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Abdominal Muscle Recruitment in Adults
With And Without Cystic Fibrosis

by

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Research thesis submitted to the Faculty of Graduate and
Postdoctoral Studies in partial fulfillment of the requirements for the
M.Sc. degree in Human Kinetics

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Dedication

This thesis is lovingly dedicated to my mother Katherine Doris Taillon and the memory of my father William Vincent Taillon.

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LIST OF ABBREVIATIONS

AH: abdominal hollowing

AH-1: abdominal hollowing at 42 mmHg

AH-2: abdominal hollowing at 50 mmHg

AH-3: abdominal hollowing at 55 mmHg

ANOVA : analysis of variance

C: control group

CF: Cystic Fibrosis

dSLR: double straight-leg-raise

EMG: electromyography

EO: externus obliquus

FEV1: forced expiratory volume in 1 second

IO: internus obliquus

MVC: maximual voluntary contraction

PBU: pressure biofeedback unit

PFT: pulmonary function test

RA-MID: rectus abdominis-middle fibers

RA-UP: rectus abdominis-upper fibers

RMS: root mean square

sEMG : surface electromyography

subMVC : submaximal voluntary contraction

TrA : transversus abdominis

ULL: unilateral leg lift

Abstract

The electromyographical (EMG) of the superficial and deep abdominal muscle activity during voluntary and automatic tasks has been well researched, particularly in the normal population as well as individuals with low back pain and more recently in individuals with stress urinary incontinence. Two common normalization procedures used to reference the test data are the percent of maximum contraction (%MVC) and the double straight-leg-raise (dSLR). No EMG study to date has included participants with a pulmonary disease such as cystic fibrosis, who also have a high prevalence of low back pain and stress urinary incontinence. Therefore the purpose of this study was to investigate the recruitment patterns of the superficial and deep abdominal muscles in individuals with stable cystic fibrosis. The two primary objectives of this study were: i) to compare the electromyographic (EMG) activity of four abdominal muscles (the upper and middle fibers of rectus abdominus (RA-UP and RA-MID respectively) the obliquus externus (EO), and the obliquus internus/tranversus abdominus (IO/TrA) group during the abdominal hollowing exercise (AH)) and the unilateral leg load (ULL)) between a group of participants with stable cystic fibrosis and a gender-matched control group and ii) to compare the EMG muscle activity of the superficial and the deep abdominal muscles across and within the AH and the ULL tasks. A secondary objective was to compare the study's results when using two different normalization techniques: the %max-referenced contractions and %dSLR-referenced contractions. **METHODS:** Twenty-eight adults (14 with stable CF and 14 controls) performed (i) the AH exercise to three motor target pressures (42mmHg, 50mmHg, and 55mmHg) using a pressure biofeedback unit (PBU) and (ii) a right-leg ULL. Bipolar surface electrodes were used to record the EMG data. Two types of reference contractions (percent of maximum voluntary contraction (%max) and the double straight-leg-raise (dSLR)) were used to normalize the data. **RESULTS:** A 3-way ANOVA indicated no difference between the groups, but a significant muscle*task interaction was found. Post-hoc Bonferonni tests on pooled data revealed significant differences between the mean EMG amplitudes of the superficial and the deep abdominal muscles during all of the abdominal hollowing exercises as well as an increase in superficial abdominal muscle activity as the abdominal hollowing task became more difficult. No group differences were found in the ULL activity but significant differences were found between the superficial and deep muscles. The conclusions were the same regardless of the normalization procedure. **DISCUSSION:** The results from this study demonstrate that individuals with stable CF do not present with over-activity of the superficial abdominal muscles or inhibition of the deep abdominal muscles as compared to a control group. The EMG patterns and intensities found here support those of previous studies and could serve as normative data for future studies involving both CF and control group participants who are symptomatic of low back pain or stress urinary incontinence.

Chapter One: Introduction

This thesis addressed the topic of voluntary and automatic abdominal muscle recruitment patterns in a group of adults with stable cystic fibrosis (CF) as compared to a group of adults without cystic fibrosis. This area of scientific inquiry had yet to be investigated in adults with a pulmonary illness.

1.1. Statement of Purpose

The purpose of this study was to investigate the recruitment activity of the superficial and deep abdominal muscles in a group of adults with stable cystic fibrosis (CF) and a control group (C). The objectives of this study were i) to compare the patterns of muscle activity of the superficial and deep abdominal muscles during a task of voluntary recruitment (the abdominal hollowing exercise (AH)) and a task of automatic recruitment (unilateral leg load (ULL)) and (ii) to compare the individual muscles' activity between tasks and within tasks. A secondary objective of this study was to compare the results according to two types of normalization procedures; the percent of maximal contraction procedure (%max) and the percent of double straight-leg-raise (%dSLR) procedure. This study addressed a gap in both the pulmonary and motor control literature, where studies describing the recruitment patterns of these abdominal muscles had yet to include a participant group with a pulmonary illness. The dependent variable of this study was the electromyographical (EMG) amplitude measurements of the rectus abdominis (upper fibers – RA-UP and middle fibers – RA-MID), the externus obliquus (EO) and the internus obliquus/transversus abdominis (IO/TrA) muscles. The muscles' activity was compared during two separate experimental conditions: voluntary recruitment during the AH exercise

at three pressure gauge readings (42mmHg, 50mmHg and 55mmHg) on a pressure biofeedback unit (PBU), and automatic recruitment during a right ULL.

1.2 Justification for the Study

1.2.1. Scope of the Problem

Cystic fibrosis was once a disease where patients died in infancy. Due to the remarkable advances in medical care and management in the last 50 years, the median age of survival is now 33 years of age and is expected to reach beyond 50 years of age by the year 2015 (Massery, 2005). The increase in life expectancy of this population has significantly impacted the scope of services provided to the adult with CF, and the growth of the adult CF population is expected to continue (Yankaska et al., 2004). Historically, most medical interventions have focused on the patient's pulmonary and systemic needs. However, orthopedic issues in this population such as vertebral deformities, osteoporosis, and skeletal pain are now requiring more medical investigations than previously, since individuals with CF are now living long enough to develop biomechanical and neuromuscular deficiencies that have not previously been investigated, but for which they are at risk as secondary consequences of their disease (Dodd & Prasad, 2005). Such examples include back pain (Parasa & Maffuli, 1999), postural deformities (Tattersall & Walshaw, 2003), muscle imbalances of the trunk and scapular region (Rose et al., 1987) as well as stress urinary incontinence (McVean et al., 2003). Scientific evidence exists regarding abdominal muscle neuromotor deficiencies underlying such orthopedic issues in the non-CF population (O'Sullivan et al., 1997, Sarhman, 2002, Sapsford et al., 2001). Physiotherapy assessment and interventions for these have proven successful in alleviating

some of these symptoms (O'Sullivan et al., 1999, Sapsford et al., 2001), the importance of which lies in the optimization of the muscle responses of anterior and posterior structures in the lumbopelvis to the mechanical loading of posture. Therefore, should this study identify abdominal recruitment neuromotor deficiencies in the stable CF participants, physiotherapy intervention could assist in their correction.

1.2.2. Significance of the Study Results

Results from this study will create knowledge regarding the recruitment activity of the abdominal muscles in a group of individuals with stable CF, knowledge which to date does not exist. Such results could also serve as normative data for future studies involving the cystic fibrosis population. Results from this study will also help to confirm those neuromotor recruitment patterns in healthy individuals. Should the results here reveal faulty motor recruitment strategies of the superficial and deep abdominal muscles such as those found in populations with mechanical low back pain and stress urinary incontinence, physiotherapy intervention could address these and attempt to correct them. This could lead to an improved quality of participation in daily living activities for adults with CF.

Chapter Two: Review of the Literature

2.1. Cystic Fibrosis: Definition and Musculoskeletal Manifestations

Cystic fibrosis is an autosomal recessive genetic disease. In the UK, its occurrence is 1/2500 Caucasian births and its carrier rate is 1:25 (Yankaska et al., 2004). This disease affects the exocrine glands, causing systemic dysfunction in the pancreas, the gastrointestinal tract, and particularly in the lungs (Denton et al., 1981). Diagnostic procedures include the sweat chloride test, indicating the dysfunction of the sodium/chloride pump which underlies the pathology of this disease. Genetic phenotype testing for the cystic fibrosis transmembrane mutation (CFTR) is also performed. Longevity is now approximately 35 years of age. Diagnosis is most commonly made in infancy however the frequency of adult diagnoses is increasing (Yankaska et al., 2004).

Management of this complex disease focuses on pulmonary care and nutritional care. Significant dysfunction occurs in the lungs, leading to thickened airway secretions which create breeding grounds for bacteria causing pneumonia. From infancy, the person with cystic fibrosis adopts a daily routine of chest physiotherapy involving distal airway secretion mobilization and proximal airway secretion expectoration (Lannefors et al., 2004). Interestingly, this daily routine involves using the superficial abdominal muscles for sputum production during coughing. When the patients are ill with lower respiratory tract infections, secretion clearance increases in importance, as does the effort of the abdominal muscles activity to promote secretion mobilization and pulmonary clearance.

Adult patients with CF lead active lives. The Consensus Conference Report of Adult Cystic Fibrosis Care (Yankaska, 2004) described the complexity of life of this

patient group. Approximately 50% of patients are employed full-time or part-time, while others are students. More than one third are married, and many have families, all of which involve busy activities of daily living. Unfortunately, their healthcare needs are considerable. Approximately 4.7 clinic visits are made per year by the adult CF person, and they experience on average 1.5 acute exacerbations annually, possibly requiring hospitalization. In the United States, the number of adult care programs is greater than 80 today, up from less than 10 programs approximately 15 years ago.

Patients are now living long enough to experience the richness of adulthood (work, leisure activities, families) but also to develop musculoskeletal complications which have not been encountered in the past. For examples, bony fractures are commonly found in the ribs (Aris et al., 1998) as well as compression fractures in the lumbar spine, postural deformities such as thoracic kyphosis (Denton et al., 1981) and lumbar sway back (McVean, et al., 2004) as well as an abnormally high incidence of low back pain (Parasa & Maffuli, 1999). Associated with all of these are diffuse skeletal muscle imbalances (Rose et al., 1987), and one case study identified imbalances involving the abdominal muscles (Massery, 2005). No research has yet been done addressing the etiology of these issues in the CF population. In the non-CF population, abdominal muscle imbalances are known to be associated with mechanical low back pain (Hodges & Richardson, 1996; O'Sullivan, 1997) poor posture and overuse syndromes (Sarhmann, 2002), postural deformities (Kendall, 1972) and stress urinary incontinence (Sapsford et al., 2001). Repetition of specific movements can lead to patterns of overactivity in some muscles and a related underactivity in others (Richardson et al 1992). In the proximal trunk muscles, the obliquus internus and externus muscles tend to become weakened (Sarhman, 1988). In addition,

there is empirical clinical evidence that repetitive use of the rectus abdominis is associated with poorer recruitment of the deeper abdominal muscles. No study to date has investigated whether these concepts hold true for a pulmonary population such as individuals with cystic fibrosis. Given that neuromotor deficiencies of abdominal muscles are associated with musculoskeletal symptoms similar to those reported to exist in the CF population and that the ability to independently recruit the abdominal muscles is measurable, the interest of this study was to compare the recruitment activity of these muscles between a group of participants with stable CF and a control group in order to describe any differences in automatic and voluntary recruitment of the superficial and deep abdominal muscles. Results from this study could generate normative data of the recruitment activity of the abdominal muscle in the stable CF adult, lead to a better general understanding of the impact of this pulmonary disease on neuromotor function, could enlighten a new area of care for this group, and could assist in directing symptom management.

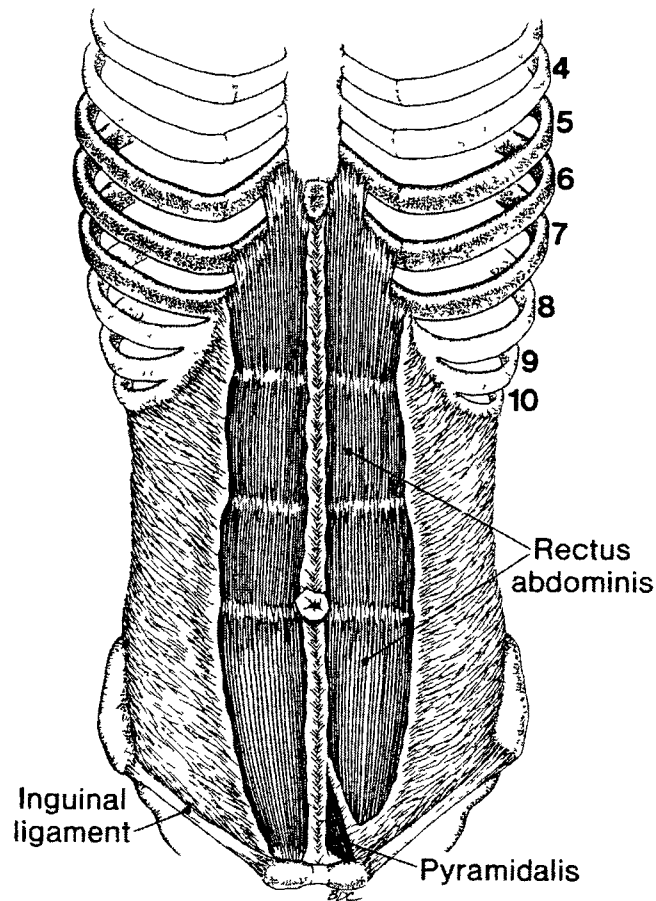
2.2. Anatomical Description of the Abdominal Muscles

The four abdominal muscles of interest in this study were the rectus abdominis (upper fibers: RA-UP and middle fibers RA-MID), the external obliquus (EO), the internal obliquus (IO), and the transversus abdominis (TrA). The latter two are found in the deep abdominal muscle layer and the former three in the more superficial muscle layer. A fifth abdominal muscle, the diaphragm, has been previously included in the methodology of Allison et al. (1998), however, the pilot data from our study suggested considerable

electrode crosstalk from the EO muscle and therefore the diaphragm muscle was not included here. The anatomical description of these is as follows (Moore et al. 2003):

Rectus abdominis:

Characterized by three fascial digitations, the rectus abdominis originates proximally from the anterior surfaces of the xiphoid process and the 5th to 7th costal cartilages and inserts distally on to the symphysis pubis and the pubic crest. Centrally, this muscle is distinguished by the linea alba, and its lateral borders form the linea semilunares where it



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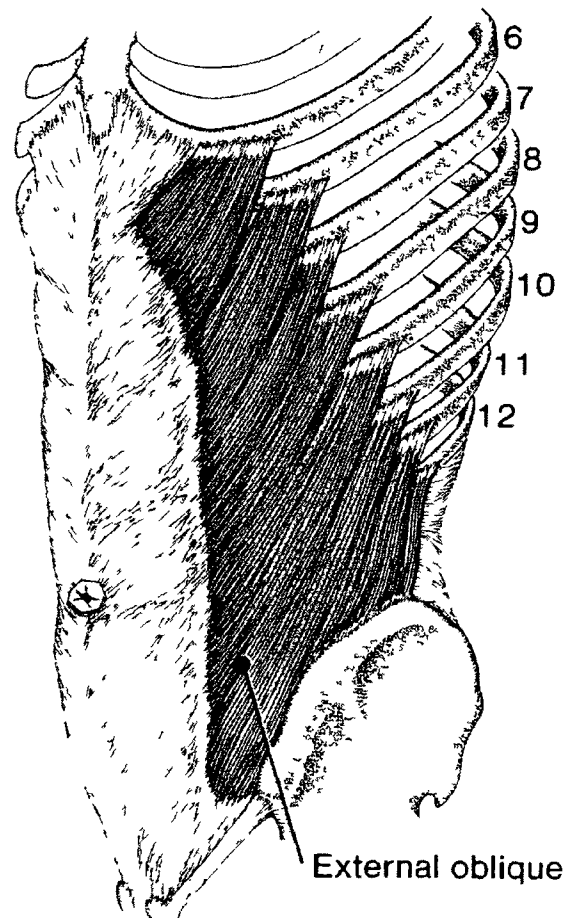
blends with the muscle fibers of the externus obliquus muscle bilaterally. It is the primary flexor of the trunk and is the most superficial of the abdominal muscles. It also depressed the ribs and stabilizes the pelvis during walking. It is mechanically categorized as a global mobiliser of the trunk (Bergmark, 1998). This muscle is enveloped in a strong fibrous sheath, the rectus sheath, creating three digitations beginning at the xiphoid process and extending to the umbilicus, which also relates it fascially to the other superficial abdominal muscle, that being the externus obliquus muscle. Its nerve supply comes from the ventral rami of the inferior five intercostals nerves and the subcostal nerve.

Externus obliquus

The largest and most lateral of the abdominal muscles, the externus obliquus originates proximally from the external surfaces of the 5th to the 12th ribs. The superior four of these interdigitate laterally with the serratus anterior muscle while the inferior four slips interdigitate laterally with the latissimus dorsi muscle.

Thereafter, the digitations form a fan-shaped muscle, the fibers of which course antero-infero-medially to insert distally into the linea alba, the pubic tubercle, and the anterior half of the iliac crest.

Mechanically, this muscle is a global mobilizer (Beigmark, 1998) and acts to contralaterally rotate the trunk as well as flex the trunk. It also serves to compress and support the abdominal contents. It is innervated by the inferior five costal nerves, the subcostal nerve, and the iliohypogastric nerve.

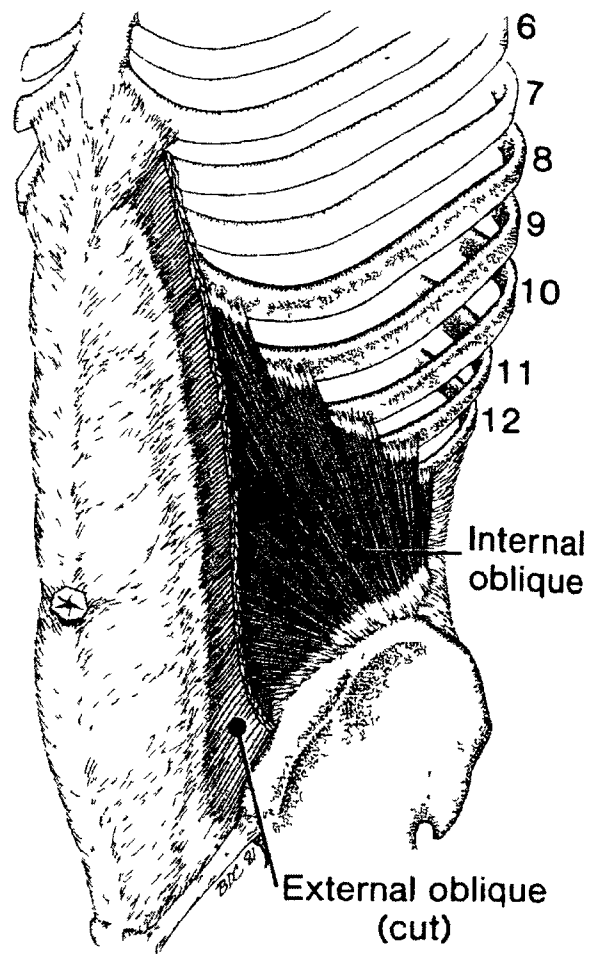


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Internus Obliquus

This global stabilizer muscle (Bergmark, 1998) lies deep to the externus obliquus and the rectus abdominus muscles and originates proximally from the inferior borders of the 10th to the 12th ribs, the linea alba and a conjoined tendon from the pubis symphysis to insert in to the thoracolumbar fascia laterally, the iliac crests, and the lateral two-thirds of the inguinal ligament. Its fibers course in the direction opposite to those of the externus obliquus, which enable it to ipsilaterally rotate the trunk while also

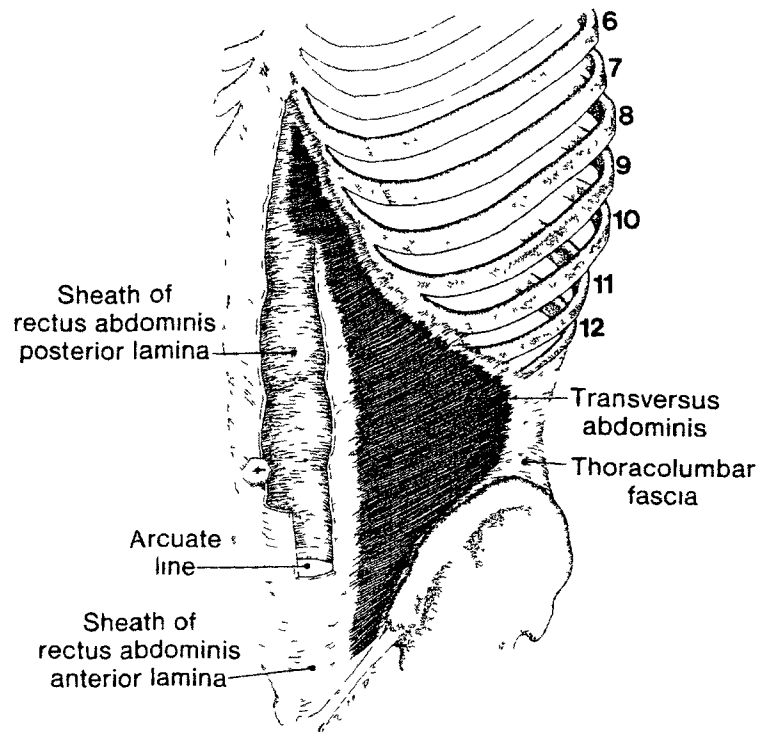
participating in some trunk flexion. This muscle also serves to compress and support the abdominal viscera. It is innervated by the inferior five intercostal nerves, as well as the subcostal, iliohypogastric, ilioinguinal and subcostal nerves.



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Transversus Abdominis:

Located in the deepest layer of the abdominal muscles, this corset-like muscle originates superiorly from the internal surfaces of the six costal cartilages where they interdigitate with fibers of the diaphragm, posteriorly



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from the thoracolumbar fascia spanning from L1 to L5, and inferiorly from the iliac crest and the lateral third of the inguinal ligament. The fibers course horizontally and slightly inferiorly to blend into the linea alba, the pubic crest, and the pectin pubis via a conjoint tendon. This muscle supports the viscera. Mechanically it is classified as a local stabilizer (Bergmark, 1988), serving to stabilize the joints of the lumbar spine prior to contractions of the erector spinae. It is innervated by the ventral rami of the inferior five thoracic spinal nerves, and the subcostal, iliohypogastric, ilioinguinal nerves.

The synchronicity of neuromotor recruitment of the four abdominal muscles was of special interest to this study. The motor control of these muscles is complex, as they are also involved in the postural control of the trunk, respond to respiration, modulate intra-abdominal pressure, and provide myofascial stabilization for the lumbar spine and sacroiliac joints via the thoracolumbar fascia in both neutral and loaded conditions. To this end, the central nervous system recruits these muscles both automatically and voluntarily. The purpose of this study was to describe the patterns of superficial and deep abdominal muscle recruitment in a group of individuals with CF as compared to a healthy control group during two types of tasks: an automatic task involving a right unilateral leg load and a voluntary task involving the abdominal hollowing exercise.

2.3. Automatic Muscle Recruitment

The abdominal muscles were once thought to contract and function as a group (DeTroyer et al., 1990) and this is now known to be untrue. Scientific evidence from motor control studies investigating the response of the superficial and deep abdominal muscles to perturbations of the center of mass have shown that the two layers function concertedly but independently. Research involving automatic postural motor control of the abdominal muscles has included studies of their recruitment patterns in responses to flexion/extension of the trunk (Cresswell et al., 1992), trunk flexion/extension with a loaded vest (Cresswell et al., 1994), rapid arm movements in standing (Hodges & Richardson, 1996; Hodges et al., 1999; Hodges & Richardson, 1997a) arm movements at varying speed (Hodges & Richardson, 1997b) and arm movements and reaction time (Hodges & Richardson, 1999),

standing unilateral arm elevation (Allison et al., 2008), hip movement (Hodges et al., 1997a), and supine leg loading (Jull et al 1993; Hodges et al., 2003). All of these studies have confirmed that the central nervous system automatically recruits the deep layer of abdominal muscles prior to the superficial layer as part of a pre-programmed pattern for stabilizing the trunk within its base of support, accomplished in part by causing the lumbopelvis' myofascial structures to provide stability to a neutral lumbar spine. Studies have also investigated the coordinated recruitment of the abdominal muscles during such functional activities as hip flexion in sitting (Ainscough-Potts et al., 2006), walking on a treadmill, and running on a treadmill at different speeds (Saunders et al., 2004). The deep abdominal muscle layer and the diaphragm, more so than the superficial layer of abdominals, have been demonstrated to increase intra-abdominal pressure, which in turn mechanically support the lumbar spine (Cresswell, 1993). All of the abdominal muscles support respiration (Abe et al., 1996). The TrA muscle in particular supports forced expiration such as during voice production, laughing (DeTroyer et al., 1990) and forced expiration such as forced expiratory maneuvers (Misuri et al., 1997). Only the deep layer, notably the TrA muscle, is harmonized with the diaphragm during respiration (Hodges & Gandevia, 2000a) and limb movement (Hodges & Gandevia, 2000b), and increases its respiratory role during experimentally-induced hypercapnia (Hodges et al., 2001) as well as in advanced chronic pulmonary obstruction (Ninane et al., 1992). It has also been suggested that the TrA muscle has separate motor units for postural and respiratory function that are not found in the other abdominal muscles (Hodges & Gandevia, 2000a; Treethambal et al., 1998). In summary, the automatic neuromotor function of the superficial and deep abdominal muscles is part of a pre-programmed CNS response for

postural stability and demonstrates feedforward characteristics. The recruitment of these muscles is not simultaneous, but concerted. Interestingly, these automatic recruitment patterns become altered in the presence of low back pain (Hodges & Richardson, 1996, Hodges et al., 1999), wherein the activity of the superficial abdominal muscles increases, the activity of the deep abdominal muscles decreases (Comerford & Mottram, 2001) and the feedforward postural responses of all of the abdominal muscles change (Hodges et al., 2003).

