The more comments the better! If you like you may refine or change your answer to the previous questions (round one), once you have read the summary.

Summary of the answers to round one:

The main topics discussed in round one were structural alignment, force projection, balance, stability, injury prevention, efficient work with extremities. Core stability was seen as a vital component in enabling surfers to perform manoeuvres, to give sufficient aid in balance and aiding the extremities to work with ease and efficiency. Injury prevention was also seen as a vital function for core stability. Core stability was described as giving stability and/or balance to perform manoeuvres.

The questions for round two:

a) Which surfing manoeuvres require core stability?

b) Which of those manoeuvres are the most critical and why?

c) How is core stability used in these manoeuvres?

I will send one more round after this - if needed - that I would like you to answer to according to your own professional view on the matter. For each round you have two weeks time to answer, but please answer as soon as possible. Don't think too much, but rather answer according to what is your first impression on the matter. On the third round I will also present a summary of the responses to the previous questions for you to comment on again. If you like you may refine or change your answer to the previous questions once you have read other respondents' answers.

Hope to hear from you soon!

Best regards,

Liisa Airaksinen
Physiotherapy student

APPENDIX 6(1).

Third round email

Dear receiver,

Thank you for your response to the second round. If you like you may refine or change your answer to the previous questions (round two), once you have read and commented on the summary.

Summary of the answers to round two:

The main topics discussed in round two were big turns, structural alignment, force projection and injury prevention. According to the answers received basically all surfing manouvres, but especially big strong turns were seen as critical manouvres and needing good core stability. This was seen critical as good core stability prevents injuries by controlling structural alignment, protecting the deep segments from strong forces and thus enabling the extremities to act on these forces projected on the body.

The questions for final round:

a)What exercises do you suggest surfers should do in order to improve their core stability? Why?

Again, you have two weeks' time to answer, but please answer as soon as possible. Don't think too much, but rather answer according to what is your first impression on the matter.

Hoping to hear from you soon!

Best regards,

Liisa Airaksinen
Physiotherapy student