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OPTIMIZING PHYSICAL AND PSYCHOSOCIAL ASSESSMENT IN PATIENTS WITH NON-SPECIFIC CHRONIC LOW BACK PAIN

BENEDICTE VAN DAMME

THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR IN MOTOR REHABILITATION AND PHYSIOTHERAPY

DEPARTMENT OF REHABILITATION SCIENCES AND PHYSIOTHERAPY

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LIST OF PUBLICATIONS

This manuscript-based dissertation consists of the following papers:

1. Van Damme B, Stevens V, Van Tiggelen D, Duvigneaud N, Neyens E, Danneels L. Velocity of isokinetic trunk exercises influences back muscle recruitment patterns in healthy subjects. Journal of Electromyography and Kinesiology 2013:23(2):378-86

2. Van Damme B, Stevens V, Perneel C, Van Tiggelen D, Neyens E, Duvigneaud N, Moerman L, Danneels L. A surface electromyography based objective method to identify patients with nonspecific chronic low back pain, presenting a flexion related movement control impairment. Journal of Electromyogaphy and Kinesiology 2014:24(6):954-64

3. Van Damme B, Stevens V, Van Tiggelen D, Perneel C, Crombez G, Danneels L. Cross-cultural adaptation and reproducibility of a battery of self-report questionnaires for French and Dutch speaking patients with non-specific chronic low back pain. Journal of Back and Musculoskeletal Rehabilitation, manuscript submitted *(09/03/2015: out for review)*

4. Van Damme B, Stevens V, Crombez G, Van Tiggelen D, Perneel C, Roussel N, Demoulin C, Danneels L. Cut-off scores and minimal clinical important changes for screening and primary outcome self-report questionnaires in non-specific chronic low back pain. Manual Therapy, manuscript submitted *(09/03/2015: decision in process)*

5. Van Damme B, Stevens V, Van Tiggelen D, Perneel C, Crombez G, Danneels L. Performance based on sEMG activity is related to psychosocial components: differences between back and abdominal endurance tests. Journal of Electromyography and Kinesiology 2014:24(5):636-44

LIST OF ABBREVIATIONS

AE test	Isometric endurance test for the abdominal muscles
BMI	Body Mass Index
B-S test	Biering-Sorensen Test
CGIC	Clinical Global Impression of Change
CLBP	Chronic low back pain
CNS	Central nervous system
COS	Cut-off scores
COP_{imp}	Optimal cut-off point for improvement
CT	Computed tomography
DRAM	Distress Risk Assessment Method
DV	Dutch version
EMG	Electromyography
ENTER	A logistic regression analysis with the ENTER-method
EO	External obliques
Ex1	Seated uni- and bilateral knee extension
Ex2	Standing unilateral hip extension with extended knee
Ex3	Seated uni- and bilateral shoulder flexion with extended elbow
Ex4	Seated hip flexion
Ex5	Sitting bow test
Ex6	Standing bow test
FABQ	Fear-avoidance beliefs questionnaire
FV	French version
FWD-Wald	Forward Wald logistic regression analysis
GLM	General Linear Model
HADS	Hospital Anxiety and Depression Scale
	$HADS_{AX}$ Anxiety
	$HADS_{DP}$ Depression
ICC	Intraclass correlation coefficients

ICF	International Classification of Functioning, Disability and Health
ICLT	Thoracic part of the iliocostalis lumborum
IO	Internal obliques
LBP	Low back pain
LMF	Lumbar part of the multifidus
MCI	Motor control impairment
MCIC	Minimal clinical important change
$MDC_{95\%}$	Minimum detectable change
MF	Median frequency
MHQA	Military Hospital Queen Astrid
MPI_{part1}	Multidimensional Pain Inventory (Part 1)
	MPI-PS: pain severity
	MPI-I: interference with the daily life due to pain
	MPI-LC: perceived life control
	MPI-AD: affective distress (negative mood)
	MPI-S: social support
MRI	Magnetic resonance imaging
MSPQ	Modified Somatic Perception Questionnaire
MVIC	Maximal voluntary isometric contraction
MZDI	Modified Zung Depression Index
NMF_{slope}	Normed median frequency slope
NS-CLBP	Nonspecific chronic low back pain
OMPQ	Orebro Musculoskeletal Pain Screening Questionnaire
PC	Principal Component or factor
PCA	Principal Component Analysis
PCS	Pain Catastrophizing Scale
PGIC	Patient Global Impression of Change
PHQ-15	Patient Health Questionnaire with 15-items
PT	Peak Torque
RA	Rectus Abdominis