2.4. Voluntary Muscle Recruitment

Both layers of abdominal muscles can be recruited voluntarily. The superficial muscles are phasic, prime movers of the trunk, creating trunk flexion (RA) and trunk rotation (EO and IO) and are well suited to move the lumbar spine out of a neutral position (Grenier & McGill, 2006). With the spine in a neutral position, these muscles are recruited during posterior pelvic tilting (Vezina & Hubley-Kozey, 2001; Urquhart et al., 2005; Drysdale et al., 2004) and abdominal bracing (Allison et al., 1998; Urquhart et al., 2005). The IO and specifically the TrA however are not phasic muscles but more tonic ones, demonstrating low-level, continuous muscle activity constituting the background muscle activity upon which the phasic muscles produce functional movements (Hodges & Richardson, 1996; Bergmark, 1989; Comerford & Mottram, 2001). These deeper abdominal muscles can be voluntarily recruited during specific exercises such as abdominal hollowing, where the lumbar spine is held in a neutral position. During this exercise, the EMG of the superficial muscles remains relatively silent, demonstrating an

independence of muscle activation (Jull & Richardson, 1995; Hodges et al., 1996). In the presence of neuromotor dysfunction of the superficial and deep abdominal muscles, the superficial layer shows increased activity and there is empirical clinical evidence that this occurs in individuals who have abdominal muscle imbalances caused by the over-training of the superficial abdominal muscles (Sarhmann, 2002). The importance of maintaining synchronized abdominal muscle recruitment lies in optimizing the mechanical function of the thoracolumbopelvic region. Cadaveric studies have shown that tension exerted on the thoracolumbar fascia by contraction of the deep abdominal muscles contribute to compressing the lumbar spine and preparing it for mechanical loading (Barker et al., 2004; MacIntosh et al., 1987). Without optimal neuromotor recruitment, clinical movement dysfunction will occur, with or without the presence of pain (Sarhman, 2002). These dysfunctions, when present, are clinically treatable in physiotherapy. Such dysfunctions are evidenced in the normal population by muscle imbalances and postural deformities, symptoms of which have been documented in the cystic fibrosis literature (Tattersall & Walshaw, 2003; Rose et al., 1987; Massery, 2005).

2.5. Voluntary Abdominal Muscle Recruitment during the Abdominal Hollowing Exercise

The abdominal hollowing exercise is the motor task which, when performed correctly, requires the independent recruitment of the superficial and deep abdominal muscles. It has been validated in the normal population (Hall, 1995) and has been proven to be repeatable between trials (Richardson et al. 1992). This movement selectively activates the deep abdominal muscles (TrA and IO) with little or no increase in activity of

the superficial muscles (RA and EO) (Hodges et al., 1996; Jull & Richardson 1995) and this was confirmed by Urquhart et al 2005, in a study of unprecedented anatomical specificity and improved fine-wire EMG technique. Some discrepancy exists in the literature as to the degree of specific deep abdominal activity during abdominal hollowing in different positions. Beith et al. (2001) reported the lack of isolated activity of the deep muscles during the abdominal hollowing in four point kneeling and in prone, as measured by surface electrodes. However, their study did demonstrate the preferential activity of this abdominal layer, supporting findings from other studies (O'Sullivan et al., 1997; Allison et al., 1998; Hides et al., 2006, Springer et al., 2006, McMeeken et al., 2004; Harrison & Hodgson, 2001). Despite the findings by Beith et al. (2001), this current study did use four point kneeling as the position for instructing the abdominal hollowing exercise, given that the aim here was not to obtain isolated electrical activity from within the two deep abdominal layer muscles, but rather to compare the recruitment amplitudes between the superficial and the deep layers. The instruction of the abdominal hollowing was provided by an experienced physiotherapist.

Urquhart et al.'s (2005) findings also support previously documented motor substitution patterns observable during the abdominal hollowing maneuver when neuromotor dysfunction of the abdominal muscles is present. An increase in the activity of the superficial muscles is seen resulting in rib flaring (EO activity), breath holding, or posterior pelvic tilting (RA muscle use) (Hides et al., 2000). These substitution patterns occur as the central nervous system recruits synergistic muscles to perform an activity (Edgerton, 1996). These patterns are clinically observable, palpable (Hides et al., 2000), and correctable (O'Sullivan et al. 1998).

Several studies have used the abdominal hollowing exercise in supine crooklying to identify the recruitment patterns of the superficial and deep abdominal muscles and demonstrated muscle activity using surface electromyography (sEMG). Many studies have included the use of indwelling needle electrodes, but these methodologies were not being considered for this study due to the invasiveness and risks to the participants and surface EMG has been found to be a valid and reliable technique for measuring deep abdominal muscles, globally rather than specifically (McGill et al., 1996). Using standardized abdominal positions surface electrodes (Ng et al., 1998) placed at an inter-electrode distance of at least 2.5 cm to minimize cross-talk. O'Sullivan et al. (1997) demonstrated a statistically significant difference in the ratio of superficial and deep abdominal muscle use between subjects with low back pain due to spondilolisthesis/spondylolysis and a control group, when performing the abdominal hollowing exercise. Their results indicated that the back pain group recruited less activity of their deep layer than their superficial layer, when asked to contract their muscles using a motor target of generating 10mmHg of pressure change in a pressure biofeedback unit (PBU) (Chattanooga, Australia). This device has been proven to be valid and reliable for reflecting changes in air pressure (measured in mmHg) created by the contraction of the deeper abdominal muscles (Richardson et al, 1992; Jull et al. 1993) and has been repeatedly used in studies investigating the abdominal muscle recruitment patterns (Cairns et al. 2000; Evans & Oldreive, 2000; Hides et al., 2006; Hides et al., 2007). Allison et al. (1998) supported previous studies (Jull et al., 1993) and confirmed the utility of the PBU to identify changes in superficial and deep abdominal muscle recruitment using the abdominal hollowing maneuver in their study using three motor targets of 5mmHg,

10mmHg, and 15mmHg. They demonstrated that the muscles of the deep layer is preferentially activated at 5mmHg while the superficial layer, including the diaphragm, increase in force output at the higher readings. They also confirmed the substitution patterns used when higher pressures are required of the task.

2.6. Automatic Recruitment of the Abdominal Muscles using a Unilateral Leg Load Exercise

The study by Jull et al. (1993) used hip flexion in supine lying as a load on the spine to investigate the ability of the deep abdominal muscles to stabilize the lumbar spine. Surface electrodes were used to detail the motor control of the abdominal muscles. This study confirmed the use of hip flexion as a load to which the abdominal muscles must automatically contract to stabilize the trunk. Hodges et al. (1996) also used hip flexion from a supine lying position in documenting the automatic recruitment of the deep abdominal muscles with ultrasound imaging, comparing a group of participants with low back pain and a control group. The back pain group's automatic recruitment was statistically slower than the control group. A recent study was conducted to investigate the differences in motor activity of the IO and the TrA in sitting with the feet stationary and using unilateral hip flexion. It was found that unilateral hip flexion caused a greater recruitment of the deep abdominal muscles than sitting with the feet stationary (Ainscough-Potts et al., 2006). These studies showed that the automatic motor recruitment of the abdominal muscles can be investigated using a unilateral leg lift/load. Therefore, this study used the task of a unilateral leg lift to describe any recruitment pattern differences

between the superficial and deep abdominal layers and between individuals with CF and controls during this task of automatic muscle recruitment

2.7. Coughing as an Abdominal Muscle Exercise

Coughing is an activity which requires voluntary and automatic recruitment of the abdominal muscles. They are recruited simultaneously to create a powerful muscle force which generates impressive intrathoracic pressure. Coughing can be separated into two phases: the inspiratory phase and the rapid expiratory flow phase (Fontana, 2008) and the abdominal muscles are used to create maximum expiratory cough pressure, peak expiratory flow rate, as well as maximum expiratory pressure (Lee et al., 2008).

Coughing is a sequence of controlled motor activity from the abdominal muscles and the respiratory muscles. The muscle activity generated during coughing has been reported as being as high as 179% of maximal voluntary contraction (MVC) in the TrA muscle, and 136% of MVC in the IO muscle (Neumann & Gill, 2002), indicating the tremendous force output that can be generated by the deep abdominal muscles. Their study also identified differences in recruitment of the EO and the IO muscles between a group of women with SUI and a control group. Although the abdominal hollowing exercise was not used to identify the ability to independently recruit the two layers of abdominal muscles in that study, it seemed that coughing might have had an effect on changing the recruitment patterns of the abdominal muscles in people with SUI.

However, there is no suggestion in the literature as to the effect of chronic coughing on the recruitment patterns of the abdominal muscles. But given that coughing requires the

frequent use of the abdominal muscles for tasks other than the physiological movements of the trunk, and that people with CF are chronic coughers, it could be suggested that the abdominal muscles of these individuals are more frequently used than in a group of individuals who do not frequently cough and thus could be considered to be “over-used” in comparison. Given that “over-use” of the superficial abdominal muscles has been associated with more dominant activity of the superficial abdominal muscles and less activity of the deep abdominal muscles and that coughing requires activity of the abdominal muscles, these individuals may be at risk of presenting with imbalances in the recruitment activity of abdominal muscles. Given that there is empirical evidence suggesting that over-use of the superficial abdominal muscles leads to lesser activity of the deep abdominal muscles and greater activity of the superficial ones, the study’s hypotheses were that individuals with CF would demonstrate increased use of the superficial muscles and decreased activity of the deep abdominal muscles as compared to a control group of non-chronic coughers, during both the activities of abdominal hollowing and a supine unilateral leg load.

2.8. Abdominal Muscle Imbalances in CF: Proposed Hypothetical Model

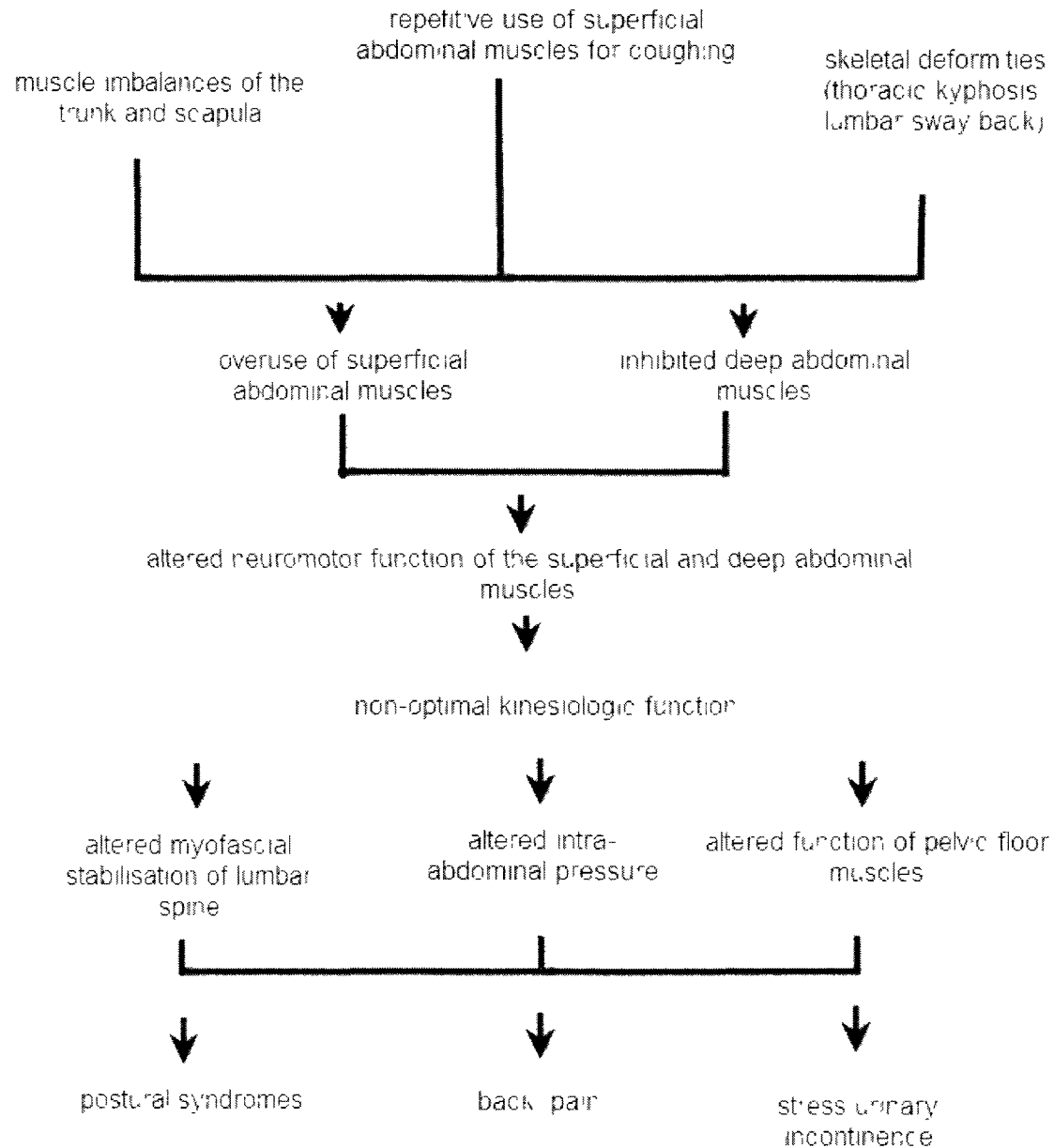
Clinical physiotherapists are well aware of the development of muscle imbalances in many different patient populations. These imbalances occur in a myriad of individuals such as those with sedentary lifestyles, work/leisure activities involving repetitive movements, as well as in elite athletes. Of particular interest to this study was the concept of a repetitive movement causing muscle imbalances. The intent was to investigate

the existence of abdominal muscle imbalances in the cystic fibrosis population, imbalances for which they might be at risk due to the repetitive use of the abdominal muscles for coughing and sputum production during their daily pulmonary care.

The hypothetical clinical model underlying the concepts outlined above lies in the reasoning that, in the repetitive abdominal muscle use during secretion clearance required to expectorate the excessive pulmonary secretions caused by their disease, the recruitment of the superficial and deep abdominal layers in the person with CF might become altered. In the non-CF person, the superficial abdominal muscles are used as primary trunk movers, and support sputum production only in the presence of pulmonary congestion associated with viruses (i.e. the common cold). However, the CF population recruits their superficial abdominal muscles, on a daily basis, for sputum production, and it was suggested here, that this could lead to an overuse of the superficial abdominal layer which research in the non-CF population has shown to be associated with diminished activity of the deep abdominal layer demonstrating altered neuromotor recruitment of the abdominal muscles (Comerford & Mottram, 2001). In addition to which, the CF population is recognized to have skeletal deformities such as thoracic kyphosis and lumbar sway back, as well as muscle imbalances of the scapula and chest. These factors might also render them vulnerable to imbalances of the abdominal muscles. As outlined previously, the importance of optimal abdominal muscle recruitment is to promote efficient and effective kinesiology function of the trunk and spine so as to minimize stress/strain on their osteoligamentous/myofascia structures (Panjabi, 1992). Without this, the tissues of the spine and pelvic floor are at risk for injury or weakening, and hence the associations between low back pain, urinary stress incontinence, deep abdominal muscle inhibition and

altered spatial and temporal recruitment of the superficial and deep abdominal muscles. This study suggested the following possible clinical reasoning pathway leading to the development of neuromotor deficiencies abdominal muscle recruitment in the CF population.

Clinical model of abdominal muscle neuromotor dysfunction in Cystic Fibrosis
(adapted from Sarhmann (2001) and Comerford & Mottram (2001))



Many other factors such as nutritional/metabolic, skeletal (bony deformities) or respiratory mechanics could contribute to altered neuromotor control of the abdominal

muscles in the CF population, however no research evidence supports this. In the exercise physiology and muscle performance literature related to CF, for example, the limitation to anaerobic exercise tolerance is thought to be due to nutritional factors whereas cardiopulmonary status would limit aerobic capacity (Shah et al., 1998). However, no measures have been made of abdominal muscle recruitment to assess if these could influence exercise capacity. Peripheral muscle strength differences between the CF and non-CF person have been investigated and found to be statistically different, but when the data are normalized for mass, the difference becomes non-significant (Elkin et al., 2000). Sahlberg et al. (2005) found a decreased abdominal muscle strength when performing repeated sit-ups in people with CF, but no physiological measures such as EMG were done to document the recruitment activity of the abdominal muscles, nor were these separated into superficial and deep muscle activity. Some mention is made in the literature regarding the weakening effect of steroid therapy on proximal muscles, but no mention is made of any effect on the abdominal muscles, nor on their ability to be recruited during a low-level task (20 to 30% of the maximal voluntary capacity of the muscle; Hides et al., 2000) which was the contraction intensity proposed for this study. The degree of pulmonary obstruction has been identified in the literature as affecting the recruitment of the TrA muscle in patients with chronic obstructive pulmonary disease (COPD). As the percent of forced expiratory volume in one second (%FEV1) decreased (from 82% to 17%), Ninane et al. (1992) found overactivity of the TrA muscle as it supported exhaling. However, none of the participants were those with cystic fibrosis, the breathing patterns of which differ significantly from COPD.

In summary, using available evidence from the literature, this study described the voluntary and automatic recruitment of the superficial and deep abdominal muscles in an adult population with stable CF, as compared to an age-gender-parity matched control group. The etiology of motor control deficits and their association with muscle imbalances, postural syndromes, low back pain and urinary stress incontinence is well documented in the literature. Despite the awareness of these same symptoms in the CF population, no study to date had attempted to describe the motor recruitment patterns of their abdominal muscles, which may be associated with the presence of symptoms in this population group. The voluntary motor task that is recognized as being validated and reliable for indicating independence of recruitment of the superficial and deep abdominal layers is the abdominal hollowing (AH) exercise while a unilateral leg load (ULL) is a valid and reliable task for producing automatic recruitment of these muscles. The protocols of Allison et al (.1998) and O'Sullivan et al. (1997) were suitable to address the research question of this study and were adapted to include a measure of automatic abdominal muscle recruitment using voluntary right hip flexion similar to that of Jull et al. (1993).

2.9. Research Hypotheses

For the purpose of this study, two groups were identified. One group consisted of adults with stable cystic fibrosis (CF) and the control group consisted of age and gender matched healthy non-cystic fibrosis adults (C). Both groups participated in the same testing exercises.

It was expected that, compared with the control group, the CF group would show preferential recruitment of their superficial abdominal muscles during the abdominal hollowing exercises rather than the preferential recruitment of the deep abdominal muscles. It was also expected that the CF group would show diminished recruitment activity of the deep abdominal muscles during the AH task. Thirdly, it was hypothesized that the CF group would demonstrate increased use of their superficial abdominal muscles during the automatic recruitment task of unilateral hip flexion and finally that the deep abdominal muscles would be recruited to a lesser degree in the ULL than the control group. The overall goal of this study was to learn about the recruitment patterns of the superficial and deep abdominal muscles and to compare these to a control group in order to better understand the impact of this disease on the motor control of these muscles.

2.10. Objectives of the Study

This study had two primary objectives: i) to identify differences between individuals with stable CF and an age and gender matched non-CF control group (C) in the recruitment of the superficial and deep abdominal muscles during the abdominal hollowing (AH) exercise and during the automatic activity of a unilateral leg load (ULL). The second objective was to compare the relative levels of muscle activation between the superficial and deep abdominal muscles during the AH tasks and the ULL task. To accomplish these, two experimental conditions were involved: voluntary recruitment during the abdominal hollowing exercise causing three sequential pressure gauge readings of 42, 50, and 55 mmHg of the PBU device and sustained for ten seconds and during an automatic

recruitment task (ULL) which was also sustained for ten seconds. A secondary objective was to compare the results with respect to the two surface EMG normalization procedures: the percent maximum voluntary contraction procedure (%max) and the double straight-leg-raise (dSLR) procedure.

Chapter Three: Detailed Methodology

3.1. Participants

3.1.1. Participant Characteristics

Participants recruited for this study consisted of two groups. The first group (n=14) consisted of adults with a diagnosis of cystic fibrosis, as diagnosed by sweat chloride test and CFTR mutation results. These individuals were between the ages of 18 and 41 years and had stable symptoms at the time of testing. .

The second group consisted of 14 healthy, age-gender matched controls recruited from the general population. The sample was a convenience sample.

Participants in either group were excluded if they were smokers or had a history of lung disease other than CF. People with mechanical symptoms such as urinary stress incontinence, low back pain (greater than 6 months duration), sacroiliac joint dysfunction, previous major abdominal surgeries (including caesarian sections) were also excluded. The CF participants were excluded if they had been hospitalized in the previous month, or had experienced symptoms of malaise (fever, increased sputum production, change in color of sputum, increased cough) within the week prior to testing. Any participant with prior experience in core strengthening exercises such Pilates® or Yoga, or any other training of the deep abdominal muscles was also excluded. Table 1 (Appendix D) provides a summary of the characteristics of the participants.

3.1.2. Sample Size

The sample size was based on a power analysis using a power level of 0.80, an alpha level of 0.05, an expected group mean difference of 6 percent of maximum EMG

amplitude and a standard deviation of 5 percent of maximum EMG amplitude. This estimation was calculated based on the results from O'Sullivan et al., 1997 and Allison et al., 1998. It was estimated that both groups required 14 participants for the results to reach significance (Dupont & Plummer, 2004).

3.1.3. Recruitment Process

Both participant groups were recruited via poster advertisements (see Appendix C: poster advertisement) located in the Bruyère Continuing Care building and the University of Ottawa campuses. Telephone conversations (see Appendix C: telephone script) were used to establish the suitability of the individual for the study. Once the participant consented to participate, a time was established to meet for testing. A sample of convenience was used and the snow-ball technique was also used.

The participants with CF were additionally recruited via email and during CF Clinic, held weekly at the Ottawa Hospital, General Campus in Ottawa, Ontario. An emailing of the poster was sent through the CF clinic nurse. Recruitment occurred for 10 weeks, from October 2009 to January 2010. During each weekly CF Clinic visit located at the Ottawa Hospital General Campus, the primary CF physician (Dr. Shawn Aaron) as well as the clinic nurse would introduce the project to a patient. Following verbal consent from the patient to meet the primary investigator (Anne Taillon-Hobson), she then explained the details of the study to the patient (see Appendix C: information letter and consent form) and the general health questions were asked (see Appendix C: general health questionnaire for participants with CF). If the CF patient consented to participate in the study, a time and

date was set to meet for testing and the consent/information letter was given to the patient as written information. Overall, eighteen potential participants expressed an interest in the study. Of those, four people were excluded: one had just recently had a hospital admission, two had had extensive exposure to core strengthening through Pilates classes, and a fourth declined.

Each participant was met by the primary investigator (Anne Taillon-Hobson) in the lobby of Bruyère Continuing Care, 43 Bruyère St., Ottawa, Ontario on the day of testing. The participants were then escorted to the Ageing and Movement Lab in room 700B-B where the study was explained to the participant for a second time and the consent form was signed in triplicate: one for the participant to keep, one for the records of Dr. Aaron, and the third for the records of Anne Taillon-Hobson and Dr. Bilodeau. The participants also completed the Leicester Cough Questionnaire (see Appendix C) which was used as an indirect measure of coughing behavior indicating any differences between the two groups. A higher value on the questionnaire is indicative of less coughing behavior (Birring et al., 2003). This questionnaire was used to confirm that there were no chronic coughers in the control group and that the CF patients were those with a chronic cough.. The testing procedure followed thereafter.

3.2. Materials

3.2.1 Surface Electrodes

Surface electromyographic (EMG) signals were obtained using four Delsys differential surface electrodes (DE 2.1 Bagnoli System, Delsys TM, Baltimore, Maryland,

U.S.A.)(see Appendix E) which were taped to the skin overlying the abdominal muscles, on the right side of the body as described in 3.2.2. The signals were amplified, filtered (band-pass filter 10-1000Hz, CMRR 92dB at 60 Hz) digitized at a sampling rate of 1000 Hz using a 1401digital/analog acquisition card (Cambridge Electronic Design Ltd; England) and stored on a personal computer. Data were processed using Spike 2 version 5.6™. The intensity of 40 mmHg on the pressure biofeedback unit (PBU) (Chattanooga model, BP Medical Supplies, U.S.A.) was used to confirm that the participants maintained their lumbar spine in a neutral position during the instruction phase. Increasing the PBU intensities served as motor targets during the three AH tasks.

3.2.2 Electrode Positions

The primary outcome measure consisted of surface EMG measurements from the abdominal muscles of the right side of the body, the rectus abdominus (upper fibres: RA-UP and middle fibres: RA-MID), the externus obliquus (EO), and the internus obliquus/transversus abdominis group (IO/TrA). The RA and the EO muscles were the superficial abdominal muscles and the IO/TrA group reflected activity of the deep abdominal muscles. Four pre-amplified bipolar surface EMG electrodes (Delsys, Inc.) were positioned with a fixed inter-electrode distance of 10 mm and oriented parallel to the muscle fibers. (Ng et al.,1998). The electrode placement for the right RA was 7 cm inferior to the xiphoid process and 3 cm laterally from the midline. The EO electrode was positioned 15 cm lateral to the umbilicus, just below the eighth costal cartilage. The IO/TrA was placed 3 cm medial to the ASIS and 3 cm inferiorly along the midline of the inguinal

ligament (O'Sullivan et al. 1997). This location was previously found to be suitable to minimize cross-talk from the EO muscles as its fibers are considered to be absent this far inferiorly over the abdominal surface (McGill et al. 1996). Since the internal oblique muscle lies superficially to the transversus abdominis muscle, the relative contribution of each muscle to the EMG recording was not identifiable. Therefore, the interpretation of the EMG data from the IO/TrA electrode reflected the activity of the deep abdominal muscles as a group rather than specifically (Allison et al. 1998b; O'Sullivan et al. 1997; Marshall & Murphy, 2003). The earth electrode was positioned over the left anterior superior iliac crest.

3.2.3. Pressure Biofeedback Unit (PBU)

The pressure biofeedback unit (PBU) (Chattanooga model, BP Medical Supplies, U.S.A.) was used to serve as a specific motor target for the AH exercises, as well as to maintain lumbar neutral. It is a 3-cell, air-filled cylinder which is attached to a pressure gauge and has been used in previous studies (Richardson et al., 1992, Evans & Oldreive, 2000, O'Sullivan et al 1997, Allison et al 1998b) and proven to be a reliable and valid tool for measuring air-pressure changes associated with contractions of the deep abdominal muscles (Cairns et al., 2000). The change in air pressure has a linear relationship with activation of the deep abdominal muscles (Jull et al. 1993). This device was placed under the lumbar spine of the participants, who were positioned in a comfortable supine crooklying position as described on page 34.

3.3. Procedures

3.3.1. Normalization Procedure

The EMG signals of the abdominal muscles have been found to best normalized to sub-maximal contractions rather than maximal contractions (McGill et al. 1996). Previous studies had used resisted isometric prime mover contractions of the abdominal muscles (Allison et al. 1998b; Jull et al. 1993; Richardson et al. 1992), strap-resisted physiological trunk movements (Hubley-Kozey & Vezina, 2000; Madill & McLean, 2007) as well as bilateral straight-leg-raise (SLR) (O'Sullivan et al. 1997; Allison et al. 1998b). In this study, each participant was first asked to perform submaximal and maximal voluntary contractions (subMVCs and MVCs respectively), as well as a double straight leg raise (dSLR) to serve as normalization conditions for each muscle group in order to compare the results relative to the normalization procedures. Thereafter, for a given muscle, the maximum EMG amplitude from any of these contractions was then used to normalize the EMG amplitude for the AH and ULL tasks. The subMVCs were performed in crooklying (lying supine, with the head in mid-line resting on two pillows, the hips and knees flexed to 60°) with the arms crossed over the chest and hands reaching to the opposite shoulders (see Appendix G). The following physiological movements were performed: trunk flexion (targeting RA-UP and RA-MID) consisting of raising the head and thorax until the inferior angles of the scapulae lifted off the plinth; trunk left rotation (targeting EO) repeating the same movement as for trunk flexion but adding trunk rotation to the left once the inferior angle of the left scapula was off the plinth; and trunk right rotation (targeting the IO/TrA), repeating the movement as for trunk flexion but adding right trunk rotation and focusing on pushing the right scapula to the floor once the left

inferior angle of the scapula had lifted off the plinth (McGill et al., 1996; Madill & McLean, 2007). All contractions were performed for 10 s, and repeated three times, with a 30-s rest between repetitions. A 1-min rest was given between repetitions of each movement. The abdominal MVCs were obtained using the same actions as for the subMVCs but with the addition of a resisting strap comfortably but securely immobilizing the participants' shoulders to the plinth (Hubley-Kozey & Vezina (2002). The subjects were asked to generate maximum efforts against the strap and were given verbal encouragements. The third normalization procedure, the dSLR, was performed by having the participants simultaneously lift both their feet off the plinth, keeping their knees straight, to a height of 10cm (as indicated by the primary investigator) and to hold this position for 10 s (O'Sullivan et al., 1997). This was repeated three times.

3.3.2. Instruction of Abdominal Hollowing Exercise

Patients were taught the abdominal hollowing exercise according to the protocol of Allison et al. 1998b and O'Sullivan et al., 1997 who used the protocol of Richardson & Jull (1995). The participants were positioned in comfortable 4 point kneeling (hands and knees) with their shoulders positioned in 90 degrees flexion, shoulder-width apart, and neutral rotation. The hips were be in 90 degrees flexion. hip-width apart, neutral rotation, with knees flexed to 90 degrees, and ankles comfortably plantarflexed on one pillow. The spine was positioned in neutral flexion/extension.

From this four point kneeling position, the participants were instructed the AH exercise. The standardized teaching instructions were as follows (Hides et al. 2000): "I am

going to teach you how to do the abdominal hollowing exercise, also called the tummy tucking exercise. Listen to the instructions first and then I will ask you to perform the exercise. After you take a relaxed breath in and then a relaxed breath out, bring your belly button up towards your back without moving any other parts of your body or holding your breath. You can now try this.” Any substitutions strategies were identified and corrected (posterior pelvic tilting, flexing the thoracic spine, breath holding, flexing the neck, altering the scapular position). The participants practiced this activity to become familiar with the movement (to a maximum of ten minutes).

The participant was then re-positioned in comfortable crooklying on the plinth (supine lying with the head elevated on two pillows, hips in 45 degrees of flexion, knees in 30 degrees of flexion and ankles in neutral (O’Sullivan et al., 1997). The PBU was placed under the lumbar spine, between L1 and S1, as palpated by the primary investigator (A.T.-H.) and as agreed upon by the participant that the PBU was ‘in the middle of the small of their back.’ (see Appendix H).

The participant was then asked to repeat the AH exercise in this new position as described by Richardson et al., 1992 with the following instructions: “You are lying on the PBU device which measures changes in pressure because it is filled with air and is attached to a pressure gauge. I am going to inflate the PBU to 40 mmHg and you will feel a slight bulging in your low back like you are now lying on a small pillow. The tummy-tucking exercise you did on your hands and knees you are also going to do lying on the PBU, but this time I want you to raise the pressure in the PBU by 2 mmHg so that the gauge goes up to 42 mmHg and I want you to hold it there for a count of 10 seconds. You do this the same way as before: you take a relaxed breath in and then a relaxed breath out and then

you bring your belly-button in towards your back.” Any substitution strategies were identified and corrected. The participant practiced this to familiarize themselves with the movement (to a maximum of ten minutes).

3.3.3. Instruction of the unilateral leg lift

Participants were taught the lying in supine crooklying, with their left hip and knee flexed to 60° (as measured by a goniometer) and their right leg resting comfortably on the plinth. The hip and knee of the right leg were in extension and the ankle in neutral dorsiflexion/plantarflexion. The participant was then asked to raise their right leg to a height 20 cm (as demonstrated by the examiner’s hand) and then to return the leg to its resting position.

3.3.4. Abdominal Hollowing Task

The testing exercises were then performed as follows: three repetitions of AH, held for 10 s, with 30-s rest between each repetition, at sequential PBU pressure gauge readings of 42 mmHg (AH-1), 50 mmHg (AH-2), and 55 mmHg (AH-3). A 2-min rest was given between different pressure gauge trials. The order of the testing was fixed, beginning with the lowest PBU pressure and proceeding to the next two pressures. The ULL task (as described below) was performed after the abdominal hollowing exercise.

3.3.5. The Unilateral Leg Lift Task

The ULL task was then performed with the participants lying in supine crooklying, with their left hip and knee flexed to 60° (as measured by a goniometer) and their right leg resting comfortably on the plinth. The hip and knee of the right leg were in extension and the ankle in neutral dorsiflexion/plantarflexion. This position (as opposed to the active straight leg raise test) was considered appropriate for future use with participants experiencing low back pain and therefore was used here in this initial protocol. The participant was then asked to raise their right leg to a height 20 cm (as demonstrated by the examiner's hand) and sustain this height for 10 s. This activity was repeated three times with a 30-s rest between each repetition.

4.3. Data Processing and Analysis

4.3.1. Signal Processing

All data were inspected for the presence of electrocardiogram (ECG) signals, given the high likelihood of cardiac noise recorded during measurements of trunk muscle activity (Butler et al., 2009). ECG artifact was present in the RA-UP recordings only, in both the control and the CF groups. Further analysis revealed that the amplitude of the ECG activity represented less than one percent of the total energy in the EMG signals of interest. This amount of contamination was considered negligible, and therefore no procedures were implemented to remove the ECG artifact from the original signals.

The Root Mean Square (RMS) value of each EMG recording was calculated for each muscle over a 5-s window located in the middle of the 10-s AH-1, AH-2, AH-3 and ULL tasks. The RMS values using the reference contractions (subMVCs, MVCs and dSLR) were also calculated over a 5-s window for the subMVCs and dSLR, but were calculated over consecutive 1-s windows for MVCs. The highest value obtained from any of these types of contraction was used to normalize the RMS value of a given muscle (expressed as % max) for the AH and ULL tasks.

4.3.2. Data Analysis

Normal distribution of all the data was confirmed using the Kolmogorov-Smirnov test and therefore the use of parametric statistical tests was deemed appropriate.

The presence of outliers was found to be equal in both groups (less than 1%). They were therefore left in the data set (see Appendix D for calculations).

A three-way mixed-model analysis of variance (ANOVA) was used to test for differences in mean EMG amplitude between the four muscles, across the AH tasks, and between the two groups of subjects. There were two dependent (repeated measures) factors: task (42 mmHg, 50 mmHg, 55 mmHg) and muscle (RA-UP, RA-MID, EO, IO/TrA) and one independent factor: group (CF versus C). Post-hoc tests using Bonferonni corrected alpha levels were used to further test pair-wise comparisons of interest (see Appendix D: calculation of Bonferonni adjusted alpha). A two-way mixed-model ANOVA was used to test for differences in mean amplitude EMG between muscles (dependent factor) and groups for the ULL task.

Chapter Four: Voluntary and automatic recruitment of superficial and deep abdominal muscles in adults with and without cystic fibrosis

Voluntary and automatic recruitment of superficial and deep abdominal muscles in adults
with and without cystic fibrosis

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Abstract

Recruitment patterns of the superficial and deep abdominal muscles have been well documented in individuals who are asymptomatic and symptomatic of low back pain. Individuals with cystic fibrosis demonstrate muscle imbalances and have a high prevalence of low back pain. However they have been excluded from previous studies looking at muscle imbalances. Therefore the two objectives of this study were 1) to identify whether recruitment of the superficial and deep abdominal muscles during abdominal hollowing (AH) and unilateral leg load (ULL) tasks differed between individuals with CF and a non-CF control group (C); and 2) to compare the muscle activity between the superficial and deep abdominal muscles across these tasks.

METHODS: Twenty-eight participants (14 with CF and 14 controls) performed (i) AH in supine at three target pressures of a pressure biofeedback unit (PBU) and (ii) a right-sided ULL. Surface electromyography (EMG) of the abdominal muscles was recorded and the amplitude of the signal was normalized to a maximum value (% max). **RESULTS:** For the AH, a 3-way repeated measures ANOVA showed a muscle x task interaction for both groups, but no between group differences in EMG amplitude. Bonferonni post-hoc tests on pooled data showed the deep abdominal muscles to be significantly more active than the superficial muscles. A 2-way repeated measure ANOVA indicated no group differences in EMG amplitude during the ULL. **DISCUSSION:** The results of this study demonstrate that adults with stable CF recruit their abdominal muscles similarly to a healthy control group during the AH task and during the ULL task. This normative data could be used to investigate recruitment patterns in stable CF individuals who are symptomatic of low back pain.

1. Introduction

The study of abdominal muscle recruitment has gained much interest in the last two decades. Once considered to be recruited as a group (Detroyer, 1990), the abdominal muscles are now recognized to act concertedly yet independently to control the body's centre of mass during postural perturbations (Cresswell et al., 1992 & 1993), create axial trunk movements (Urquhart et al., 2005), support respiration (Abe et al., 1996; Misuri et al., 1997; Hodges & Gandevia, 2000b), and control intra-abdominal pressure (Cresswell et al., 1994; Hodges & Gandevia, 2000a). These studies have revealed intricate motor recruitment patterns between the superficial (rectus abdominis (RA), external obliquus (EO)) and the deep (internal obliquus (IO), transversus abdominis (TrA)) abdominal muscle layers, according to the task.

Tasks requiring voluntary and simultaneous activation of the abdominal muscles include trunk flexion, trunk rotation (Williams et al., 1999; Urquhart et al., 2005b) and abdominal bracing (isometric contraction of all the abdominal wall muscles) (Vera-Garcia et al., 2007). Sequential and independent voluntary recruitment of these muscles can become very skilled, as evidenced by the recruitment activity of the RA and the EO in eastern-style belly dancing (Moreside et al., 2005). The standard exercise used to demonstrate the independence of recruitment of the superficial from the deeper layer of abdominal muscles is the abdominal hollowing (AH) exercise. It requires the independent activation of the deep and superficial abdominal muscle layers (Jull et al., 1993; Hodges et al., 1999; Hides et al., 2000; Hides et al., 2006; Urquhart et al., 2005b) and is performed by “drawing-in” of the umbilicus, up and towards the spine. When performed using a pressure biofeedback unit (PBU) to grade the intensity of effort, this exercise highlights the

differential activation of the abdominal muscle layers. There is preferential recruitment of the TrA muscle (and to some degree the lower fibers of the IO muscle) at lower target pressures of 42 mmHg to 45 mmHg, while the RA and the EO remain relatively silent. Higher target pressures of 50mmHg or 55mmHg require greater activity of the IO, EO and RA muscles (O'Sullivan et al., 1997; Allison et al., 1998). During the AH maneuver, use of the superficial abdominal muscles during low PBU pressures is considered a substitution pattern (Hides et al., 2000) and indicative of abdominal muscle imbalance, where there is overactivity of the superficial muscles and slower onset in the recruitment of the deep muscles (Comerford & Mottram, 2001). Altered patterns of recruitment of the superficial and deep abdominal muscles are not generally present in the normal population, and have been identified in people with non-specific mechanical low back pain (Hodges & Richardson, 1996; Hodges et al., 1999), mechanical low back pain due to spondylolysis/spondilolisthesis (O'Sullivan et al., 1997), experimentally-induced low back pain (Hodges et al., 2003) and experimentally-induced hypercapnia (Hodges et al., 1997b). Interestingly, people with stress urinary incontinence have altered automatic recruitment of their abdominal and pelvic floor muscles (Sapsford et al., 2001).

To date, normative data on the recruitment pattern of abdominal muscles has not been researched in populations with concurrent cardiorespiratory diseases. The literature in cystic fibrosis (CF) reports a high prevalence of low back pain (Dodd & Prasad, 2005; Yankaska et al. (2004, however, no study has investigated the recruitment patterns of the abdominal muscles in these individual or even in asymptomatic individuals with CF. This group is also known to present with skeletal deformities (McVean et al., 2004), postural deformities (Tattersall & Walshaw, 2003) as well as skeletal muscle imbalances (Rose et

al., 1987; McVean et al., 2004) all of which have are known to contribute to muscles imbalances in the normal population (Kendall et al., 1975). The chronic coughing associated with CF may be a source of superficial abdominal muscle training and overuse, which, if present, may also lead to altered abdominal recruitment patterns.

The purpose of this study was to investigate the recruitment patterns of the superficial and deep abdominal muscles in individuals with stable cystic fibrosis and in individuals without CF. Both groups were asymptomatic of low back pain and the CF participants had stable cardiorespiratory symptoms. The normative CF data from this study could serve as reference to study the abdominal recruitment patterns in individuals with CF suffering from low back pain.

The specific objectives of this study were twofold. The first objective was to identify differences between individuals with stable CF and an age matched non-CF control group (C) in the recruitment of the superficial and deep abdominal muscles during the abdominal hollowing (AH) exercise and during the automatic activity of a unilateral leg load (ULL). The second objective was to compare the relative levels of muscle activation between the superficial and deep abdominal muscles during the AH tasks and the ULL task.

The four hypotheses for this study were: (i) individuals with CF would demonstrate higher EMG activity of their superficial abdominal muscles during the AH exercise as compared to the control group and (ii) would demonstrate lower EMG activity of the deep abdominal muscle group during the AH exercise as compared to the control group. The third and fourth hypotheses were that (iii) the group with CF would

demonstrate higher EMG muscle amplitudes in the superficial abdominal muscles when performing the ULL and (iv) lower EMG amplitudes in the deep abdominal muscles when compared to the control group.

2. Materials and Methods

2.1 Sample and recruitment

Fourteen individuals with stable CF (9 women and 5 men) and 14 healthy control subjects (8 women and 6 men) participated in the study. None of the participants had a previous history of stress urinary incontinence, chronic low back pain in the previous six months, or any previous experience with abdominal muscle training or “core strengthening” such as is participating in Pilates® or Yoga. All were in good general health. The participants with stable CF were excluded if they had experienced any fever or malaise, change in sputum color or quantity, tiredness, or increase in cough frequency during the week prior to testing. Participants with a neurological disease, a respiratory disease other than cystic fibrosis, or abdominal pain were also excluded. All participants signed a written consent form approved by the Ethics Boards of Bruyère Continuing Care, the Ottawa Hospital, and the University of Ottawa. Control subjects were recruited via poster advertisements, and the CF participants were recruited through the Cystic Fibrosis Clinic at the Ottawa Hospital, Ottawa, Ontario, Canada. All participants completed the Leicester Cough Questionnaire (LCQ) (Birring et al., 2003) which is a questionnaire investigating the coughing habits of individuals with respiratory disease and has been used in the CF population.

2.2 Instrumentation

Surface electromyographic (EMG) signals were obtained using four Delsys differential surface electrodes (DE 2.1 Bagnoli System, Delsys TM, Baltimore, Maryland, U.S.A.) which were taped to the skin overlying the abdominal muscles, on the right side of the body. The signals were amplified, filtered (band-pass filter 10-1000Hz, CMRR 92dB at 60 Hz) digitized at a sampling rate of 1000 Hz using a 1401digital/analog acquisition card (Cambridge Electronic Design Ltd; England) and stored on a personal computer. Data were processed using Spike 2 version 5.6TM. The intensity of 40 mmHg on the pressure biofeedback unit (PBU) (Chattanooga model, BP Medical Supplies, U.S.A.) was used to confirm that the participants maintained their lumbar spine in a neutral position during the instruction phase. Increasing the PBU intensities served as motor targets during the three AH tasks.

2.3. Procedures

Surface electrodes were positioned and oriented parallel to the muscle fibers over the right abdominal muscles (Ng & Kippers, 1998). The skin was prepared by rubbing with water and shaving the area when necessary. Conductive gel was applied to the electrodes and these were taped to the skin using Delsys TM 2-slot adhesive skin interface tape (Delsys, Baltimore, Maryland, U.S.A.) and further secured using hypoallergenic tape. The following anatomic locations were used for electrode placement: upper fibers of RA (RA-UP) centered 7 cm inferior and 3 cm lateral to the xyphoid process, middle fibers of RA (RA-MID) centered 3 cm lateral to the umbilicus, EO centered 13 cm lateral to the umbilicus, and IO and TrA (IO/TrA) centered 3 cm medial and inferior to the right anterior

superior iliac spine (ASIS). These positions have been used previously (O'Sullivan et al., 1997; Allison et al., 1998) and considered valid for measuring deep abdominal muscle function (McGill et al., 1996). A reference electrode was placed over the left ASIS.

Each participant was first asked to perform submaximal and maximal voluntary contractions (subMVCs and MVCs respectively), as well as a double straight leg raise (dSLR) to serve as normalization conditions for each muscle group. For a given muscle, the maximum EMG amplitude from any of these contractions was then used to normalize the EMG amplitude for the AH and ULL tasks. The subMVCs were performed in crooklying (lying supine, with the head in mid-line resting on two pillows, the hips and knees flexed to 60°) with the arms crossed over the chest and hands reaching to the opposite shoulders. The following physiological movements were performed: trunk flexion (targeting RA-UP and RA-MID) consisting of raising the head and thorax until the inferior angles of the scapulae lifted off the plinth; trunk left rotation (targeting EO) repeating the same movement as for trunk flexion but adding trunk rotation to the left once the inferior angle of the left scapula was off the plinth; and trunk right rotation (targeting the IO/TrA), repeating the movement as for trunk flexion but adding right trunk rotation and focusing on pushing the right scapula to the floor once the right inferior angle of the scapula had lifted off the plinth (McGill et al., 1996). All contractions were performed for 10 s, and repeated three times, with a 30-s rest between repetitions. A 1-min rest was given between repetitions of each movement. The abdominal MVCs were obtained using the same actions as for the subMVCs but with the addition of a resisting strap comfortably but securely immobilizing the participants' shoulders to the plinth (Hubley-Kozey & Vezina (2002)). The subjects were asked to generate maximum efforts against the strap and were given

verbal encouragements. The dSLR was performed by having the participants simultaneously lift both their feet off the plinth, keeping their knees straight, to a height of 10cm (as indicated by the primary investigator) and to hold this position for 10 s (O'Sullivan et al., 1997). This was repeated three times.

The participants were first taught the AH exercise while positioned in four point-kneeling with their hands shoulder-width apart and perpendicular to their thorax. Their knees were hip-width apart and perpendicular to their pelvis. This position is considered to be the most suitable one for teaching the abdominal hollowing exercise (Hides et al., 2000). The standardized instructions consisted of asking the participant to breathe in and out in a relaxed manner and to then “draw their belly button up and in towards their spine” (Hides et al., 2000; Urquhart et al., 2005b; Bjerkefors et al. 2010). Substitution strategies such as rib flaring, breath-holding, thoracic flexion, and posterior pelvic tilt were corrected using tactile and verbal cues. Participants were all comfortable with the task and visual inspection of the EMG confirmed the appropriate muscle activation in all the participants, showing the preferential recruitment of the deep abdominal muscles. The participants were then positioned in supine crooklying and the PBU was placed underneath the lumbar spine, in midline, between L1 and S1 and inflated to a baseline pressure of 40mmHg, which is the standard used to reflect a neutral lumbar spine when performing abdominal hollowing (Richardson et al., 1993; Hodges & Richardson, 1999). Participants were then re-instructed on how to do the abdominal hollowing exercise in this position with visual feedback from the PBU's pressure gauge. Any substitution strategies were corrected. Visual inspection of EMG signals confirmed the appropriate activation of IO/TrA in this position.

The testing exercises were then performed as follows: three repetitions of AH, held for 10 s, with 30-s rest between each repetition, at sequential PBU pressure gauge readings of 42 mmHg (AH-1), 50 mmHg (AH-2), and 55 mmHg (AH-3). A 2-min rest was given between different pressure gauge trials. The ULL task was then performed where the participants laid in supine crooklying, with their left hip and knee flexed to 60° while their right leg was resting comfortably on the plinth, with the hip and knee in extension and the ankle in neutral dorsiflexion/plantarflexion. This position (as opposed to the active straight leg raise test) was considered appropriate for future use with participants experiencing low back pain and therefore was used here in this initial protocol. The participant was asked to raise their right leg to a height 20 cm (as demonstrated by the examiner's hand) and sustain this height for 10 s. This activity was repeated three times with a 30-s rest between each repetition.

3. Data processing and analysis

3.1 Signal processing

All data were inspected for the presence of electrocardiogram (ECG) signals, given the high likelihood of cardiac noise recorded during measurements of trunk muscle activity. ECG artifact was present in the RA-UP recordings in both the control and the CF groups. Further analysis revealed that the amplitude of the ECG activity represented less than one percent of the total energy in the EMG signals of interest. This amount of contamination was considered negligible, and therefore no procedures were implemented to remove the ECG artifact from the original signals.

The Root Mean Square (RMS) value of each EMG recording was calculated for each muscle over a 5-s window located in the middle of the 10-s AH-1, AH-2, AH-3 and ULL tasks. The RMS values using the reference contractions (subMVCs, MVCs and dSLR) were also calculated over a 5-s window for the subMVCs and dSLR, but were calculated over consecutive 1-s windows for MVCs. The highest value obtained from any contraction was used to normalize the RMS value of a given muscle (expressed as % max) for the AH and ULL tasks.

3.2 Data analysis

Normal distribution of all the data was confirmed using the Kolmogorov-Smirnov test and therefore the use of parametric statistical tests was deemed appropriate.

A three-way mixed-model analysis of variance (ANOVA) was used to test for differences in mean EMG amplitude between the four muscles, across the AH tasks, and between the two groups of subjects. There were two dependent (repeated measures) factors: task (42 mmHg, 50 mmHg, 55 mmHg) and muscle (RA-UP, RA-MID, EO, IO/TrA) and one independent factor: group (CF versus C). Post-hoc tests using Bonferonni corrected alpha levels were used to further test pair-wise comparisons of interest. A two-way mixed-model ANOVA was used to test for differences in mean amplitude EMG between muscles (dependent factor) and groups (independent factor) during the ULL. Where Mauchly's Test of Sphericity indicated differences in variances of the levels (equality not assumed), the reported F values are those of Greenhouse-Geisser with the appropriate correction in the degrees of freedom values (George & Mallory, 2007).

4. Results

The mean age of the CF participants was 25 years (men: 28, SD= 6; women: 23, SD= 7 and the mean age of the control (C) group was 26 years (men: 25, SD=5; women 26, SD= 8). There was no statistically significant difference in age between the two groups ($p = 0.67$). Results from the Leicester Cough Questionnaire showed a significant difference in scores between the two groups, the CF group scoring less than the control group (CF: mean = 95, SD = 20; controls: mean = 130, SD = 1) indicating that the CF participants experienced significantly greater coughing behavior than the control group ($p = 0.0000007$).

4.1. Task 1: Abdominal hollowing

The EMG amplitudes recorded from each muscle during the AH tasks are presented in figure 1. The three-way repeated-measures ANOVA revealed a significant muscle x task interaction ($F(6, 156) = 4.247, p = 0.001$) indicating that the change in EMG amplitudes across the AH tasks was significantly different across the muscles. However, no group interaction was found ($F(1, 26) = 0.043, p = 0.837$) indicating that both EMG amplitude of both groups behaved similarly.

Given that no difference was found between the two groups, their data were pooled to compare the mean EMG amplitude of the deep (IO/TrA) and the superficial muscles (RA-UP, RA-MID and EO) in a pair wise fashion. The Bonferonni corrected alpha level was 0.0083 (0.05/6 muscle combinations). The mean EMG amplitude of the IO/TrA muscle was significantly higher than that seen in the superficial muscles (RA-UP, EO, and RA-MID) during all three AH tasks. Within the superficial group, the amplitude of the EO

muscle was significantly higher than that of the RA-UP and RA-MID. The RA-UP and the RA-MID did not differ from each other.