RMS	Root Mean Square
ROC	Receiving operating characteristics
ROM	Range of motion
SEM	Standard error of measurement for agreement
sEMG	Surface electromyography
SF-36	Short Form 36 Health Survey
	$SF\text{-}36_{PF}$ Physical Functioning
	$SF\text{-}36_{RP}$ Role Physical
	$SF\text{-}36_{BP}$ Bodily Pain
	$SF\text{-}36_{GH}$ General Health
	$SF\text{-}36_{VT}$ Vitality
	$SF\text{-}36_{SF}$ Social Functioning
	$SF\text{-}36_{RE}$ Role Emotional
	$SF\text{-}36_{MH}$ Mental Health
	$SF\text{-}36_{PCS}$ Physical Component Summary
	$SF\text{-}36_{MCS}$ Mental Component Summary
	$SF\text{-}36_{TS}$ Total Scale
TrA	Transversus abdominis
TEF	Trunk extension-flexion
TSK	Tampa Scale for Kinesiophobia
QBPDI	Quebec Pain Disability Index
QOL	Quality of life
US	Ultrasonography
WHO	World Health Organization

The research projects performed in the current dissertation were enabled with support of the Royal Higher Institute for Defence. In collaboration with the Department of Physical Therapy and Motor Rehabilitation of the Ghent University, the studies were conducted at the Military Hospital Queen Astrid (Brussels) in order to optimize the care of patients with non-specific chronic low back pain in the Center of Musculoskeletal Medicine and Rehabilitation.

GENERAL INTRODUCTION

1. Definitions, epidemiology and consequences of non-specific chronic low back pain

Low back pain (LBP) is defined as pain and discomfort, localized below the costal margin and above the inferior gluteal folds, with or without referred leg pain.[1-2] Chronic low back pain (CLBP) involves LBP persisting for at least 12 weeks.[1-2] "Nonspecific" chronic low back pain (NS-CLBP) is CLBP that is not attributable to a recognizable, known specific pathology such as infection, tumor, osteoporosis, fracture, structural deformity, inflammatory disorder (e.g. ankylosing spondylitis), radicular syndrome or cauda equina syndrome.[1-2] Specific causes of LBP are uncommon (<15% of all back pain).[1-2] After a brief diagnostic triage, on the basis of identification of red flags and a limited neurological and musculoskeletal examination, about 85% patients can be classified as having NS-LBP.[2-3] The present dissertation focuses on NS-CLBP.

LBP is one of the most frequent health problems in developed countries. The lifetime prevalence of LBP (without differentiating between acute or chronic LBP) is up to 85% and all age groups are affected by LBP.[1,4-5] The point prevalence of LBP is between 15% and 45% depending on the population studied and the definition of LBP used.[5-6] In Belgium, according to a health survey performed in 2008 by the Scientific Institute for Public Health, 16.7% of the population suffers from a LBP problem (point prevalence). Although most episodes of LBP appear self-limiting, recurrence with a variable course is common, with 10–15% of cases leading to chronic pain.[1,4] There is little scientific evidence on the prevalence of NS-CLBP[1]: best estimates suggest that the prevalence in western countries is approximately 23%.[1,4,7]

LBP is disabling for 11 to 12% of the population.[1,4,8] This imposes, certainly in the chronic state, major burdens on patients, their families and the community.[9-11] The consequences of LBP are not only personally, but also economically of great importance. LBP is due to its high incidence and prevalence rate, one of the most common reasons to consult the health system.[11] It is responsible for a significant amount of sick leave, leading to high health and social costs. [9,11-13] This is also the case in Belgium where LBP comports significantly higher sick leave and costs than other diseases.[6] Seventy-five percent of all costs caused by LBP are due to a very small group, which are the patients with CLBP.[4,14-16] The total direct medical costs for NS-CLBP in Belgium are estimated between 81 and 167 million euros a year. The total cost for the Belgian society (sick leave, etc.) is estimated between 270 million and 1.6 milliard euros a year.[11]

Studies have shown that also in the military population LBP is a common problem[17-22] that may lead to job absenteeism and to long-term disability.[23-24] Prevalence of LBP in the military population seems even higher than in the civilian population. A recent survey of the Belgian military department of Well Being (BeWell, 2013) with 8117 participants in the Belgian military population found that 60,6% of the participants had LBP in 2013 (year prevalence) and 36.1% of these encountered a certain degree of disability (unpublished data). Studies conducted in the US demonstrated that LBP is a common problem in the US army, and that LBP is even more prevalent during deployment and among military veterans.[25-26] In a group of veterans (of various military conflicts) without LBP and with no history of major back problems before the start of the military mission, 67% reported LBP in the course of the following three years.[27] Epidemiologic features about NS-CLBP were also studied in the Army of the Netherlands; NS-CLBP is one of the three most diagnosed disorders during consulting hours of the Dutch Military Company doctors and takes on average 15% of their weekly time of consulting hours.[19]