To investigate changes in EMG amplitude of one muscle across the three AH tasks, the Bonferonni test (corrected alpha level of 0.0167 (0.05/3 tasks combinations)) was used. The IO/TrA muscle demonstrated no significant increase in amplitude across the three AH tasks. Although visually there was an increase in amplitude, this was not significant, indicating that once the IO/TrA was recruited from its baseline of 40mmHg to 42 mmHg its activity remained constant. In contrast, all of the superficial muscles demonstrated significant amplitude differences between AH-1 and AH-2 and AH-1 and AH-3 but not between AH-2 and AH-3. This indicated that once the EMG amplitude created a PBU pressure of 50mmHg at AH-2, the recruitment of the superficial muscles did not increase significantly in order to accomplish the 5 mmHg increase in pressure to achieve AH-3. These results are presented in figure 2.

4.2. Task 2: Unilateral Leg Lift

The results of the EMG recordings during the ULL are presented in figure 3. The two-way (group x muscle) ANOVA indicated that there was a difference in EMG amplitude recorded from the different muscles ($F(3, 78) = 7.869$, $p = 0.00$) but that the pattern of recruitment was similar in both groups ($F(1,26) = 0.005$, $p = 0.945$). Pooling the group data and using a Bonferonni corrected alpha level of $p = 0.0083$ (0.05/6 muscle combinations), the amplitude of the IO/TrA was found to be significantly greater than that of the RA-UP and RA-MID ($p = 0.008$ and $p = 0.0063$), but not significantly different from EO ($p = 0.337$) indicating that there was no difference in the recruitment of the oblique

muscles during this task. The amplitude of EO was significantly different than that of RA-UP but not RA-MID ($p = 0.0004$ and $p = 0.05$ respectively). RA-UP and RA-MID were not significantly different from each other ($p = 0.704$). These results are illustrated in figure 4.

5. Discussion

The purpose of this study was to investigate differences in EMG activity of the superficial and deep abdominal muscles in a sample of individuals with CF and a control group. Because of the potential for preferential training of the superficial muscles caused by chronic coughing in the CF group, it was hypothesized that this group would demonstrate significantly greater EMG amplitude in the superficial muscles during the AH activities than the control group and secondly, that the CF group would demonstrate a lower normalized EMG amplitude in IO/TrA than the control group during the AH-1 task. It was also hypothesized that the CF group would demonstrate greater recruitment of the superficial abdominal muscles and lower recruitment in IO/TrA during the ULL.

Individuals with CF versus controls

Our results indicate that there were no significant differences in muscle recruitment between the two groups during the voluntary task of abdominal hollowing or during the automatic task of a unilateral leg load. Thus, the participants with CF did not preferentially recruit their superficial muscles as was hypothesized. The absence of overt superficial muscle use during the AH-1 indicated that no substitution strategies were being employed by individuals with CF to perform this low-load task. The muscle recruitment

patterns found in this study support those found in previous studies (Allison et al., 1998; Chanthapetch et al., 2009).

Our second hypothesis that the deep abdominal muscles would show less EMG activity in the CF group was also not confirmed. Therefore these abdominal muscles do not appear to be inhibited nor do they demonstrate differences when compared to a non-CF control group. Even though the amplitude of the IO/TrA in the CF group seemed higher (12.97 % vs 23.11%) the difference did not reach significance ($p = 0.18$). The between-subject variability (reflected in standard deviation) for both groups was high for the deep abdominal muscles and this is a consistent finding amongst the many studies of abdominal muscle activity (Chanthapetch et al. 2009, Madill and McLean, 2007, Allison et al. 1998, O'Sullivan et al. 1997).

The asymptomatic stable CF-group's EMG amplitudes also differ from those found in the population with low back pain (O'Sullivan et al., 1997). The IO and TrA are considered to be tonic muscles and as such are expected to contract to approximately 20% of their maximum voluntary capacity during the abdominal hollowing at low PBU pressures (Hides et al., 2005). The mean activation amplitude found in the CF group in this study (23.11%) is consistent with those found by Chanthapetch et al. (2009) and Allison et al. (1998), and is also consistent with that which is expected to be found of these tonic muscles during a low-load task which is below 30% (Hides et al., 2005).

Individuals with stable CF do not appear to develop “over-active” superficial abdominal muscles as related to their chronic coughing. The results from this study might suggest that since the only significant difference between the two groups was the Leicester

Cough scores ($p = 0.0000007$) and that the mean EMG amplitude of IO/TrA of the CF group was larger (though not statistically significant) than that of the control group, chronic coughing might affect the deeper abdominal muscles more than the superficial ones. Given that Neumann & Gill (2002) have documented deep abdominal muscle activity in the TrA and IO muscles during maximal coughing (179% of maximum and 136% of maximum respectively), it could be suggested that coughing might contribute to increased EMG amplitude recordings in the deeper abdominal muscles as opposed to the superficial abdominal muscles during AH.

Variations in EMG amplitudes

The recruitment patterns of the deep and superficial abdominal muscles during low-load conditions found in previous studies (Beith et al., 2002; Drysdale et al., 2005; Urquhart et al., 2005a) are consistent with those found in the AH-1 task here. All subjects from both groups were able to preferentially recruit their IO/TrA muscle during a low-load task (AH-1) where the superficial muscles were relatively inactive. As the low-load task increased in difficulty, the superficial muscles began to be recruited as indicated by the significant increase in mean EMG amplitude across the three PBU pressures. Other studies have investigated the specific recruitment of the superficial muscles during AH, pelvic tilt and trunk stability tests, and found EO to be more active than RA (Vezina & Hubley-Kozey, 2000; Hubley-Kozey & Vezina, 2002), which was consistent with the results found in the AH-1 task here. Overall, these studies highlight the specificity of abdominal muscle recruitment according to load and task.

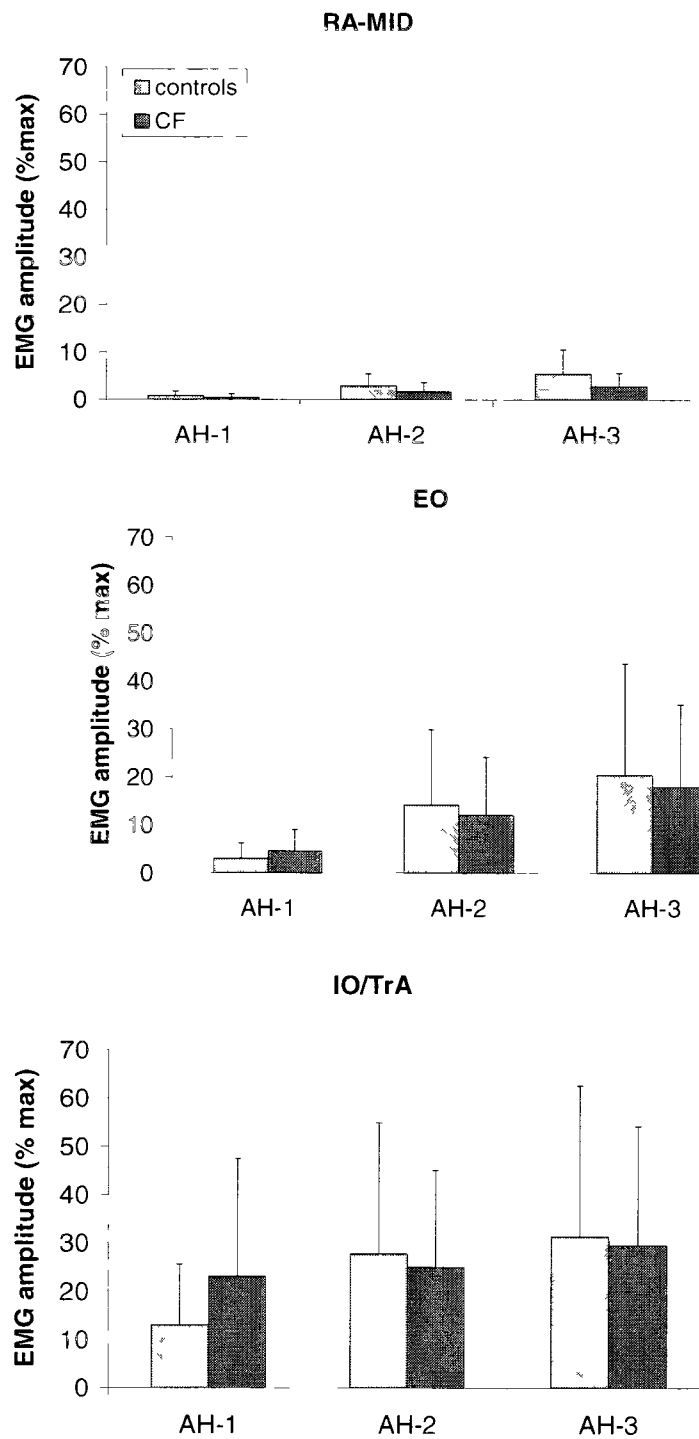
Within the superficial muscle group, the activity of RA-UP did not differ from the activity of RA-MID, which was not surprising as there is no indication in the literature of preferential regional recruitment within this muscle during this task. The EO muscle increased its amplitude to a greater degree than RA-UP and RA-MID at higher task intensities (PBU pressures 50 and 55mmHg) in both groups. This is the first study to compare the EMG amplitudes of the superficial muscles across three AH tasks.

6. Conclusion

This study compared the abdominal muscle activity of 14 participants with stable CF to a control group of 14 participants using surface EMG. We demonstrated no significant differences in mean EMG amplitude of the superficial and deep abdominal muscles between the two groups during three AH exercises of increasing intensities and during the ULL. This is evidence that patients with stable CF do not have inhibited recruitment of their deep abdominal muscles and do not have overactive superficial abdominal muscles during these tasks. Individuals with CF demonstrated the same ability to preferentially activate their deep and superficial abdominal muscles as did the control group. The results from this study could be used as normative data for comparisons to a group of stable CF participants who are symptomatic of low back pain. Therefore, individuals with stable CF who are asymptomatic of low back pain may not be at greater risk than asymptomatic non-CF individuals for developing low back pain associated with faulty recruitment of deep abdominal muscles.

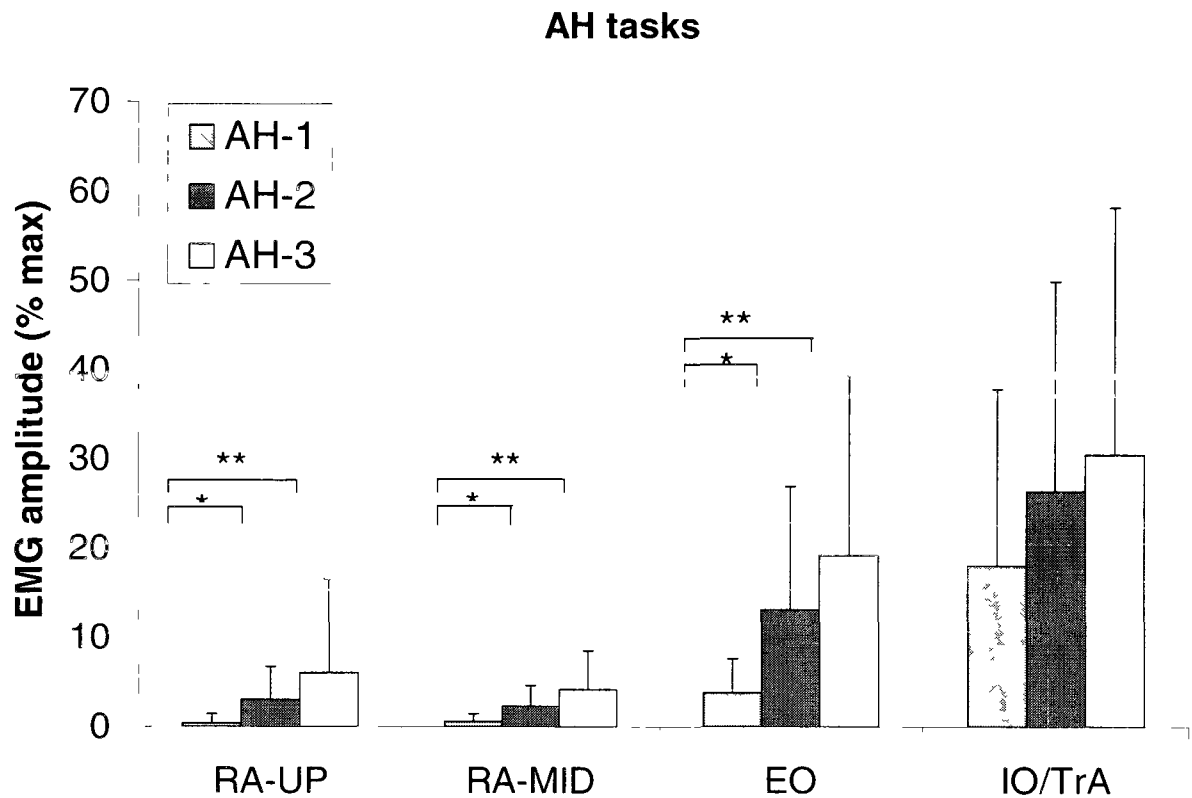
Figure 1. Between group of muscle EMG amplitude during the abdominal hollowing

Figure
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Mean and standard deviation of %max normalized EMG amplitudes of the superficial and deep abdominal muscles during the three abdominal hollowing exercises. Bars indicate the mean normalized EMG amplitude and whiskers indicate the standard deviations. Muscle amplitudes did not differ between groups. Superficial muscles: RA-MID (rectus abdominis middle fibers) and EO (externus obliquus) (RA-UP not shown). Deep muscles: IO/TrA (internal obliquus/ transversus abdominis group).

Figure 2. Between-task comparisons of EMG muscle activity during the abdominal hollowing



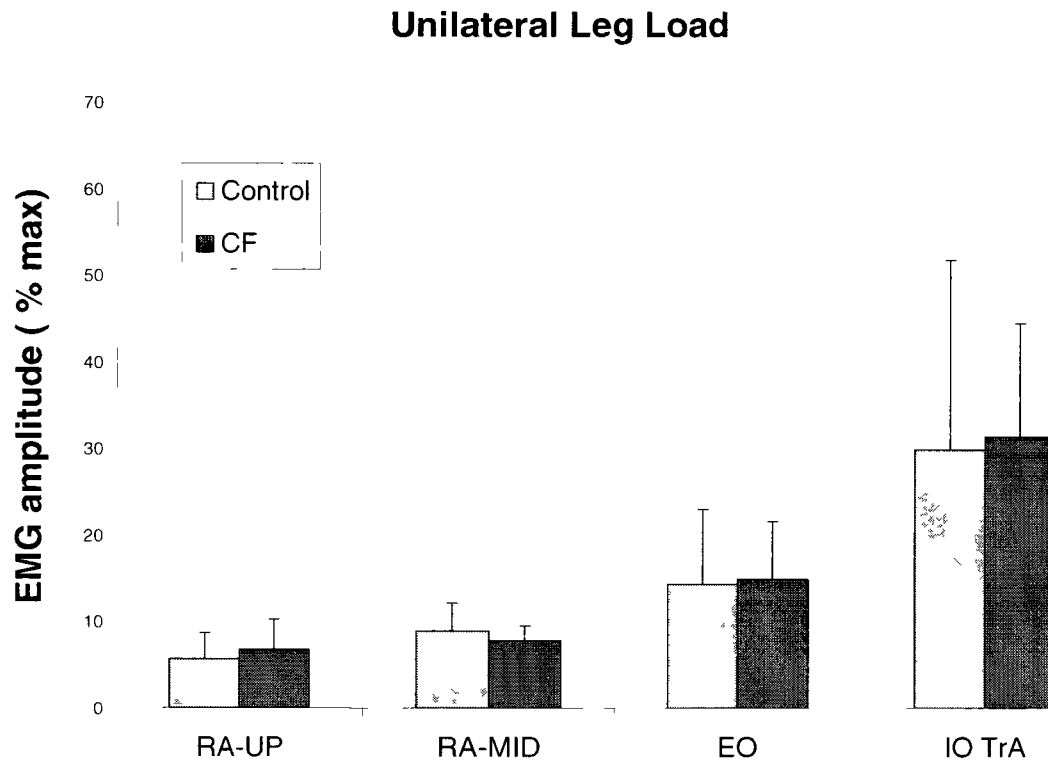
Comparisons of mean and standard deviation of EMG amplitude between AH tasks.

Significant differences were found in all the superficial muscles but not between all the tasks. No between task differences were found for the deep abdominal muscles. Superficial muscles: RA-UP (rectus abdominis upper fibers), RA-MID: (rectus abdominis middle fibers) and EO: (externus obliquus). Deep muscles: IO/TrA: internal obliquus/ transversus abdominis group.

RA-UP: * $p = 0.0008$ ** $p = 0.0006$; RA-MID: * $p = 0.0007$ *** $p = 0.00006$

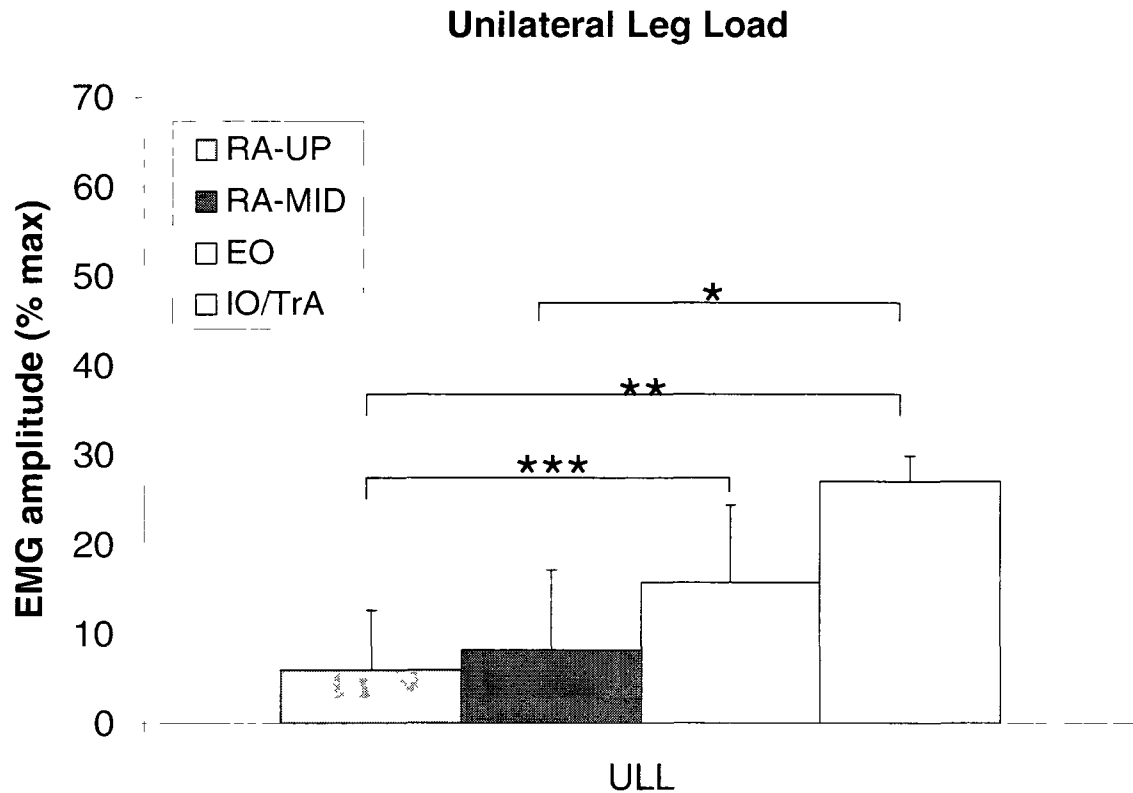
EO: * $p = 0.001$ ** $p = 0.0002$

Figure 3. Between-group comparisons of EMG amplitude during the ULL



Mean and standard deviation of %max normalized EMG amplitudes of the superficial and deep abdominal muscles during the unilateral leg load. Bars indicate the mean normalized EMG amplitude and whiskers indicate the standard deviations. Muscle amplitudes did not differ between groups. Superficial muscles: RA-UP (rectus abdominis upper fibers), RA-MID: (rectus abdominis middle fibers) and EO: (externus obliquus). Deep muscles: IO/TrA: internal obliquus/ transversus abdominis group,.

Figure 4. Between-muscle comparisons of muscle activity during the ULL



Mean and standard deviation of EMG amplitudes for between-muscle comparisons during the ULL. No difference was found between EO and IO/TrA or between EO and RA-MID. Superficial muscles: RA-UP (rectus abdominis upper fibers), RA-MID: (rectus abdominis middle fibers) and EO: (externus obliquus). Deep muscles: IO/TrA: internal obliquus/transversus abdominis group.

* $p = 0.006$

** $p = 0.0083$

*** $p = 0.0004$

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Chapter Five: General Discussion and Conclusion

The purpose of this study was to investigate the patterns of recruitment of the superficial and deep abdominal muscles between a group of participants with stable CF and a group of participants without CF. The two objectives involved comparing the abdominal muscle activity during a task of voluntary recruitment (AH tasks) and a task of automatic recruitment (ULL task). Regardless of the type of muscles recruitment involved, no difference was found between the control group and the CF group. The statistically significant differences in the recruitment patterns of the specific muscles found in the cross-comparisons support previous findings involving the AH tasks. However, this is the first study to introduce the AH task to individuals with stable CF and to identify the abdominal motor patterns used by this group. Based on the results here, the stable CF person could be included as a participant in studies using the AH exercise such as it was used here.

5.1. Normalization procedures

The secondary objective of comparing the two normalization procedures of %max and dSLR did not yield any different conclusions. The between-group and muscle X task interactions were the same in both procedures and these are presented in appendix D. The dSLR procedure yielded significantly higher values of EMG amplitudes than the %max. However, the statistical conclusions comparing the superficial and deep abdominal muscle activity were the same. Because the performance of a double leg lift in patients with low back pain could potentially increase pain owing to the high mechanical loading of the spine caused by this activity, it may thus be less appropriate than performing

physiological trunk movements with or without a resisting strap for this type of population. Therefore, the use of physiological movements of the trunk as normalization exercises to generate normative data for an asymptomatic CF and non-CF population appears appropriate and could then be extended to symptomatic populations. It is also suggested here that the %max procedure likely better reflects individual muscle capacity and is a more suitable normalization activity for a protocol comparing individual abdominal muscle activity such as the one used in this study.

5.2. Leicester Cough Questionnaire and PFT's

The relationship of the Leicester Cough Questionnaire (LCC) to EMG amplitude of the IO/TrA does not seem to be predictable. From visual inspection of the raw data, there was no trend of low LCC scores and high IO/TrA amplitudes and therefore no correlation analysis were performed. In addition, there did not seem to be a relationship between pulmonary function test (PFT) value and EMG amplitude of IO/TrA. Ninane et al. (1992) found a relationship between low PFT values and increased deep abdominal muscle activity using ultrasound, but this did not appear in the raw surface EMG data here.

5.3. Limitations of the Study

The experimental activities and the use of the supine crooklying position involved in this study are not considered to reflect the activity of the abdominal muscles during such functional activities such as walking, sitting, running, or activities requiring

the simultaneous use of the upper and lower extremities such as swimming or tennis. The AH and ULL activities were chosen given the existence of previous methodologies in the literature, the application of a low load to the trunk and spine, as well as its relevance to current clinical assessment techniques. Future studies could include more functional daily recreational activities such as walking, cycling, and reaching for examples, all of which also have previous protocols.

Other studies have investigated the activity of the superficial and deep abdominal muscles during low-load tasks as well as in positions of prone-lying and 4 point kneeling (Beith et al, 2002), during abdominal bracing and pelvic tilting (Urquhart et al. 2005). The recruitment patterns of the deep versus superficial muscles during low-load conditions found in these studies are consistent with those found in the AH-I position of this study. Given that the abdominal hollowing in recumbent positions is the starting point of all therapeutic rehabilitation exercises aimed at creating/restoring appropriate motor control timing of the superficial and deep abdominal muscles and, therefore, the confirmation of the appropriate motor patterns here is of clinical use

The results from this study are exclusive to its participants. These results do not extrapolate to the population of other people with cystic fibrosis, including those who do not have stable disease, who have low back pain or chronic stress urinary incontinence, or who have undergone major surgery such as lung-transplants. None of the participants in either group had experience with voluntary recruitment of the deep abdominals, and therefore the results here could not be applied to individuals who have had such muscle training. None of the control group participants had a chronic cough therefore these results

could not be extrapolated to such a group. The results here are specific to individuals with CF and not to other cardiorespiratory diseases such as COPD or asthma.

Most of the participants with CF were casually coughing during rest periods, between the actual data collection. The effect of this on the recruitment of the abdominal muscles is unknown but could be further studied by comparing a group of chronic coughers, both with CF and without CF using the same protocol.

5.4. General Conclusion

Superficial and deep abdominal muscle recruitment activity was measured in this study, using the AH exercise and a ULL exercise. The CF group demonstrated no significant differences in the recruitment activity of the superficial (RA-UP, EO, and RA-MID) and the deep abdominal muscles (IO/TrA) as compared to the control group. This group of individuals with stable CF who were pain-free, did not have stress urinary incontinence nor had any skeletal deformities did not demonstrated increased activity of their superficial abdominal muscles nor decreased activity of their deep abdominal muscles during the three as AH tasks and the ULL task. Therefore, from a mechanical view-point, this group demonstrated suitable neuromotor recruitment patterns necessary to ensure proper mechanical stability of the osteoligamentous structures of the lumbopelvis when the lumbar spine is in a neutral position and under low mechanical loading conditions. The results here demonstrated the concertedness yet independent recruitment activity required of the abdominal muscles to perform the low-load mechanical task that is the AH and the

ULL. Further research is necessary to investigate any differences in patterns of abdominal muscle activity during more functional positions, and with other types CF patients.

Contribution of Collaborators

Anne Taillon-Hobson, graduate student in the School of Human Kinetics is the sole author of this thesis. She was the primary investigator of this study and the primary author of the article and overall thesis underlying this study.

Dr. Shaun Aaron assisted in the development of the protocol. He also facilitated the recruitment of participants with CF and the logistics therein, and assisted with the reviewing of the article.

Dr. Linda McLean was instrumental in the development of the protocol for this study as well as the analysis of the data. She also assisted in the reviewing of the article.

Dr. Martin Bilodeau was the thesis supervisor for Anne Taillon-Hobson. He assisted in the development of the initial proposal underlying this study, instructed her regarding the use of the laboratory equipment, administrative procedures regarding testing and data collecting, as well as the statistical analyses and the review of the article.

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Appendices



Bruyère pour des soins continus.
Bruyère Is Continuing Care.

Hopital Elisabeth Bruyere Hospital
43 rue Bruyere St
Ottawa ON K1N 5C8
Tel Tel 613 562 6262
Telec Fax 613 562 6367

Hopital Saint Vincent Hospital
60, rue Cambridge St N
Ottawa ON K1R 7A5
Tel Tel 613 562 6262
Telec /Fax 613-782-2785

Institut de recherche Elisabeth Bruyere
Elisabeth Bruyere Research Institute
43 rue Bruyere St
Ottawa ON K1N 5C8
Tel Tel 613 562 6045
Telec Fax 613 562 4266

Residence Saint Louis Residence
879, chemin Hiawatha Park Road
Ottawa ON K1C 2Z6
Tel Tel 613 562 6262
Telec Fax 613 683 5001

Residence Elisabeth-Bruyere Residence
75 rue Bruyere St
Ottawa ON K1N 5C8
Tel /Tel 613 562-6262
Telec /Fax 613 562 4223

Centre de medecine familiale Bruyere
Bruyere Family Medicine Centre
75 rue Bruyere St
Ottawa ON K1N 5C8
Tel Tel 613-241-3344
Telec Fax 613 241 1971

Centre de medecine familiale Primrose
Primrose Family Medicine Centre
45 rue Primrose St
Ottawa ON K1R 0A1
Tel Tel 613 230 7788
Telec Fax 613 230 7778

Fondation Bruyere Foundation
13 rue Bruyere St
Ottawa ON K1N 5C8
Tel Tel 613 562 6419
Telec Fax 613 562 6023

April 28, 2009

Ms Anne Taillon-Hobson
EBRI
43 Bruyère St
Ottawa, ON

RE: Effect Abdominal Muscle Activity in Adults with Cystic Fibrosis (Bruyere REB Protocol # M16-08-091)

Dear Ms Taillon-Hobson

Thank-you for the revised COREB and accompanying documentation, which were received on April 24 and 28, 2009. These have been reviewed by the Chair and writer.

The information received has satisfied all the conditions set out in our letter of January 16, 2009. As such, the Bruyère Continuing Care Research Ethics Board (REB) is pleased to give ethical approval for one year (April 28, 2009 – April 28, 2010) to proceed with the above titled study.

Any changes to the protocol must be submitted to the REB for approval. You are also expected to provide written request for renewal or notification of the termination of the study by April, 2010.

We wish you the best of luck with this study.

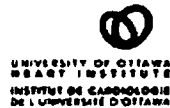
Sincerely,

Dr Lisa Sweet, C Psych
Chair of the Research Ethics Board
Bruyère Continuing Care
(613) 562-6262 ext 1368
lsweet@bruyere.org

Affiliated with



uOttawa



Ottawa Hospital Research Ethics Boards / Conseils d'éthique en recherches

751 Parkdale Avenue Suite 106, Ottawa, Ontario K1Y 1J7 813-798-5555 ext. 14902 Fax 813-761-4311
<http://www.ohri.ca/ohreb>

Tuesday, September 08, 2009

Dr. Martin Bilodeau
Elisabeth Bruyère Research Institute
Aqina & Movement Group

Dear Dr. Bilodeau

Re: Protocol # 2009088-01H Abdominal Muscle Activity in Adults with Cystic Fibrosis

Protocol approval valid until - Tuesday, September 07, 2010

Thank you for the letter from Anne Taillon-Hobson dated September 1, 2009. I am pleased to inform you that this protocol underwent expedited review by the Ottawa Hospital Research Ethics Board (OHREB) and is approved. Approval is conditional upon the receipt of the University of Ottawa Health Sciences and Sciences REB approval letter. Approval is also conditional upon the existence of a fully executed agreement between the Ottawa Hospital Research Institute, Principal Investigator and Sponsor. No changes, amendments or addenda may be made to the protocol or the consent form without the OHREB's review and approval.

Approval is for the following

- Revised COREB application received June 19, 2009
- English Leicester Cough Questionnaire (2001) version June 6, 2007
- English Health Questionnaire for Participants with Cystic Fibrosis dated August 5, 2009
- English Health Questionnaire for Participants dated August 5, 2009
- English Telephone Script dated August 5, 2009
- English Poster received August 6, 2009
- French Leicester Cough Questionnaire (2001) version June 6, 2007
- French Health Questionnaire for Participants with Cystic Fibrosis dated August 6, 2009
- French Health Questionnaire for Participants dated August 6, 2009
- French Telephone Script dated August 5, 2009
- French Poster received August 6, 2009
- English Consent Form/Information Letter dated August 5, 2009
- French Consent Form/Information Letter dated August 5, 2009

The validation date should be indicated on the bottom of all consent forms and information sheets (see copy attached). If the study is to continue beyond the expiry date noted above, a Renewal Form should be submitted to the OHREB approximately six weeks prior to the current expiry date. If the study has been completed by this date, a Termination Report should be submitted.

The Ottawa Hospital Research Ethics Board is constituted in accordance with, and operates in compliance with the requirements of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans; Health Canada Good Clinical Practice: Consolidated Guideline; Part C Division 5 of the Food and Drug Regulations of Health Canada; and the provisions of the Ontario Health Information Protection Act 2004 and its applicable Regulations.

Yours sincerely,

Raphael Saginur, M.D.
Chairman
Ottawa Hospital Research Ethics Board

Encl.

/ll



Université d'Ottawa University of Ottawa

UNIVERSITY OF OTTAWA / UNIVERSITÉ D'OTTAWA

November 2, 2009

Martin Bilodeau
School of Rehabilitation Sciences
University of Ottawa

Anne Taillon-Hobson
School of Human Kinetics
University of Ottawa

Shawn Aaron
Division Head – Respiratory Medicine
The Ottawa Hospital

Re: U of O Ethics file no. H 07-09-03 – “Abdominal Muscle Activity in Adults with Cystic Fibrosis”

Dear Dr. Bilodeau, Ms. Taillon-Hobson and Dr. Aaron,

Thank you for the protocol documents for the above named project as well as for the Certificates of Approval from Bruyère Continuing Care REB (BCC REB) and the Ottawa Hospital REB (OHREB)

This is to confirm that, in accordance with the agreement between the University of Ottawa and the BCC REB, the University of Ottawa has authorized the BCC REB to act as Board of Record for the review and oversight of research involving human subjects conducted at or through the hospital.

Final approved documents, if different from those initially submitted to the Health Sciences and Science REB, as well as copies of annual reports and renewals of the BCC REB and the OHREB approvals must be provided to our office.

We remind you of your obligation to.

- Follow all procedures of the CHEO REB including reporting and renewal procedures;
- Submit to the authority of the CHEO REB and that you are subject to CHEO REB requirements, including, without limitation, the requirement to modify or stop the research on demand of the CHEO REB.

If you have any questions, please contact our ethics office at 562-5841

Sincerely yours,

Catherine Paquet
Assistant Director (Ethics)

UNIVERSITY OF OTTAWA / UNIVERSITÉ D'OTTAWA
UNIVERSITY OF OTTAWA / UNIVERSITÉ D'OTTAWA
UNIVERSITY OF OTTAWA / UNIVERSITÉ D'OTTAWA
UNIVERSITY OF OTTAWA / UNIVERSITÉ D'OTTAWA

Collaborative Research Project Agreement

Between

Ottawa Hospital Research Institute ("OHRI")
(Research arm of The Ottawa Hospital)
725 Parkdale Avenue, Ottawa, Ontario K1Y 4E9

and

Elisabeth Bruyere Research Institute ("EBRI")
43 Bruyere Street, Ottawa, Ontario

and

Dr. Martin Bilodeau, Site Investigator ("SI")
Scientist, Aging and Movement Group, Health of the Elderly Division
Elisabeth Bruyere Research Institute
43 Bruyere Street
Ottawa, Ontario K1N 5C8

and

Anne Taillon-Hobson, Principal Investigator ("PI")
Scientist, Graduate Student, Aging and Movement Division Group, Health of the Elderly Division
Elisabeth Bruyere Research Institute
43 Bruyere Street
Ottawa, Ontario K1N 5C8

and

Shawn Aaron, MD, FRCSC, Co-Investigator ("CI")
Division Head – Respiratory Medicine
The Ottawa Hospital (General Campus)
501 Smyth Road
Ottawa, Ontario K1H 8L6

Date: September 29, 2009

Project Protocol Title: "Abdominal Muscle Activity in Adults with Cystic Fibrosis"
(OHREB # 2009088-01H, Bruyère Continuing Care REB # M16-08-091)

Period of Collaboration: May 1, 2009 – June 30, 2010

Project Responsibilities: OHRI, EBRI, SI, PI and CI, each with respect to their Project role, agree to perform the Project as set out in the Protocol as approved by the Ottawa Hospital Research Ethics Board, and the Bruyère Continuing Care REB in accordance with ICH/GCP, as applicable, Tri-Council Policy Statement guidelines, applicable laws and regulations, and obtain and maintain all necessary Project approvals or certifications prior to the start of the Project

The Project Protocol requires the identification of Cystic Fibrosis patients ("Potential Participant") from The Ottawa Hospital, by the CI to the PI. PI shall approach the Potential Participant(s) to seek their consent to participate in the Research Project ("Research Participant")

All Project tests and procedures involving Research Participant(s), including obtaining their informed consent, will be conducted by or under the supervision of the PI

Site Budget: Funded by a grant from the Physiotherapy Foundation of Canada awarded to the PI

Publication: The PI, together with CI and SI, intend to present the Project results at symposia, national or regional professional meetings, and to publish in peer-reviewed journals or other publications. Authorship will be determined in accordance with EBRI and OHRI policy

Data: Project data will be owned by the PI. The CI and SI shall have the right without payment to use the Project data for his own internal administrative, research or educational purposes, but such use shall only be made in a manner that does not breach the provisions of this Agreement. After publications have been submitted, the OHRI and the EBRI shall have the right without payment to use the Project data for their own internal administrative, research or educational purposes

Intellectual Property: Should any inventions, discoveries, new uses, processes, or compounds (the "Inventions") arise directly out of the Study, they shall be disclosed and owned by the inventing party in accordance with the institutional policies of any inventing party. Inventions jointly developed shall be owned jointly by the inventing parties in accordance with the institutional policies of the inventing parties, and the inventing parties agree to negotiate in good faith a revenue-sharing agreement which reflects the respective contributions of the parties to the creation of an Invention

Privacy: The Project requires that personal health information and medical records at The Ottawa Hospital of Research Participants be accessed and used by the CI for the purpose of identifying Potential Participants to be approached by PI. The CI will ensure that such personal health information and medical records are kept confidential. The Project will not require that Research Participants' hospital medical records be accessed, copied or removed from The Ottawa Hospital by the PI. However, in the course of performing the Project, the PI may collect personal information including personal health information, as defined in the *Personal Health Information Protection Act*, 2004, S.O. 2004, c. 3 ("PHIPA"), from Research Participants

Each party will comply with the applicable requirements of PHIPA, including, but not limited to, secure data storage and disposal, access to personal information limited to team members who have agreed to maintain the confidentiality requirements and the collection, use, disclosure and disposal of Research Participants' personal health information in accordance with the terms of the informed consent form. The Parties shall make their employees and agents aware of the importance of maintaining the confidentiality of collected or transferred personal information. These provisions shall survive the completion or earlier termination of this Agreement

Each party hereto with respect to itself/himself shall be responsible for damage, loss or cost to the extent arising from their breach of this provision. The Ottawa Hospital Research Ethics Board, the OHRI, and the EBRI and the Bruyere Continuing Care REB may audit the Project records under supervision of the PI

Project records will be stored at EBRI by the SI for 15 years after termination of the Project, and then destroyed (paper records will be shredded and electronic records deleted). If the event that the SI leaves the EBRI within the 15 year period above, the EBRI will assume the responsibility for storage or will obtain agreement of the remaining parties for early termination of the storage of records

Indemnities: The EBRI and OHRI each agree to indemnify one another from any liabilities in relation to the Project, to the extent arising out of the negligence or willful misconduct of each. These indemnity provisions shall survive the completion or termination of the Project and shall enure to the benefit of and be binding upon the parties, and their respective successors

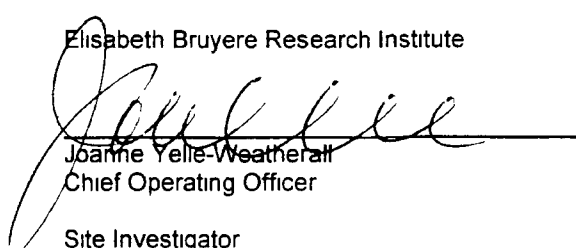
Subject Injury Compensation: EBRI agrees to ensure that adequate medical care/treatment is provided to the participant in the case of injury

Insurance: During the term of this Agreement, and afterward as necessary to cover their liabilities under this Agreement, EBRI and OHRI shall maintain appropriate and sufficient insurance, including general liability insurance of a minimum of \$5 million per occurrence and \$5 million annual aggregate

Termination: The Project may be terminated by any party (a) upon thirty (30) days' written notice to all parties of another party's material breach of this Agreement, (b) immediately on written notice, if serious or life-threatening events raise issues of Research Participant safety (in the reasonable judgment of the notifying party), or (c) upon ninety (90) days written notice by any party for any reason. In the event that any party hereto becomes unable to carry out the Project for reasons beyond their control this Agreement may be terminated by the other parties

Governing Law This Agreement shall be governed by and construed in accordance with the laws of the Province of Ontario and the federal laws of Canada applicable therein

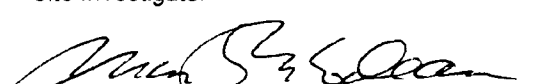
Elisabeth Bruyere Research Institute


Joanne Yelle-Weatherall
Chief Operating Officer

Site Investigator

Date

Sept 16/09


Dr. Martin Bilodeau

Date

Oct. 1, 2009

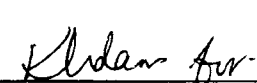
Principal Investigator


Anne Taillon-Hobson

Date

Oct - Oct 2009

Ottawa Hospital Research Institute


Marisa Akow
Director, Research Administration
Ottawa Hospital Research Institute

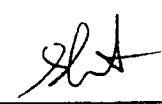
Date

Sept 29, 2009

Kim Adams

Director, Research Administration

Co-Investigator


Dr. Shawn Aaron
The Ottawa Hospital

Date

Sept 30/09

Appendix B Article submission, Copyright permission and Awards

Article Submission Confirmation

From: "Journal of Electromyography and Kinesiology" <esubmissionsupport@elsevier.com>
Subject: Submission Confirmation
Date: Tue, 7 September, 2010 1:56 pm
To: atail026@uottawa.ca

Dear Anne,

We have received your article "Voluntary and automatic recruitment of superficial and deep abdominal muscles in adults with and without cystic fibrosis" for consideration for publication in Journal of Electromyography and Kinesiology.

Your manuscript will be given a reference number once an editor has been assigned.

To track the status of your paper, please do the following:

1. Go to this URL: <http://ees.elsevier.com/tek/>
2. Enter these login details:
Your username is: Anne Taillon-Hobson
If you need to retrieve password details, please go to
http://ees.elsevier.com/tek/automail_query.asp
3. Click [Author Login]
This takes you to the Author Main Menu.
- 4 Click [Submissions Being Processed]

Thank you for submitting your work to this journal.

Kind regards,

Elsevier Editorial System
Journal of Electromyography and Kinesiology

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04/27/10

INVOICE AND CONDITIONS

TAILLON-HOBSON ANNE

Invoice # P60262111 Customer # 000170834143

Dear Requestor:

We are pleased to grant permission to you for the reproduction of the following:

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Please sign and date this agreement and return with payment (if applicable) in the enclosed envelope. Please retain a copy for your files.

Payment can be made via credit card (Amex, VISA, Discover and MC) or by check.

Card # _____ Exp Date: _____

Requestor Accepts: _____ Date: 20 May, 2010



June 30, 2009

Anne Taillon-Hobson

Dear Anne,

I am pleased to inform you that your application for the Alun Morgan Memorial Award in Orthopaedics Physiotherapy was favourably reviewed by the Scientific Awards Committee and approved by the Board of Governors of the Physiotherapy Foundation of Canada

Your approved grant amount is \$5,000 for a period of twelve months. Your grant period begins on July 1, 2009 and will end on June 30, 2010

This award has been made to you on the condition that the Physiotherapy Foundation of Canada is in the position to meet all of their financial requirements. If PFC, at their sole discretion, determines that there are not sufficient funds to meet all of the financial requirements, all or part of the award for future years may not be advanced to you

In order to proceed, we require you to provide written acceptance of this grant

Your administering agency will receive payment of the award in July. In accepting the award, you agree to comply with, and be bound by, all provisions contained in the Alun Morgan Memorial Award in Orthopaedics Physiotherapy regulations and procedures, which are enclosed for your reference

The Physiotherapy Foundation of Canada asks that you submit a brief (up to 50 words) lay description of your project *Abdominal Activity in Adults with and without Cystic Fibrosis* for use in publication. Please submit an electronic description, attention Norma Spall, no later than July 15, 2009

Before releasing the funds, the PFC must have received an up to date ethics review and approval, if we don't already have one in hand. An itemized financial report is required by June 30, 2010. Unspent funds must be returned to the PFC unless you can demonstrate that the money is essential for completion of the funded project. As well, we require a brief written report summarizing your findings and listing any publications, presentations or abstracts arising from your work by August 31, 2010.

Congratulations and we wish you success with your project.

Sincerely yours,
PHYSIOTHERAPY FOUNDATION OF CANADA

~~Norma Spall~~
Executive Director

Encl.: Rules and Regulations

Appendix C: Participant Forms and Recruitment

Version August 5, 2009

Consent Form/Information Letter

PROJECT TITLE:

Abdominal muscle activity in adults with cystic fibrosis

INVESTIGATORS:

Anne Taillon-Hobson (B.Sc.P.T.)
Graduate Student
School of Human Kinetics

Martin Bilodeau, Ph.D.
School of Rehabilitation Sciences
Faculty of Health Sciences

Shawn Aaron, M.D., F.R.C.P.C., M.Sc.
Division Head- Respiratory Medicine
The Ottawa Hospital (general campus)



I am being asked to participate in the research project called Abdominal muscle activity in adults with cystic fibrosis being conducted by Anne Taillon-Hobson and Martin Bilodeau. It is up to me whether or not I decide to take part in the study. Before I decide, I need to understand what the study is for, what risks (if any) there might be to me and what benefits (if any) there might be for me. This consent form explains these things. If I decide to not participate in the study, this will not in any way affect the usual health care and clinic care that I receive in the Cystic Fibrosis clinic.

Introduction

This study is to learn about how adults with cystic fibrosis use their abdominal muscles during some exercises. Two groups, one with individuals with cystic fibrosis and one without individuals with cystic fibrosis, will participate in this study. Each group will have 14 people, both men and women. Both groups will be doing the same exercises. The same information will be asked in each group. The reason that the researchers want to learn about how adults with cystic fibrosis use their abdominal muscles during these exercises is that they think there is a difference between the cystic fibrosis group and the non-cystic fibrosis group. Because people without cystic fibrosis do not cough as much as people with cystic fibrosis, their abdominal muscles are not being used as in the same way as in the cystic fibrosis participants, who use their abdominal muscles a lot in order to cough and to do their physiotherapy care for their lungs. Since this is not very well understood, the researchers would like to study this. The new information that might be gained by doing this study will help better understand the impact of coughing on abdominal muscle activity, as well as the difference in abdominal activity between the two groups. This could also help to create a new area of care for people with cystic fibrosis or people that have a chronic cough.



Purpose of the study

The purpose of the study is to find out how people with cystic fibrosis use their abdominal muscles during three particular exercises as compared to a group of people who do not have cystic fibrosis.

Description of the study exercises

The study will involve coming, once, to the Ageing and Movement lab, on the 7th floor of the Elizabeth Bruyère Hospital, for about one hour. The investigator Anne Taillon-Hobson will meet me and bring me to the lab. She will ask me if I still agree to participate in the study. I will then sign three copies of the consent form. One copy is for the records of Dr. Martin Bilodeau, the second copy is for the records of Dr. Shawn Aaron. The third copy is mine to keep. Anne Taillon-Hobson will ask me to fill out the Leicester Cough Questionnaire again, and she will keep this copy along with my consent forms. The copies which are to go to Dr. Aaron will be placed in an envelope to be hand-delivered to his office by Anne Taillon-Hobson. The questionnaire will take approximately 5 minutes to complete. I will then change into a loose fitting top and some shorts that I will have brought with me, either in the lab while the research members wait outside, or in the washroom at the end of the hallway. Once I have changed, she will place surface electrodes on my stomach area. There will be four of them. These electrodes will measure the electrical activity of my abdominal muscles while I am doing the exercises. The electrodes sit on the surface of my skin and hypoallergenic tape is used to attach them (tape like on a band-aid). Once the electrodes are on, I will be asked to lie on my back on a treatment bed, with two pillows under my head, and one pillow under my knees, and I will be asked to do an exercise of lifting both heels 8 cm off the treatment bed, keeping my knees straight, and hold this position for a count of ten seconds. I will also be asked to perform the following activities: lifting my shoulders off the bed, lifting my shoulders off the bed and turning to the left side, lifting my shoulders off the bed and turning to the right side, and taking in a deep breath. These activities will be held for ten seconds, and repeated three times each. They will then be repeated with a strap placed above my shoulders which I will hold on to as I repeat the same four exercises. I will then be asked to lie on my stomach and lift my torso off the bed for a hold of ten seconds. This will be repeated three times. Next, Anne Taillon-Hobson will explain to me how to do an exercise called the abdominal hollowing maneuver. I will be on my hands and knees on the plinth, and she will instruct me to bring my belly button up towards my back. I will practice this movement and she will correct any muscle activity that I may be doing that is not necessary for the exercise. I will then lie on my back on a small air pressure device which will measure any changes in air that occur as I do the abdominal hollowing maneuver lying on my back. The air pressure device is placed in the small of my back and feels like lying on a small pillow. I will then be instructed to do the abdominal hollowing maneuver and will be shown the change in air pressure on the air pressure device that occurs when I do this. I will have the chance to practice this for 5 minutes. I will then rest for one minute and repeat the same exercise but this time I will have to hold a pressure reading of 45 mmHg on the air pressure device for ten seconds. I will rest for 30 seconds and do this again two more times. I will then get to rest for one minute and after that I will be asked to do the same exercise but this time create a pressure of 50 mmHg on the pressure biofeedback unit and hold for 10 seconds. I will rest for 30 seconds before repeating this two more times.

The second exercise I will do will be to lie on my back in the same position as before, and lift one leg 20 cm off the plinth. I will have a 30 second rest between doing this exercise another two times.

The last exercise I will do will be to do an abdominal hollowing maneuver and create 45 mmHg of pressure on the air pressure device and hold this for a count of 60 seconds.

The surface electrodes will then be taken off my skin and the session will end.



Risks

This study will measure the electrical activity of my abdominal muscles. There is a certain risk with this study. The risk is that my might develop a skin rash where the tape is used, but is unlikely since the study is using hypoallergenic tape. If I do, it will disappear in one to three days. It is possible that I might feel my abdominal muscles contracting, which may give me some mild muscle soreness. This soreness is due to performing an exercise that is new, and will disappear in one to three days.

Benefits

My participation in this study will help understand how the abdominal muscles are used in people who cough a lot compared to people who do not cough a lot as well as in people with cystic fibrosis and people who do not have cystic fibrosis. This information will help to also understand the impact that coughing due to this disease can have on the abdominal muscles. If there is a difference between the two groups in this study, then a different treatment area for cystic fibrosis could emerge.



Compensation

I will receive \$20.00 to participate in this study to cover the cost of parking when I come to the lab for my data session.

Confidentiality and anonymity

All personal health information will be kept confidential, unless release is required by law. The Ottawa Hospital Research Ethics Board, the Ottawa Health Research Institute, the University of Ottawa Health Sciences and Sciences Research Ethics Board, and the Bruyère Continuing Care Research Ethics Board may review my relevant study records for audit purposes only. My Leicester Cough Questionnaire will not be recorded with my name on it but with a participant number. No one will be able to identify the information as being mine. The results of this study (including my study number) will presented during scientific conferences and published in scientific journals but there will be no indication of my name. The results will all be pooled together and I will not be identified in the reports or publications.

The information and data that is collected will be stored in a locked filing cabinet in the offices of Dr. Martin Bilodeau at the Elizabeth Bruyère Research Institute and of Dr. S. Aaron at the Ottawa Health Research Institute. No one has access to this information except the members of the research team. After fifteen years, any written material will be shredded and placed in "Confidential Waste" garbage. Any information on computer disc will be deleted.

Data conversion

The data collected, including the information on the Leicester Cough Questionnaire and the electrophysiological data will be recorded on a computer in the laboratory which is password protected. My data will be kept for a period of fifteen years and then be destroyed by deleting the files.