Therefore the assessment of patients with NS-CLBP at the Military Hospital Queen Astrid (MHQA) is already long-time established, but needed to be refined in order to offer a more tailored rehabilitation and to improve the therapy outcome. Different investigations were conducted at the Military Hospital Queen Astrid, in order to (1) refine the intake assessment of NS-CLBP patients at the Military Hospital Queen Astrid; (2) to make a valuable contribution to guidelines in the assessment of NS-CLBP in general. Because the current project was conducted in the setting of Belgian Defence, all participants to the studies described in this dissertation (both civilian and military) were employed in the military setting (except for the study described in chapter 4). Although a lot of similarities with a general population might occur, potential implications for the results, arising from this particular setting, are described in the discussion section.

2. The assessment of NS-CLBP from a biopsychosocial perspective

The overall aim in the rehabilitation of patients with NS-CLBP should be to restore as much as possible the functioning of the patient. As functioning is the result of a complex interaction between physical, psychological and individual contextual factors, a biopsychosocial approach of these patients is required. The International Classification of Functioning model (ICF) published by the

World Health Organization (WHO)[28] describes well how the level of functioning of a person (and the presence of eventual disability) depends on the interaction between these factors. The components of the ICF model[28] are represented in Figure 1 and briefly defined below.

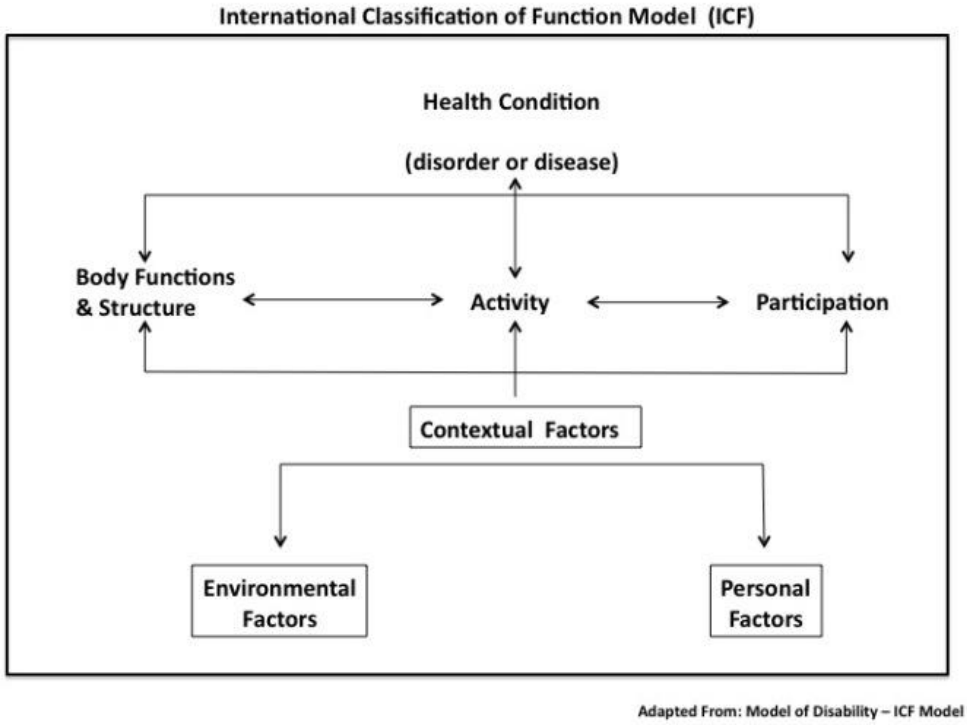

Figure 1 International Classification of Function Model (WHO, 2001)

The health condition implies body function, body structures, activities and participation. 1) Body function refers to the physiological functions of the body (e.g. neuromuskuloskeletal and movement-related functions), including psychological functions (e.g. mental functions, sensory functions and pain). 2) The term 'body structures' designates anatomical parts of the body such as musculoskeletal structures, structures of the nervous system and their components. 3) Activities include the execution of tasks or actions (e.g. walking, sitting) by an individual and participation related to the subject's involvement in a life situation (e.g. self care, work, social life).