Voluntary participation

My participation in this study is entirely voluntary. I am free to withdraw from it at any time, and/or refuse to answer questions, without any negative consequences.



Acceptance: I, _____ (name of participant), have read this five page consent form and accept to participate in this research conducted by Anne Taillon-Hobson of the School of Human Kinetics of the Faculty of Health Sciences of the University of Ottawa and supervised by Martin Bilodeau, professor at the University of Ottawa school of rehabilitation Sciences and director of Ageing and Movement of the Elisabeth Bruyère Hospital.

Questions: I am encouraged to ask questions. If I have any questions about the research study itself, I can contact: Anne Taillon-Hobson

If I have any questions about the rights of the research subjects or I have ethical concerns about this study, I can contact the Dr. Lisa Sweet, Chair of the Research Ethics Board at Bruyère Continuing Care
the Protocol Officer for Ethics in Research, University of
Ottawa, Tabaret Hall, 550, Cumberland Street, room 159, Ottawa, ON K1N 6N5, at
or the Chairman of the Ottawa Research
Ethics Board

There are three copies of the consent form, one which is mine to keep.

Signature of the participant: _____ Date: _____

Printed name of investigator/delegate: _____

Signature of the investigator: _____ Date: _____

(Valid until September 7, 2010)

This study has been approved by the Research Ethics Boards of the Ottawa Hospital and the Bruyère Continuing Care.

Version 5 août, 2009



Lettre informative et formulaire de consentement

**L'ACTIVITÉ MUSCULAIRE DES MUSCLES ABDOMINAUX
CHEZ LES ADULTES ATTEINTS DE LA FIBROSE KYSTIQUE**

CHERCHEURS

Anne Taillon-Hobson (B.Sc.P.T.)
Étudiante diplômée
École des sciences de l'activité physique
Faculté des sciences de la santé

Martin Bilodeau, Ph.D.
École des sciences de la réadaptation
Faculté des sciences de la santé

Shawn Aaron, M.D., F.R.C.P.C., M.Sc.
Chef de division – Médecine respiratoire
L'Hôpital d'Ottawa (Campus Général)



Invitation à participer: Je suis invité à participer à l'étude citée ci-dessus, effectuée par les chercheurs mentionnés dans la section précédente. Je suis une personne en santé âgée de 18 à 45 ans.

Explication de l'étude : L'étude a pour but de déterminer comment les adultes atteints de la fibrose kystique utilisent leurs muscles abdominaux dans le cadre de certains exercices. L'étude comportera deux groupes, avec 14 participants dans chacun des groupes. Les mêmes informations et les mêmes exercices seront exigés des deux groupes. Puisque les personnes atteintes de la fibrose kystique doivent tousser beaucoup, elles utilisent leurs muscles abdominaux plus que les personnes qui ne souffrent pas de la fibrose kystique. Toutefois, les différences dans l'activité musculaire entre les deux groupes n'ont jamais été étudiées. L'information découlant de cette étude aidera à comprendre l'impact de tousser sur l'activité des muscles abdominaux chez les personnes atteintes de la fibrose kystique.

But de l'étude : Le but de l'étude constituera à comparer l'activité des muscles abdominaux durant trois tâches chez un groupe d'adultes souffrant de la fibrose kystique et un groupe contrôle (sujets en santé qui ne souffrent pas de fibrose kystique).



Participation : Si j'accepte de participer à l'étude, ma participation comprendra une visite au laboratoire de recherche sur le mouvement et le vieillissement à l'Institut de recherche Élisabeth Bruyère. La visite durera environ 60 minutes. On me demandera de signer trois formulaires de consentement, et on m'en remettra une copie. On me demandera aussi de répondre à deux questionnaires, évaluant a) ma santé générale ; et b) ma toux (« Leicester Cough Questionnaire »). Je serai libre de ne pas répondre à certaines questions, si je préfère. J'amènerai avec moi des shorts et une chemise pour me changer dans le laboratoire.

Description des exercices de l'étude : Je comprends que je devrai effectuer les tâches décrites ci-dessous durant la séance expérimentale :

- 1) Premièrement, on placera, à l'aide de ruban adhésif hypoallergénique, des électrodes sur ma peau au niveau de 4 muscles abdominaux. Par la suite, j'aurai à m'allonger sur le dos sur un lit avec deux coussins derrière ma tête et un coussin derrière mes genoux. Ensuite, je serai appelé à soulever mes deux jambes ensemble à une hauteur de 8 cm et à maintenir cette position pendant 5 secondes. J'aurai par la suite à effectuer les tâches suivantes :
 - a) croiser mes bras devant les épaules et soulever mon tronc pour 5 secondes.
 - b) soulever mon épaule droite vers le genou gauche et maintenir pour 5 secondes.
 - c) soulever mon épaule gauche vers le genou droit et maintenir pour 5 secondes.
 - d) me coucher sur le ventre et soulever mon tronc pendant 5 secondes.

Les tâches a), b) et c) seront à répéter avec une ceinture placée au niveau de mes épaules qui viendra ajouter une résistance..

Ensuite, on mesurera l'activité au niveau de mes muscles abdominaux pendant trois activités.

- 2) On me demandera de contracter les muscles abdominaux contre un cylindre gonflé d'air, pour créer une pression de 45 mmHg et ensuite créer une pression de 50 mmHg et dernièrement une pression de 50mmHg.
- 3) L'activité musculaire de mes muscles abdominaux sera également mesurée lors d'un exercice qui consistera à lever ma jambe droite à une hauteur de 20 cm du lit.

- 4) Le dernier exercice sera un exercice d'endurance où on me demandera de contracter mes muscles abdominaux créant une pression de 45 mmHg et de maintenir cette pression pendant une minute.

Pendant ces tâches, l'activité des abdominaux sera enregistrée grâce à de petites électrodes placées sur ma peau. Trois essais de 10 secondes seront effectués pour l'ensemble des exercices décrits de 1) à 4).

Risques : Je comprends que les risques possibles qui découlent de ma participation à cette étude sont :

- 1) Une **irritation mineure** de la peau est possible là où les électrodes de surface seront placées. Par contre, ceci n'est pas fréquent, puisque nous appliquons d'abord une crème conductrice non-irritante. Advenant une irritation, celle-ci devrait disparaître après quelques heures. Il est également possible que l'enlèvement des électrodes de surface à la fin d'une séance expérimentale soit inconfortable (comme lorsqu'on enlève un pansement adhésif).
- 2) Certaines personnes pourraient connaître des **douleurs musculaires** associées aux exercices après les séances expérimentales. Ces douleurs musculaires, si elles ont lieu, ne durent qu'entre 1 à 3 jours, et sont dues à une activité inhabituelle des muscles abdominaux. Pour la sécurité et le confort de tous les participants, il est possible que les membres de l'équipe de recherche décident de mettre fin à la séance expérimentale à n'importe quel moment.

Avantages

Je comprends qu'il n'y a aucun avantage personnel relié à ma participation à cette étude. Par contre, les chercheurs espèrent que dans le futur, les personnes atteintes de la fibrose kystique pourraient bénéficier de cette étude par l'approfondissement des connaissances concernant l'effet sur les muscles abdominaux d'une maladie qui cause une toux quotidienne prolongée.

Coûts : Je comprends qu'il n'y a pas de coûts reliés à la participation à cette étude. Je comprends également qu'on m remettra un montant de 20\$ pour mes dépenses reliées à ma participation à la séance expérimentale.

Confidentialité et anonymat : Je comprends que ma participation à cette étude demeurera confidentielle, conformément à la loi. Mon identité demeurera confidentielle par l'utilisation d'un code ou numéro au lieu d'informations personnelles. Seuls les membres de l'équipe de recherche auront accès aux documents contenant mon information personnelle, et ceux-ci seront gardés dans un classeur verrouillé dans les bureaux du Dr. Martin Bilodeau et du Dr. Shawn Aaron. Ces informations seront conservées pour 15 ans et détruites par la suite.



Utilisation des données : Je comprends que les résultats de cette étude (incluant les miens) seront présentés lors d'un congrès scientifique et seront également soumis à des fins de publication dans une revue scientifique. Quand les chercheurs complèteront un rapport ou un article à propos de cette étude, je comprends qu'ils décriront les résultats sommairement, de façon à ce que je ne puisse pas être identifié.

Participation volontaire : Je comprends que ma participation à cette étude est entièrement volontaire. Je peux décider de ne pas participer du tout. Si je décide de participer, je pourrai me retirer à tout moment. Si je décide de ne pas participer ou de me retirer, je ne serai pas pénalisé ou je ne perdrai aucun avantage auquel j'ai droit.





Consentement : Je, _____, soussigné, ai lu les 5 pages de ce formulaire de consentement et accepte de participer à cette étude dirigée par Anne Taillon-Hobson et le professeur Martin Bilodeau, de l'Institut de recherche d'Élisabeth Bruyère, et le docteur Shawn Aaron, médecin à L'Hôpital d'Ottawa (Campus Général).

Questions : Je suis invité à poser des questions. Je comprends que si j'ai des questions particulières concernant l'étude, je peux communiquer avec Anne Taillon-Hobson à l'Institut de Recherche Élisabeth Bruyère, 43 rue Bruyère, Ottawa (Ontario) K1N 5C8,

Si j'ai des questions générales concernant les droits des participants aux études de recherche ou aux blessures associées à la recherche, je peux communiquer avec la psychologue Lisa Sweet, directrice du Comité d'éthique du Centre de soins continus Élisabeth Bruyère ou par courriel ou le Président du comité de déontologie de l'Hôpital d'Ottawa

Je peux également communiquer avec le responsable de la déontologie en recherche de l'Université d'Ottawa, Pavillon Tabaret, 550 rue Cumberland, pièce 159, Ottawa, Ontario, K1N 6N5, au 613-562-5841, ou par courriel ethics@uottawa.ca

Signature du participant

_____/_____/_____
jj mm aaaa

Nom du témoin

Signature du témoin

_____/_____/_____
jj mm aaaa

(Valide jusqu'au 7 septembre 2010)

Ce projet est approuvé par les comités de déontologie du Centre de soins continus Élisabeth Bruyère et de L'Hôpital d'Ottawa.

Version August 5, 2009

Health Questionnaire for Participants

Project Title: **Abdominal Muscle Activity in Adults with Cystic Fibrosis**

Investigators:

Anne Taillon-Hobson, B.Sc.P.T.
School of Human Kinetics
Faculty of Health Sciences
University of Ottawa

Martin Bilodeau, Ph.D.
School of Rehabilitation Sciences
Faculty of Health Sciences

Shawn Aaron, M.D., F.R.C.P.C., M.Sc.
Division Head- Respiratory Medicine
The Ottawa Hospital (general campus)

The following is a general health questionnaire, to determine your suitability for the study. All answers are strictly confidential. Please circle the answers that apply to you.

- | | |
|---|----------|
| 1. Are you a smoker? | Yes/No |
| 2. Do you have a lung problem other than cystic fibrosis? | Yes / No |
| 3. Have you recently, in the past ten years, had major abdominal surgery in the past such as a caesarian section, where your abdominal muscles have been cut? | Yes / No |
| 4. If yes what surgery have you had? | |
| 5. Have you had any babies? | Yes / No |
| 6. Was your baby a big baby (larger than 9lbs 8oz) or consider large for your size? | Yes / No |
| 7. Does your bladder leak when you do any of the following things: | |
| a) Laugh, cough, sneeze | Yes / No |
| b) Change positions from sitting in a chair to standing up | Yes / No |
| c) Lift heavy objects | Yes / No |
| 8. Have you ever had any low back pain? | Yes / No |
| 9. If yes: | |
| a) Do you have back pain right now? | Yes / No |
| b) Does this pain cause you to lose time at work? | Yes / No |
| c) Has this pain caused you to go and see your doctor about it? | Yes / No |
| d) Has this pain cause you to change your leisure activities? | Yes / No |
| e) Have you seen an allied healthcare practitioner about this pain? | Yes / No |
| f) Have you had this pain, constantly, for more than three months? | Yes / No |

10 Have you ever participated in Yoga, Pilates, been shown any “core strengthening abdominal exercises” or excessively exercised your abdominal muscles at the gym? Yes/No

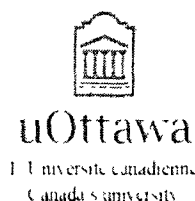
11 Do you work out more than three times per week, aerobically, for more than 30 minutes? Yes / No

Thank you for filling out this questionnaire Please show the answers to Anne Taillon-Hobson

Version 6 août, 2009

Questionnaire de santé général pour les participants

Titre du projet : **Activité des muscles abdominaux chez les adultes atteints de fibrose kystique**



CHERCHEURS:

Anne Taillon-Hobson (B.Sc.P.T.)

Étudiant diplômé

École des sciences de l'activité physique



Martin Bilodeau, Ph.D.

École des sciences de la

Readaptation

Faculté des sciences de la santé

Shawn Aaron, M.D., F.R.C.P.C., M.Sc.

Chef de division – Médecine

respiratoire

L'Hôpital d'Ottawa (Campus Général)



1. Est-ce que vous fumez? Oui/non
2. Est-ce que vous souffrez d'une maladie pulmonaire autre que la fibrose kystique? Oui/non
3. Est-ce que vous avez, dans les derniers dix ans, subi une chirurgie majeure à l'abdomen (exemple une césarienne)? Oui/non
4. Si oui, de quel type de chirurgie s'agit-il ? _____
5. Est-ce que vous avez accouché d'un bébé? Oui/non
6. Est-ce que votre bébé était un gros bébé pour votre taille? Oui/non
7. Est-ce que vous sentez de l'urine s'échapper de votre vessie lorsque vous :

- | | |
|---|---------|
| a) riez | Oui/non |
| b) levez des objets pesants? | Oui/non |
| c) vous levez debout? | Oui/non |
| 8. Est-ce que vous avez souffert d'un mal de dos par le passé? | Oui/non |
| 9. Si la réponse est oui : | |
| a) Est-ce que vous avez mal au dos en ce moment? | Oui/non |
| b) Est-ce vous avez perdu du temps au travail à cause de votre mal de dos? | Oui/non |
| c) Est-ce vous en avez parlé avec votre médecin? | Oui/non |
| d) Est-ce que vous avez dû changer vos activités de loisirs? | Oui/non |
| e) Est-ce que vous souffrez de cette douleur constamment depuis plus de trois mois? | Oui/non |
| f) Est-ce que vous avez consulté un professionnel en soins de santé autre que votre médecin? | Oui/non |
| 10. Est-ce que vous avez déjà participé à des activités telles le Yoga, le Pilates, ou avez fait des exercices pour les muscles profonds des abdominaux, ou exercer fortement vos abdominaux? | Oui/non |
| 11. Est-ce que vous participez à une activité d'aérobic pour 30 minutes, 3 fois par semaine? | Oui/non |

Version August 5, 2009

Health Questionnaire for Participants with Cystic Fibrosis

Project Title: **Abdominal Muscle Activity in Adults with Cystic Fibrosis**

Investigators:

Anne Taillon-Hobson, B.Sc.P.T.

School of Human Kinetics

Faculty of Health Sciences

University of Ottawa

Martin Bilodeau, Ph.D.

School of Rehabilitation Sciences

Faculty of Health Sciences

Shawn Aaron, M.D., F.R.C.P.C., M.Sc.

Division Head- Respiratory Medicine

The Ottawa Hospital (general campus)

The following is a general health questionnaire, to determine your suitability for the study. All answers are strictly confidential. Please circle the answers that apply to you.

- | | |
|--|----------|
| 1. Are you a smoker? | Yes / No |
| 2. Do you have a lung problem other than cystic fibrosis? | Yes / No |
| 3. Have you recently, in the past ten years, had major abdominal | |
| 4. surgery in the past such as a caesarian section, where your | |
| abdominal muscles have been cut? | Yes / No |
| 5. If yes what surgery have you had? | |
| 6. Have you had any babies? | Yes / No |
| 7. Was your baby a big baby (larger than 9lbs 8oz) or consider | |
| large for your size? | Yes / No |
| 8. Does your bladder leak when you do any of the following things: | |
| a) Laugh, cough, sneeze | Yes / No |

- b) Change positions from sitting in a chair to standing up Yes / No
- c) Lift heavy objects Yes / No
- 9. Have you ever had any low back pain? Yes / No
- 10. If yes:
 - a) Do you have back pain right now? Yes / No
 - b) Does this pain cause you to lose time at work? Yes / No
 - c) Has this pain caused you to go and see your doctor about it? Yes / No
 - d) Has this pain cause you to change your leisure activities? Yes / No
 - e) Have you seen an allied healthcare practitioner about this pain? Yes / No
 - f) Have you had this pain, constantly, for more than three months? Yes / No
- 11. Have you ever participated in Yoga, Pilates, been shown any “core” strengthening abdominal exercises” or excessively exercised your abdominal muscles at the gym? Yes/No
- 12. Do you work out more than three times per week, aerobically, for more than 3 times per week? Yes/No
- 13. Have you in the last week, felt feverish, started coughing, felt tired, felt any shortness of breath, had a change in the color of your sputum, had an increase in the amount of sputum production? Yes / No
- 14. Do you have a FEV1 score above 40 %? Yes/ No

Thank you for filling out this questionnaire. Please show the answers to Anne Taillon-Hobson.

Version 6 août, 2009

Questionnaire de santé générale pour les participants avec la fibrose kystique

Titre du projet : **Activité des muscles abdominaux chez les adultes avec la fibrose kystique**



CHERCHEURS:

Anne Taillon-Hobson (B.Sc.P.T.)

Étudiant diplômé

École des sciences de l'activité physique

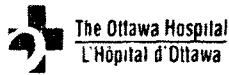


Martin Bilodeau, Ph.D.

Shawn Aaron, M.D., F.R.C.P.C., M.Sc.

École des sciences de la
réadaptation

Chef de division – Médecine respiratoire



Faculté des sciences de la santé

L'Hôpital d'Ottawa (Campus Général)

1. Est-ce que vous fumez? Oui/non
1. Est-ce que vous souffrez d'une maladie pulmonaire autre que la fibrose kystique? Oui/non
2. Est-ce que vous avez, dans les derniers dix ans, subi une chirurgie majeure de l'abdomen (exemple une césarienne)? Oui/non
4. Si oui, de quel type de chirurgie s'agit-il ?
5. Est-ce que vous avez accouché d'un bébé? Oui/non
6. Est-ce que votre bébé était un gros bébé pour votre taille? Oui/non
7. Est-ce que vous sentez de l'urine s'échapper de votre vessie lorsque vous :

- a) riez, toussiez, ou éternuez Oui/non
- b) levez des objets pesants? Oui/non
- d) vous levez debout? Oui/non
8. Est-ce que vous avez souffert d'un mal de dos par le passé?
Oui/non
9. Si la réponse est oui :
- a) Est-ce que vous avez mal au dos en ce moment? Oui/non
- b) Est-ce que vous avez perdu du temps au travail à cause
de votre mal de dos? Oui/non
- c) Est-ce que vous en avez parlé avec votre médecin?
- d) Est-ce que vous avez dû changer vos activités de loisirs?
Oui/non
- e) Est-ce que vous souffrez de cette douleur constamment
depuis plus de trois mois? Oui/non
- f) Est-ce que vous avez consulté un professionnel en soins
de santé autre que votre médecin? Oui/non
10. Est-ce que vous avez déjà participé à des activités telles le Yoga,
le Pilates, ou avez fait des exercices pour les muscles profonds des
abdominaux, ou exercer fortement vos abdominaux? Oui/non
11. Est-ce que vous participez à une activité d'aérobic pour
30 minutes, 3 fois par semaine? Oui/non
12. Dans la dernière semaine, est-ce que vous vous êtes senti
fiévreux, fatigué, avez noté un changement dans la couleur
et le volume de votre crachat, ou vous êtes senti essoufflé? Oui/non
13. Est-ce que vous avez un VEMS (volume expiratoire maximale
par seconde) de plus de 40%? Oui/non

Version June 26, 2009

Telephone Consent Script

The following is a script of the telephone conversation which will involve the primary investigator, Anne Taillon-Hobson and potential participants who have responded to the recruitment advertisements of this study.

Hello my name is Anne Taillon-Hobson. I am the primary researcher with the project titled: Abdominal Muscle Activity in adults with and without Cystic Fibrosis.

I understand that you have agreed to hear more about this study being conducted at Elisabeth Bruyère Hospital in the Ageing and Movement lab.

In order for you to decide whether you are interested in participating, I'd like to give you a full explanation of the study. Depending on what you prefer, we can either meet in person or I can explain the study to you over the phone.

If the potential participant's preference is to meet face to face, a convenient time with the investigator will be arranged.

If the potential participant's preference is to have information over the telephone, the following question will be asked:

Is now a convenient time to explain the study to you? It will take approximately 15 minutes.

If no, then an alternate time will be arranged.

If yes then the following conversation will occur:

The study is being conducted by myself and I am being helped by a group of researchers. I am a graduate student, in Human Kinetics at the University of Ottawa. I am also a physiotherapist. My supervisor is Martin Bilodeau, Ph.D., who is a researcher at the University of Ottawa and at Elisabeth Bruyère Hospital. We are all fluently bilingual in French and English so we can use whichever language you prefer. My study is interested in finding out how people use their abdominal muscles when they do three specific exercises and to see if there is a difference between people with cystic fibrosis and people without cystic fibrosis. The big difference between these two groups of people in this study is that the cystic fibrosis participants use their abdominal muscles for coughing which the group without cystic fibrosis do not do unless they have a cold. We think that this causes people with Cystic Fibrosis to use their abdominal muscles too much.

Participation in this study would involve you coming to the electromyography lab at Elisabeth Bruyère Hospital here in Ottawa for a 45 minute to 1 hour session. You would need to

come only once. We have research money to cover the cost for you to park your car, approximately \$20.00. You would need to bring shorts and a loose top to change into.

The study would involve you doing four things: answering some general health questions, answering questions on a Cough questionnaire called the Leicester Cough Questionnaire, signing three copies of the consent form, and having the muscle activity of your abdominal muscles measured while you are doing three exercises. Any and all information you give us on the general health questionnaire is only for screening purposes and will be shredded and put into "Confidential Waste" garbage. The information on the Leicester Cough Questionnaire and the consent forms will be given a study number and put in our study files. One copy will be for Dr. Martin Bilodeau and the second copy will be for Dr. Shawn Aaron. The third copy is mine to keep. There is no information on the papers which identify you or your name. This information will be kept in a locked filing cabinet in Dr. Bilodeau's office and in a locked filing cabinet in Dr. Aaron's office. No one has access to it. Any information that is in the computer will be password protected and does not have your name on it. This information will be destroyed after fifteen years by deleting the files and shredding any written information.

To measure the activity of your abdominal muscles, we will use surface electrodes on your abdominal muscles. These are used all the time in research and do not put anything into you: they sit in the surface of your skin and measure the electrical activity of your muscles. We will measure where the electrodes will be put on your skin, and then use hypoallergenic tape to tape them on. You will then be taught how to do an abdominal muscle exercise while you are on your hands and knees. This is the easiest way to learn the exercise. You will be given time to practice as well as help to do the exercise correctly. After this we will teach you the exercises to do and we will be recording the abdominal muscle activity while you do the exercises.

In order to do this you will be lying comfortably on a treatment plinth (like a treatment bed you see at your doctor's office) with two pillows behind your head and one pillow under your knees. There are three test activities: one will involve you lying on a small cylinder of air which will measure any pressure changes that your muscles create as you do the exercises. You will be asked to do the abdominal hollowing exercise while you are lying on this air cylinder and try to create two pressure gauge changes. The second test activity is to lift one leg off the treatment plinth and the third activity is to do one of the exercises and hold it for 60 seconds.

Do you have any questions?

Any questions will be answered.

The investigators will be with you all the time and will be able to answer any of questions you may have at the time and make sure that you are comfortable. You will be given a private area to change into your shorts and tee shirt (either in the lab while the research team members wait outside or in the washroom located down the hall if the participant prefers this).

The recording of the electrical activity of your muscles will be done when you are not necessarily aware of it as well as while you are doing the exercises. This type of study has been done before in people with low back pain and people without low back pain, as well as athletes.

The information that you will need to give the investigators will be confidential. Your information will be recorded as a participant number and not under your name. No one will be able to know what answers you gave on any of the questionnaires. You can withdraw from the study any time. It will have no effect on the care you are receiving right now. You do not have to provide any reasons as to why you do not want to participate.

The risks of participating in this study are minimal. You might have some skin sensitivity where the tape is used to secure the electrodes, but this is minimized by using hypoallergenic tape, and should last only 1 to 3 days. You might find your abdominal muscles are mildly sore, but this is due to doing an exercise that is new to you and should be better within one to three days. The benefits if participating in this study is to help us better understand how people use their abdominal muscles, as well as to help us learn about how participants with cystic fibrosis use their abdominal muscles. This might lead to a new area of care in cystic fibrosis and a better understanding about the effects of the disease.

Do you have any questions?

If yes, answer the questions.

If no, then the following will occur:

If you would like to check the authenticity of this project, you can contact Dr. Lisa Sweet who is the Chair of the Bruyère Continuing Care Research Ethics Board. Her telephone number You can also reach her This project has been approved by the University of Ottawa and the Ottawa Hospital Research Ethics Boards. They can be reached at ethics@uottawa.ca respectively. The investigators have permission to recruit participants.

Would you like to participate in this study?

If no, thank the potential participant for their time.

If yes, then the following questions will be asked:

We need to know some baseline information from you to make sure that we can use your data in the study. May I ask you these questions? I will be writing down your answers so that I can look at them. I will be shredding the answers once we have finished talking about the forms. Is that ok with you?

If no, thank the potential participant for their time.

If yes, ask the following questions from the general health questionnaire:

1. Are you a smoker? Yes / No
 2. Do you have a lung problem other than cystic fibrosis? Yes / No
 3. Have you recently, in the past ten years, had major abdominal surgery in the past such as a caesarian section, where your abdominal muscles have been cut? Yes / No
 4. If yes what surgery have you had?

 5. Have you had any babies? Yes / No
 6. Was your baby a big baby (larger than 9lbs 8oz) or consider large for your size? Yes / No
 7. Does your bladder leak when you do any of the following things:
 - a) Laugh, cough, sneeze Yes / No
 - b) Change positions from sitting in a chair to standing up Yes / No
 - c) Lift heavy objects Yes / No
 8. Have you ever had any low back pain? Yes / No
 9. If yes
 - a) Do you have back pain right now? Yes / No
 - b) Does this pain cause you to lose time at work? Yes / No
 - c) Has this pain caused you to go and see your doctor about it? Yes / No
 - d) Has this pain cause you to change your leisure activities? Yes / No
 - e) Have you seen an allied healthcare practitioner about this pain? Yes / No
 - f) Have you had this pain, constantly, for more than three months? Yes / No
 10. Have you ever participated in Yoga, Pilates, been shown any "core strengthening abdominal exercises" or excessively exercise your abdominal muscles in the gym? Yes / No
 11. Do you work out more than three times per week, aerobically, for more than 30 minutes? Yes / No
- The following two questions will be asked if the potential participant has cystic fibrosis:
12. Have you in the last week, felt feverish, started coughing, felt tired, felt any shortness of breath, had a change in the color of your sputum, had an increase in the amount of sputum production? Yes / No
 13. Do you have a FEV1 score above 40 %? Yes/No

If the answers to these questions are yes, the answers will be discussed for clarification. If the participant's data would be unsuitable for the study, then the potential participant will be thanked for their time and be told that the data from their participation in the study would not be

able to be used. It will be discussed then why their data would not be suitable for the study. They will be thanked for their time and interest in the study.

If the answers are no, then the following will be discussed:

From your answers to the questions, we would be able to use your data in the study. Would you be interested in coming to the lab for a data collection session?

If no, then the participant will be thanked for their time.

If yes, then the following conversation will occur:

We will need you to sign a consent form. The form explains again to you all the information that we have talked about. You can sign it when you come to do the study with us, before we put the electrodes on and we start to do the study exercises. You will also need to fill out a questionnaire about coughing before we start the study activities.

We need to make a time and date for you to come in to participate in the study. It will take about one hour of your time and I will call you the night before to make sure that you are able to attend the session. When you come to the data session, we will ask you to sign the consent form and the fill out the Leicester Cough Questionnaire that we just talked about. Then we will go through the teaching and testing procedures. I will meet you in the lobby of the Elisabeth Bruyere Hospital and take you upstairs to the lab.

Do you have any questions?

If yes, the questions will be discussed.

If no, then a specific time and date will be offered to the participant and they can choose according to their preference. Telephone information will be exchanged in order for the participant to reach the investigators in case of need.

I will be telephoning you the night before the testing to confirm that you are ok to come. Is this alright with you?

If no, then a telephone reminder will not occur.

If yes, then the participant will be contacted the night before.

The participant will be thanked for their time and the conversation will end.

Recrutement par téléphone

Bonjour :

Mon nom est Anne Taillon-Hobson et je suis la chercheuse chargée du projet « Activité musculaire des abdominaux chez les adultes atteints de la fibrose kystique ». Le projet va s'effectuer au laboratoire du Vieillissement et Mouvement à l'Hôpital Élisabeth Bruyère.

Je reconnais que vous voulez avoir de plus ample renseignements au sujet de ce projet en vue d'y prendre part à titre de sujet de recherche. Je peux vous fournir des détails maintenant, ce qui ne prendra qu'environ 15 minutes, ou je pourrais vous rencontrer en personne. Que préférez-vous?

Si la personne préfère une rencontre en personne, un rendez-vous sera fixé.

Si la personne préfère en parler au téléphone, la conversation suivante aura lieu :

Moi-même et une équipe de chercheurs effectuons cette étude. Je suis une étudiante diplômée à l'Université d'Ottawa. Mon superviseur est Martin Bilodeau, Ph.D., chercheur à l'Université d'Ottawa ainsi qu'à l'Hôpital Élisabeth Bruyère. Je suis aussi une physiothérapeute. Nous sommes tous bilingues alors nous pourrions converser en français ou en anglais selon votre préférence. L'étude a pour but de déterminer les patrons d'activités musculaires qu'utilisent les personnes atteintes de fibrose kystique lorsqu'elles effectuent trois exercices abdominaux, et comparer ces derniers aux patrons d'activités musculaires de gens non atteints de fibrose kystique. Puisque la fibrose kystique comporte une toux excessive normalement observée chez les participants sans fibrose kystique que lorsqu'ils souffrent d'un rhume, nous, les chercheurs pensons que les muscles abdominaux des gens atteints de la fibrose kystique vont démontrer une activité musculaire accrue.

Votre participation à l'étude exigera que vous vous présentiez une fois seulement au laboratoire du Vieillissement et Mouvement à l'Hôpital Élisabeth Bruyère situé, sur la rue Bruyère. Nous assumerons vos frais de déplacement (20.00 \$). La séance au laboratoire durera environ 1 heure. Vous devez apporter des shorts confortables et un T-shirt.

Vous aurez à effectuer quatre tâches une fois au laboratoire : il faudra répondre à des questions générales sur votre santé, répondre à un questionnaire de toux appelé le « Leicester Cough Questionnaire », signer les trois copies du formulaire de consentement, et participer aux exercices abdominaux. Une fois que j'aurai pris connaissance de vos réponses au questionnaire de santé, je déchiquetterai les feuilles et je les déposerai dans une poubelle à rebuts confidentiels. Vos réponses aux questionnaires Leicester seront identifiées à l'aide d'un numéro de participant, et non par votre nom. Il n'y aura donc pas de moyen de vous identifier personnellement. Votre formulaire de consentement sera également identifié à l'aide de votre numéro de participant. L'information sera sauvegardée dans un classeur verrouillé, situé dans le

bureau du Mr. Bilodeau et du docteur Shawn Aaron. Personne n'a accès à ces fichiers. Les données conservées sur ordinateur seront protégées par un mot de passe et ne porteront pas votre nom. Nous devons conserver ces informations pour une période de 15 ans et par la suite, les informations écrites seront déchetées et placées dans une poubelle pour rebuts confidentiels et les informations électroniques seront supprimées.

Afin de mesurer l'activité des muscles abdominaux, nous plaçons sur la peau du ventre des électrodes de surface qu'on attache à l'aide d'un ruban adhésif hypoallergénique. Les électrodes n'entraînent aucune douleur. Elles ne vous dégagent pas de courant. Les électrodes ne servent qu'à mesurer l'activité électrique des muscles lorsque ces derniers effectuent une contraction. Je vais vous demander de vous placez à quatre pattes et je vous démontrerai comment effectuer un des exercices abdominaux. C'est la position la plus facile pour apprendre l'exercice. Je vous donnerai le temps nécessaire pour pratiquer celui-ci. Par la suite, nous allons mesurer l'activité des muscles durant les autres exercices.

Est-ce que vous avez des questions?

Si la personne a des questions, on y répondra. Si non, la discussion se poursuivra :

Pour effectuer les exercices, vous devrez vous allonger sur le dos sur un lit, avec deux oreillers derrière la tête et un oreiller derrière les genoux. Les exercices ne sont pas difficiles à faire. Il y a trois exercices que nous allons mesurer : un exercice exigera que vous couchiez sur un petit cylindre d'air. Celui-ci nous permet de mesurer des changements de pression lorsque les muscles font des contractions. Nous allons mesurer l'activité musculaire des abdominaux lorsque vous essayez de « rentrer le ventre vers le dos » et que vous gardez trois pressions données dans le cylindre. Deuxièmement, vous devrez soulever la jambe droite à une hauteur de 20 cm du lit et troisièmement il s'agira d'effectuer un des premiers exercices pour une durée de 60 secondes.

Est-ce que vous avez des questions?

Si la personne a des questions, on y répondra. Si non, la discussion se poursuivra :

Les membres de l'équipe de recherche seront toujours présents avec vous lors de la collecte de données musculaires. On vous encourage de poser des questions. Vous aurez accès à un endroit privé pour changer vos vêtements, soit dans le laboratoire comme-tel ou dans la salle de toilette situé dans le corridor.

La collecte de données électronique se passera sans que vous en soyez conscient. Ce genre d'étude s'effectue couramment avec des participants qui ont des douleurs de dos, ainsi que des athlètes.

Toute information qui sera recueillie demeurera confidentielle. Il n'y aura aucun moyen de vous identifier à l'aide des questionnaires. Vous pourrez vous retirer de l'étude à n'importe quel moment sans que votre décision n'ait impact sur les soins que vous recevez actuellement et vous n'aurez pas à fournir une raison.

Les risques associés avec votre participation à l'étude sont minimales. Il se peut que vous présentiez une sensibilité au niveau de la peau où se trouvaient les électrodes, mais ce risque est minimisé par l'utilisation du ruban hypoallergénique. S'il y a lieu, la sensibilité ne durera que d'un à trois jours. Il est possible également que vous ressentiez un léger inconfort au niveau des muscles abdominaux, mais ceci serait dû à l'utilisation de ces muscles dans le cadre d'activités inhabituelles. L'inconfort, s'il y a lieu, ne durera que d'un à trois jours.

Votre participation à l'étude pourrait s'avérer bénéfique aux gens qui sont atteints de la fibrose kystique en nous aidant à comprendre comment ces personnes utilisent leurs muscles abdominaux comparativement avec des personnes non-atteintes de cette maladie. Ces connaissances pourraient engendrer un nouveau domaine de soins de cette maladie, ainsi qu'enrichir les connaissances sur les effets de cette maladie. Notre étude permettra également de mieux comprendre comment les gens normaux utilisent leurs muscles abdominaux.

Avez-vous des questions? Si oui, les questions seront répondues. Si non, la discussion se poursuivra :

Pour vérifier l'authenticité de l'étude, vous pouvez communiquer avec la docteure Lisa Sweet, présidente du comité de déontologie aux Soins Continus de l'Hôpital Elizabeth Bruyère au (613) 798-5555, poste 14902, ainsi que le président du Conseil d'éthique en recherches de l'Hôpital d'Ottawa au (613) 798-5555, poste 14902, ainsi que le comité de déontologie de l'Université d'Ottawa à ethics@uottawa.ca. Nous avons la permission de recruter des participants pour notre étude.

Est-ce que vous souhaitez être un participant à notre étude?

Si la personne répond non, remerciez-la pour son temps et mettez fin à la discussion.

Si la personne répond oui, la discussion suivante aura lieu :

Afin de nous assurer que nous puissions utiliser vos données, je dois vous poser des questions relatives à votre santé générale. Je vais noter vos réponses, et après avoir répondu à toutes vos questions, je déchiquetterai la feuille de réponses et je la déposerai dans une poubelle à rebuts confidentiels. Est-ce que vous êtes d'accord?

Si la personne répond non, on mettra fin à la discussion et on remerciera la personne pour son temps.

Si la personne répond oui, on posera les questions suivantes :

- | | |
|--|---------|
| 1. Est-ce que vous fumez? | Oui/non |
| 2. Est-ce que vous souffrez d'une maladie pulmonaire autre que la fibrose kystique? | Oui/non |
| 3. Est-ce que vous avez, dans les derniers dix ans, subi une chirurgie majeure à l'abdomen (exemple une césarienne)? | Oui/non |
| 4. Si oui, de quel type de chirurgie s'agit-il ? | |

5. Est-ce que vous avez accouché d'un bébé? Oui/non
6. Est-ce que votre bébé était un gros bébé pour votre taille? Oui/non
7. Est-ce que vous sentez de l'urine s'échapper de votre vessie lorsque vous :
- a) riez, toussiez, ou éternuez Oui/non
 - b) soulevez des objets lourds? Oui/non
 - c) vous levez debout? Oui/non
8. Est-ce que vous avez souffert d'un mal de dos par le passé? Oui/non
- Si la réponse est oui :
- e) Est-ce que vous avez mal au dos en ce moment? Oui/non
 - f) Est-ce vous avez perdu du temps au travail à cause de votre mal de dos? Oui/non
 - g) Est-ce vous en avez parlé avec votre médecin? Oui/non
 - h) Est-ce que vous avez dû changer vos activités de loisirs? Oui/non
 - i) Est-ce que vous souffrez de cette douleur constamment depuis plus de trois mois? Oui/non
 - j) Est-ce que vous avez consulté un professionnel en soins de santé autre que votre médecin? Oui/non
9. Est-ce que vous avez déjà participé à des activités tels le Yoga, le Pilates, ou avez fait des exercices pour les muscles profonds des abdominaux, ou exercer vigoureusement vos abdominaux Oui/non
10. Est-ce que vous participez à une activité d'aérobic pour 30 minutes, 3 fois semaine Oui/non
- Si la personne souffre de la fibrose kystique, posez également la question suivante :
11. Dans la dernière semaine, est-ce que vous vous êtes senti fiévreux, fatigué, avez noté un changement dans la couleur et le volume de votre crachat, ou vous êtes senti essoufflé? Oui/non
12. Est-ce que vous avez un VEMS (volume expiratoire maximal par seconde) de plus de 40%? Oui/non

Si les réponses aux questions ne s'avèrent pas acceptables, la discussion suivante aura lieu :

Malheureusement, nous ne pourrons pas utiliser vos données d'activité musculaire dans notre étude. Je vous remercie de m'avoir accordé votre temps pour cette étude. Je déchiquette maintenant votre feuille de réponses et je la mets dans la poubelle à rebuts confidentiels.

Si les réponses aux questions sont jugées acceptables, la discussion suivante aura lieu :

Je vois, d'après vos réponses que nous pourrons utiliser vos données advenant que vous souhaitiez participer à notre étude. Je vais maintenant déchiqueter la feuille de réponses et la

déposer dans la poubelle pour les rebuts confidentiels. Est-ce que vous souhaitiez toujours y participer?

Si la réponse est non, on remerciera la personne pour son temps.

Si la réponse est oui, la conversation suivante aura lieu :

Nous devons fixer un rendez-vous afin de nous rencontrer au laboratoire de l'Hôpital Élisabeth Bruyère. Une fois rendu, je vais vous demander de signer le formulaire de consentement ainsi que le Leicester Cough Questionnaire. Le tout prendra environ une heure. Je vais vous rencontrer au rez-de-chaussée de l'Hôpital Elizabeth Bruyère et je vais vous conduire au 7^{ième} plancher où se situe le laboratoire. Quand seriez-vous disponible?

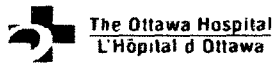
Une heure et une date seront fixées.

Si vous me fournissez votre numéro de téléphone ou votre courriel, je peux communiquer avec vous la soirée d'avant pour confirmer notre rencontre.

La personne donne son numéro de téléphone ou son courriel.

La conversation se termine en remerciant la personne pour leur participation à cette étude.

Participants needed for surface EMG study
of
Abdominal Muscle Activity in Adults
with Cystic Fibrosis



Inclusion:

Healthy men and women, aged between 19 and 45 years.

60 minute session (one-time only).

Reimbursement available for parking expense.

Exclusion:

Previous experience with core strengthening exercises (e.g. Pilates & Yoga).

If you are interested please contact:

Anne Taillon-Hobson

This study has been approved by the Research Ethics Boards of Bruyère Continuing Care, the Ottawa Hospital and the University of Ottawa.

Participants requis aux fins d'une étude
faisant appel à des électrodes de surface

Activité des muscles abdominaux chez les adultes
atteints de la fibrose kystique

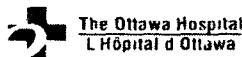


Inclusion:

Hommes et femmes, en santé, âgées de 19 à 45 ans.
Une session seulement de 60 minutes.
Remboursement des coûts associés à la participation à l'étude.



Exclusion :



Expériences antérieures relatives à l'entraînement des muscles abdominaux profonds (ex. Pilates, Yoga).

Veillez communiquer avec:
Anne Taillon-Hobson

Cette étude est approuvée par les Conseils d'éthique en recherches de Soins Continus Bruyère, de l'Hôpital d'Ottawa, et de l'Université d'Ottawa.

Leicester Cough Questionnaire. © 2001

This questionnaire is designed to assess the impact of cough on various aspects of your life. Read each question carefully and answer by CIRCULING the response that best applies to you. Please answer ALL questions, as honestly as you can.

1. In the last 2 weeks, have you had chest or stomach pains as a result of your cough?

1	2	3	4	5	6	7
All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
2. In the last 2 weeks, have you been bothered by sputum (phlegm) production when you cough?

1	2	3	4	5	6	7
Every time	Most times	Several times	Some times	Occasionally	Rarely	Never
3. In the last 2 weeks, have you been tired because of your cough?

1	2	3	4	5	6	7
All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
4. In the last 2 weeks, have you felt in control of your cough?

1	2	3	4	5	6	7
None of the time	Hardly any of the time	A little of the time	Some of the time	A good bit of the time	Most of the time	All of the time
5. How often during the last 2 weeks have you felt embarrassed by your coughing?

1	2	3	4	5	6	7
All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
6. In the last 2 weeks, my cough has made me feel anxious

1	2	3	4	5	6	7
All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
7. In the last 2 weeks, my cough has interfered with my job, or other daily tasks

1	2	3	4	5	6	7
All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
8. In the last 2 weeks, I felt that my cough interfered with the overall enjoyment of my life

1	2	3	4	5	6	7
All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
9. In the last 2 weeks, exposure to poisons or fumes has made me cough

1	2	3	4	5	6	7
All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
10. In the last 2 weeks, has your cough disturbed your sleep?

1	2	3	4	5	6	7
All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
11. In the last 2 weeks, how many times a day have you had coughing bouts?

1	2	3	4	5	6	7
All of the time (continuously)	Most times during the day	Several times during the day	Some times during the day	Occasionally through the day	Rarely	None
12. In the last 2 weeks, my cough has made me feel frustrated

1	2	3	4	5	6	7
All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
13. In the last 2 weeks, my cough has made me feel fed up

1	2	3	4	5	6	7
All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
14. In the last 2 weeks, have you suffered from a hoarse voice as a result of your cough?

1	2	3	4	5	6	7
All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
15. In the last 2 weeks, have you had a lot of energy?

1	2	3	4	5	6	7
None of the time	Hardly any of the time	A little of the time	Some of the time	A good bit of the time	Most of the time	All of the time
16. In the last 2 weeks, have you worried that your cough may indicate serious illness?

1	2	3	4	5	6	7
All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
17. In the last 2 weeks, have you been concerned that other people think something is wrong with you, because of your cough?

1	2	3	4	5	6	7
All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
18. In the last 2 weeks, my cough has interrupted conversation or telephone calls

1	2	3	4	5	6	7
Every time	Most times	A good bit of the time	Some of the time	A little of the time	Hardly any of the time	None of the time
19. In the last 2 weeks, I feel that my cough has annoyed my partner, family or friends

1	2	3	4	5	6	7
Every time I cough	Most times when I cough	Several times when I cough	Some times when I cough	Occasionally when I cough	Rarely	Never

Thank you for completing this questionnaire.

Appendix D: Data tables and dSLR results

Table 1. Characteristics of the participants

		Control	CF
N	Total	14	14
	Women	8	9
	Men	6	5
Age p = 0.67	Mean (stdev)	25 (6.5)	26 (6.5)
	Women	26 (8)	23 (7)
	Men	28 (6)	25 (5)
LCQ p = 0.000007	Mean (stdev)	130 (1)	95 (20)
	Women	130 (1)	92 (22)
	Men	130 (1)	102 (17)

Table 2. Mean and standard deviation of % maximum normalized EMG amplitude of the abdominal muscles during the AH exercises

	AH-1		AH-2		AH-3		
	Control	CF	Control	CF	Control	CF	
RA-UP	0.61 (1.24)	0.10 (0.93)	3.31 (4.30)	2.65 (3.24)	8.23 (14.47)	3.76 (3.23)	
EO	3.01 (3.19)	4.55 (4.51)	14.15 (15.64)	11.99 (12.16)	20.46 (23.26)	17.89 (17.37)	
IO/TrA	12.98 (12.69)	23.11 (24.37)	27.76 (20.17)	25.00 (20.09)	31.29 (31.30)	29.59 (24.66)	
RA-MID	0.77 (1.05)	0.37 (0.81)	2.94 (2.50)	2.16 (2.01)	5.41 (5.21)	2.92 (2.84)	

Table 3. Mean and standard deviation of % dSLR normalized EMG amplitude of the abdominal muscles during the AH exercises

	AH-1		AH-2		AH-3	
	Control	CF	Control	CF	Control	CF
RA-UP	1.55 (2.38)	0.64 (1.80)	19.22 (22.97)	10.47 (14.88)	27.66 (26.72)	14.48 (17.38)
EO	7.25 (5.80)	8.95 (7.85)	34.24 (24.43)	25.31 (22.83)	43.99 (37.84)	36.72 (30.82)
IO/TrA	40.45 (41.15)	104.485 (131.943)	84.56 (73.53)	177.55 (245.96)	87.67 (72.52)	203.380 (258.124)
RA-MID	2.744 2.562	1.954 (2.400)	13.41 (11.97)	7.84 (9.13)	27.81 (31.28)	12.711 (12.183)

Statistical results of the dSLR normalization procedure

Abdominal Hollowing

The three-way repeated-measures ANOVA revealed a significant muscle X task interaction ($F(1.571,40.849) = 3.812, p = 0.040$) indicating that the change in EMG amplitudes across the AH tasks was significantly different across the muscles. However, no group interaction was found ($F(1,26) = 1.485; p = 0.234$) indicating that the EMG amplitude of both groups behaved similarly. This is presented in figure 1.

Pooling the group data and using a Bonferonni corrected alpha level of $p = 0.0083$ ($0.05/6$ muscle combinations), significant differences were found between the superficial muscles when comparing AH-1 to AH-2 and AH-1 to AH-3, but no differences were found when comparing AH-2 to AH-3 indicating that once the EMG amplitudes had increased to AH-2 activity did not need to increase to achieve AH-3. These results are presented in figure 2 below.

Figure 1. Between group of muscle EMG amplitude during the abdominal hollowing

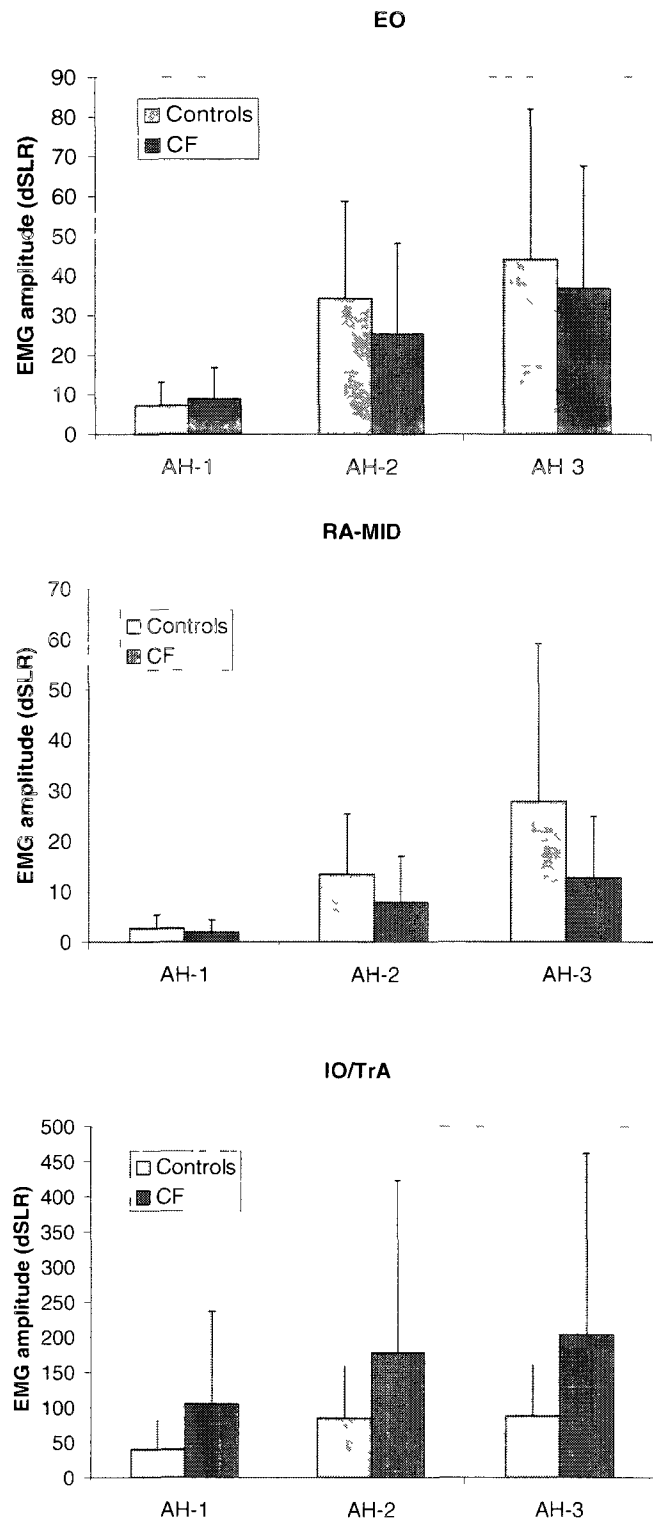
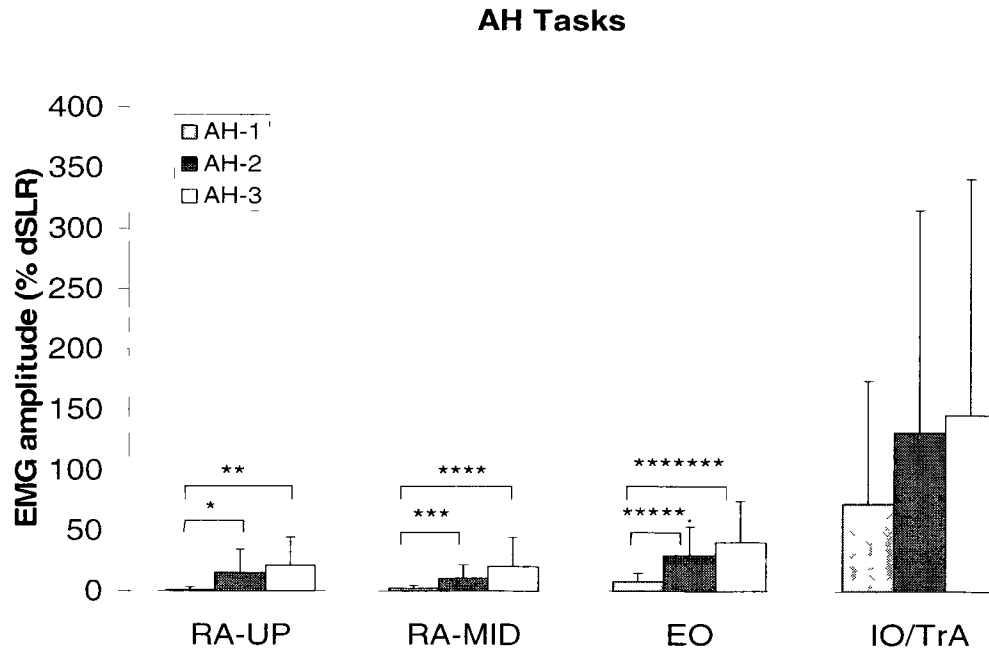


Figure 1 . Mean and standard deviation of dSLR normalized EMG amplitudes of the superficial and deep abdominal muscles during the three abdominal hollowing exercises. Bars indicate the mean normalized EMG amplitude and whiskers indicate the standard deviations. Muscle amplitudes did not differ between groups. Superficial muscles: RA-MID: (rectus abdominis middle fibers) and EO: (externus obliquus) (RA-UP not shown). Deep muscles: IO/TrA: internal obliquus/ transversus abdominis group.

Figure 2. Between-task comparisons of EMG muscle activity during the abdominal hollowing



Comparisons of mean and standard deviation of pooled EMG amplitude between AH tasks. Significant differences were found in all the superficial muscles but not between all the tasks. No between task differences were found for the deep abdominal muscles. Note the high values for IO/TrA. Superficial muscles: RA-UP (rectus abdominis upper fibers), RA-MID: (rectus abdominis middle fibers) and EO: (externus obliquus). Deep muscles: IO/TrA: internal obliquus/ transversus abdominis group.

RA-UP: * $p = 0.004$ ** $p = 0.00003$

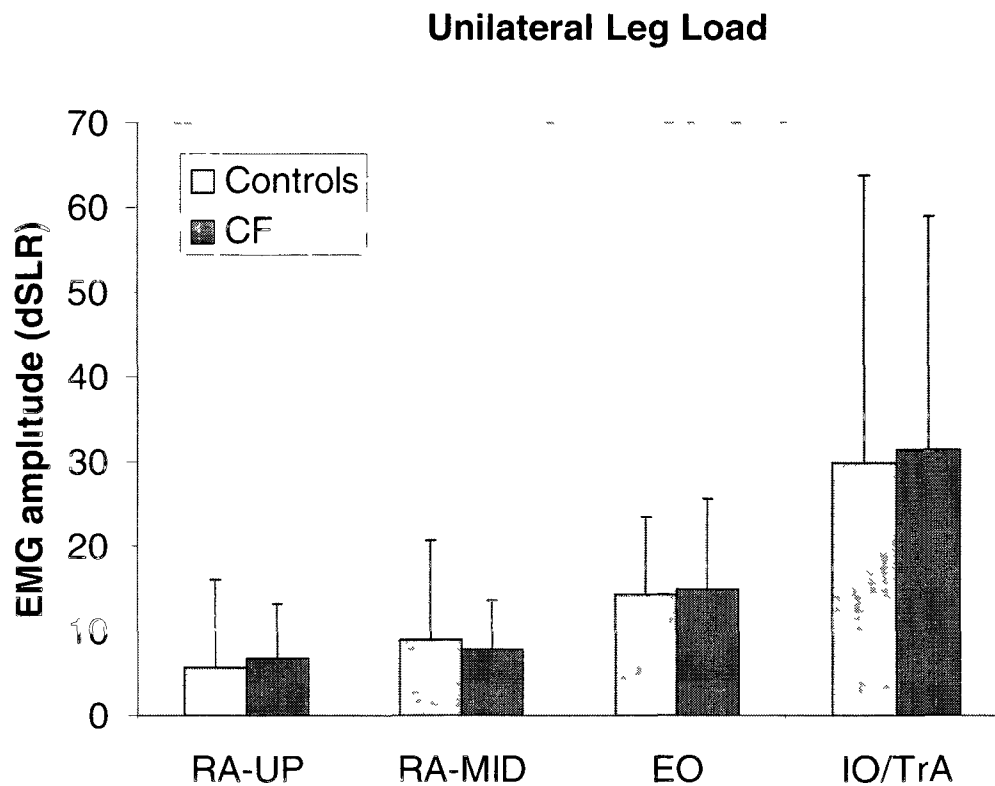
RA-MID: *** $p = 0.0002$ **** $p = 0.0003$

EO: ***** $p = 0.00002$ ***** $p = 0.000008$

Unilateral Leg Load

The two-way (group x muscle) ANOVA revealed that no muscle X task interaction was found ($F(2.822, 73.380) = 0.00$, $p = 1.00$) indicating that the change in EMG amplitudes across the muscles was the same for all the muscles. No group interaction was found ($F(1.26) = 0.011$, $p = 0.918$) indicating that the EMG amplitude of both groups behaved similarly. These results are presented in figure 3.

Figure 3. Between-group comparisons of EMG amplitude during the ULL

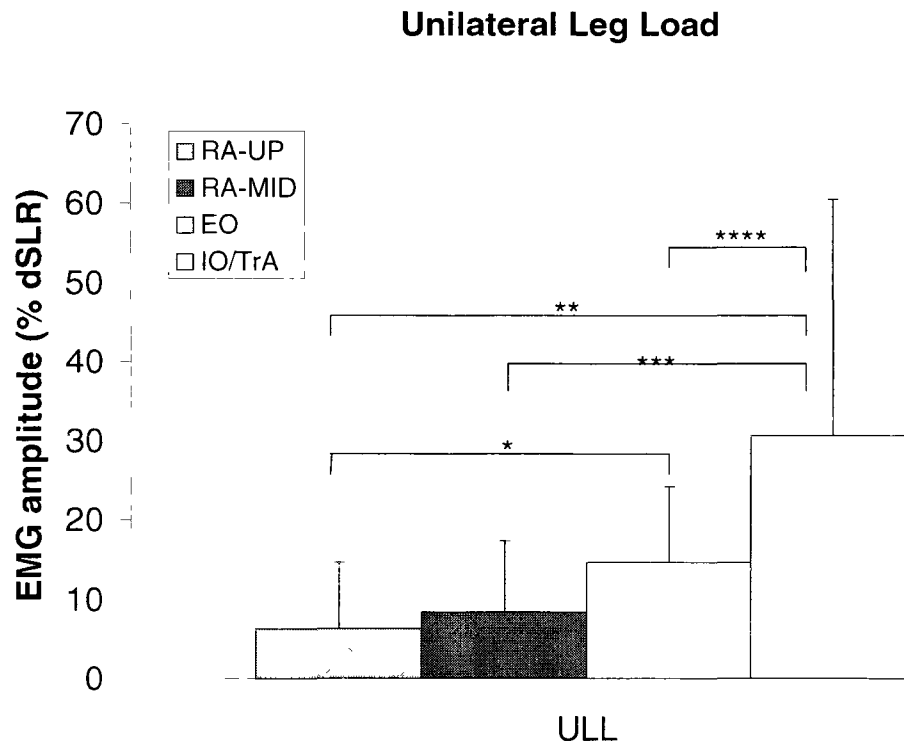


Mean and standard deviation of dSLR normalized EMG amplitudes of the superficial and deep abdominal muscles during the unilateral leg load. Bars indicate the mean normalized EMG amplitude and whiskers indicate the standard deviations. Muscle amplitudes did not differ between groups. Superficial muscles: RA-UP (rectus abdominis upper fibers), RA-MID: (rectus abdominis middle fibers) and EO: (externus obliquus). Deep muscles: IO/TrA: internal obliquus/ transversus abdominis group.

Pooling the group data and using a Bonferonni corrected alpha level of $p = 0.0167$ ($0.05/3$ muscle combinations), the amplitude of the deep abdominal muscles was found to

be significantly greater than that of the superficial muscles (RA-UP: $p = 0.0001$; RA-MID: $p = 0.0004$; EO: $p = 0.010$ respectively) indicating that this activity required significant activity of the IO/TrA. Within the superficial muscles, the EO muscle was significantly different from the RA-UP muscle ($p = 0.001$). The RA-UP and RA-MID did not differ from each other ($p = 0.36$). Noteworthy is that the RA-MID and the IO/TrA were significantly different in this normalization procedure but not in the %max procedure. These results are presented in figure 4.

Figure 4. Between-muscle comparisons of muscle activity during the ULL



Mean and standard deviation of EMG amplitudes for between-muscle comparisons during the dSLR-normalizes ULL. Significant differences were found between the superficial and deep abdominal muscles. No difference was found between RA-UP and RA-MID.

Superficial muscles: RA-UP (rectus abdominis upper fibers), RA-MID: (rectus abdominis middle fibers) and EO: (externus obliquus). Deep muscles: IO/TrA: internal obliquus/transversus abdominis group.

* $p = 0.001$ ** $p = 0.0001$ *** $p = 0.004$ **** $p = 0.010$

Calculation of Outliers

Outliers were those data points beyond three standard deviations away from the mean.

Both groups had equal distribution of outliers within their data (1%), and none of the outliers were found beyond three standard deviations away from the mean. In order to ascertain if the outliers significantly changed the outcome of any statistical calculations, an identical data set was created and the scores were transformed into z-scores. The outliers were removed by replacing the data value with the previously highest score +1.000. No statistically significant differences in means were found between the data sets. Therefore, all analysis were performed with the outliers included in the both the %max normalized data and the dSLR normalized data.

Bonferonni- corrected alpha

The Bonferonni-corrected alpha levels used in the calculations for the pair-wise comparisons were as follows:

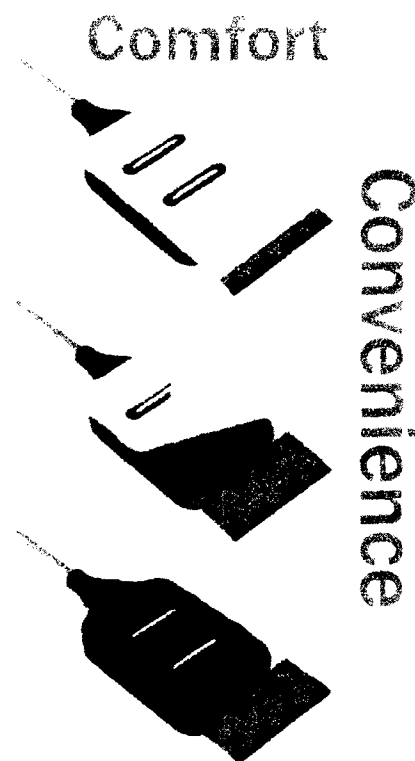
Alpha level/ # of comparisons

Muscle comparisons= $0.05/6 = 0.0083$

Task comparisons= $0.05/3 = 0.0167$

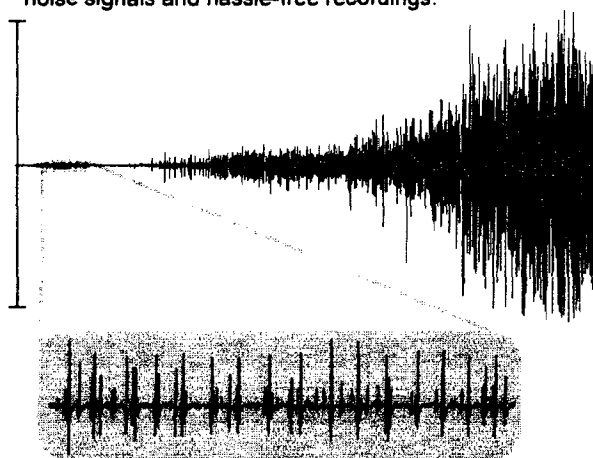
Specifications

System	DE-2.1 Bagnoli™ Single Differential	DE-3.1 Bagnoli™ Double Differential	DE-2.3 Myomonitor® Single Differential
Mechanical			
Number of Contacts	2	3	2
Contact Dimension	10.0 x 1.0 mm	10.0 x 1.0 mm	10.0 x 1.0 mm
Contact Spacing	10.0 mm	10.0 mm	10.0 mm
Contact Material	99.9% Ag	99.9% Ag	99.9% Ag
Detection Area	100 mm²	200 mm²	100 mm²
Case Dimensions	41 x 20 x 5 mm	41 x 20 x 5 mm	41 x 20 x 5 mm
Case Material	Polycarbonate	Polycarbonate	Polycarbonate
Cable Length	1.67 m	1.67 m	1.67 m
Connector	Hypertronics D04	Hypertronics D04	Hypertronics D04
Temperature Range	0-40 °C	0-40 °C	0-40 °C
Electrical			
Preamplifier Gain	10 V/V ±1%	10 V/V ±1% (per diff. pair)	1000 V/V ±1%
Bandwidth	open	open	20-450 Hz ±10%
Noise	1.2 µV (RMS, R.T.I.)	1.2 µV (RMS, R.T.I.)	1.5 µV (RMS, R.T.I.)
CMRR (0-500 Hz)	-92 dB (typical)	-92 dB (typical)	-92 dB (typical)
Power Consumption	20 mW (typical)	45 mW (typical)	40 mW (typical)
Input Impedance	>10 ¹⁵ Ω // 0.2pF	>10 ¹⁵ Ω // 0.2pF	>10 ¹⁵ Ω // 0.2pF



Full Range

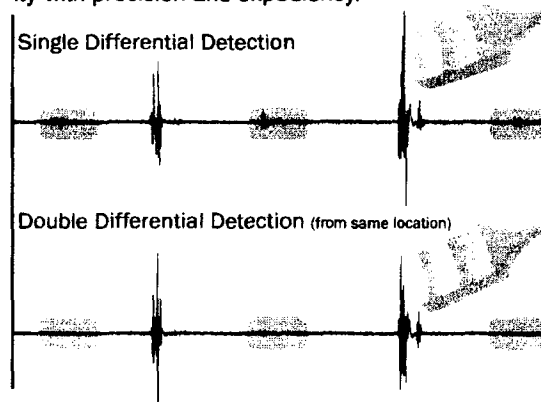
DELSYS Sensors are unsurpassed in signal quality, resolution, and range of detection. All electrode models share unique input characteristics that guarantee low-noise signals and hassle-free recordings.



High Definition

Comprehensive

DE-2.1 Sensors are designed for a broad range of applications, ideally-suited to capture all EMG activity with precision and expediency.



DE-3.1 Sensors reduce the presence of EMG crosstalk. Our Double-Differential approach offers unique research strategies for the discerning electromyographer.

Selective

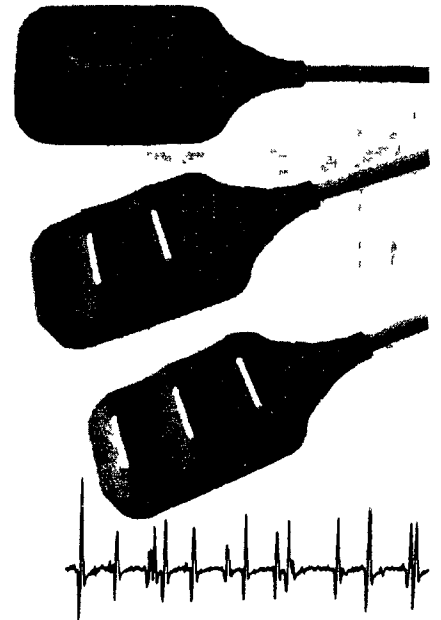


DELSYS®

Surface EMG Sensors

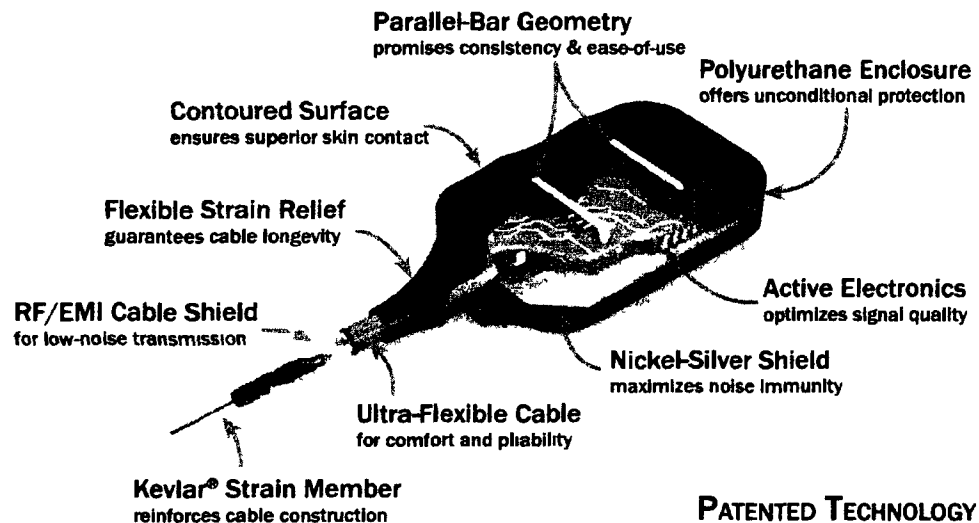
DELSYS has been at the forefront of innovative developments in electromyography since 1993. Our parallel-bar sensors establish the foundation for unmatched signal quality, consistency and reliability in DELSYS EMG Systems. A pioneer in the field, we are committed to furthering the technology and the applications of electromyography through novel sensor designs and EMG signal detection concepts.

- Single Differential and Double Differential models
- No gel or skin preparation necessary
- Can be affixed to skin or used as a probe
- Convenient adhesive skin interfaces
- Slim profile for unobtrusive usage



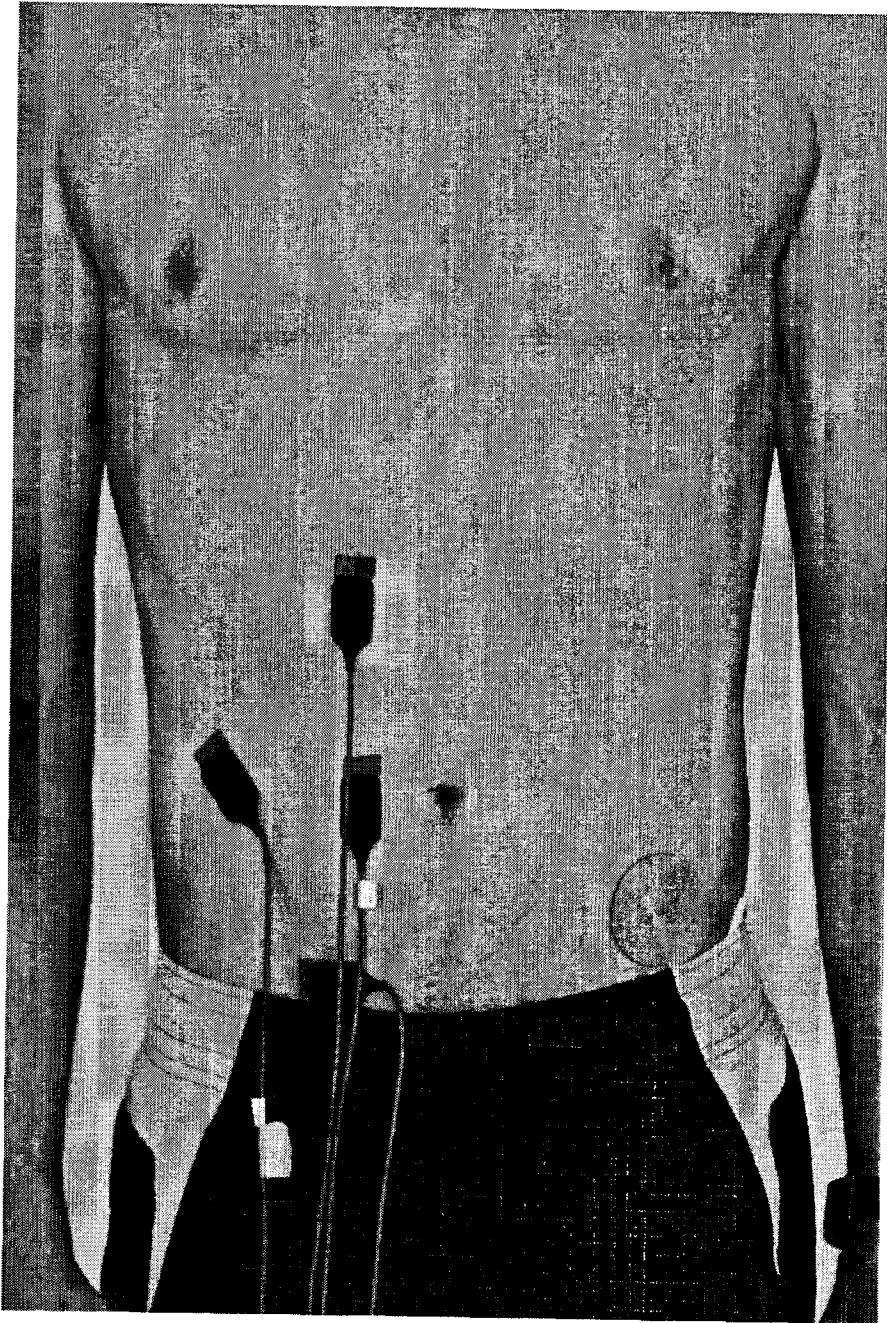
Precision

innovation



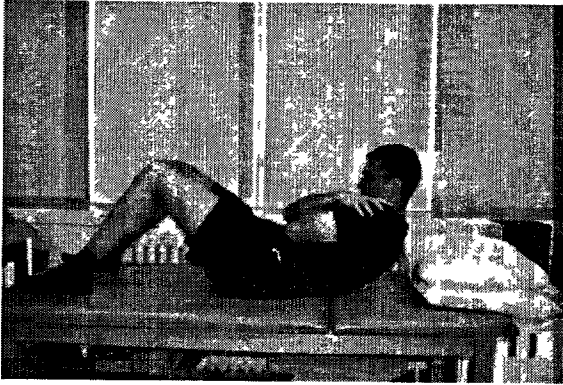
PATENTED TECHNOLOGY

Appendix F: Position of Electrodes

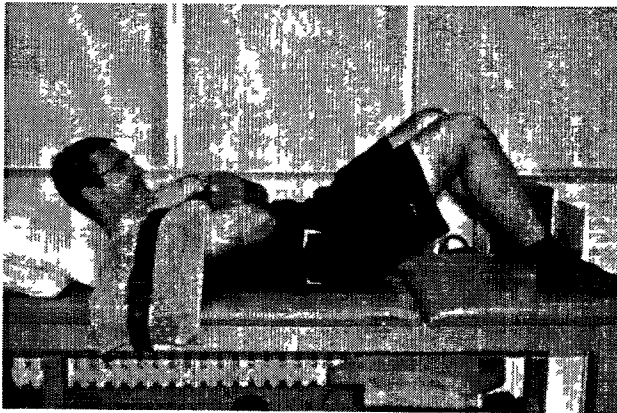


Appendix G: Illustration of the normalization exercises

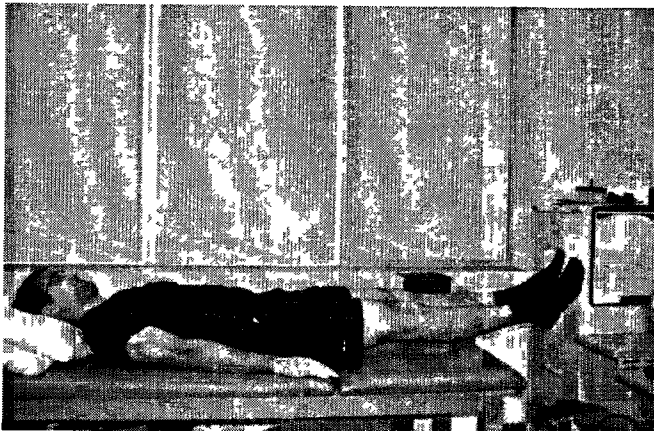
Submaximal voluntary contraction (subMVC's)



Maximal voluntary contractions (MVC's)

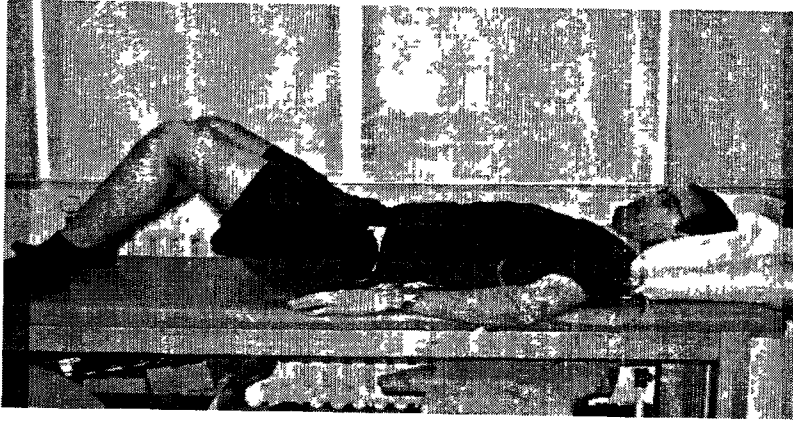


Double straight-leg-raise (dSLR)



Appendix H: Illustrations of the testing positions

Abdominal hollowing in supine crooklying



Unilateral Leg Load