Functioning denotes the interaction between the patient's health condition and the individual contextual factors, i.e. environmental and personal factors. Disability should be placed in the context of this multidimensional concept of functioning. Impairments of body functions or body structures, activity limitations and/or participation restriction could lead to disability. Environmental and personal factors should be taken into consideration as they can affect functioning and may need to be changed.

Inspired by the ICF model[28], Danneels et al.[29] proposed a didactical approach, to support the biopsychosocial assessment and treatment of musculoskeletal diseases, i.e. the planetary model. The planetary model mirrors the structure of the ICF in a vertical plan, while the pain mechanisms and psychosocial factors surround this vertical structure reflecting their continuous interaction with the different components of the vertical axis (Figure 2). This model, which was used to situate the content of the current dissertation, also underlines the interaction between different biological and psychosocial aspects, but is more focused on musculoskeletal diseases. Figure 2 represents the planetary model, which is further explained in relation to the assessment of NS-CLBP.

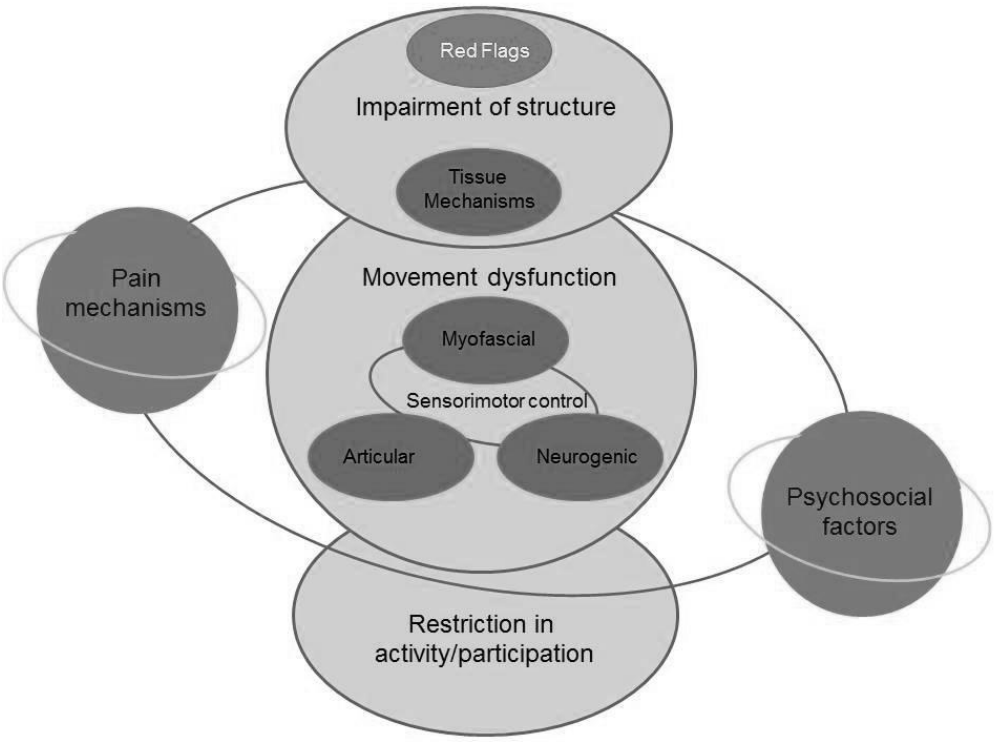

Figure 2 The planetary model (Danneels et al., 2011)

2.1. The vertical axis: physical aspects and disability in NS-CLBP

2.1.1. Assessment of structure impairment

2.1.1.1. Relevance in NS-CLBP

Impairment of structure refers to the pathoanatomy of an injury with the associated tissue mechanisms and can be an indication for a red flag.[29] Although the definition of NS-CLBP implies that no specific underlying structure impairments are present, physiotherapists should always be aware of possible structure impairment and red flags. The presence of certain signs could indicate the need for further testing and may require immediate or specific treatment.[30] In addition, abnormal tissue mechanism should be identified, to understand the condition (inflammation phase, proliferation phase, remodeling, …) of the involved structures and their tolerance to load and forces, to plan the therapy.[29,31]

2.1.1.2. Testing

The medical community has developed a series of routine enquiries to enable the clinicians to detect red flags.[30] A well-conducted case-history taking and a brief examination should be executed to screen for these red flags.[32] If serious spinal pathology is suspected, further investigation should be performed by a medical specialist before any therapeutic intervention. The diagnostic triage (non-specific LBP, radicular LBP or serious spinal pathology) recommended by international guidelines[32] should exclude specific spinal structure impairment and serious spinal pathology from NS-CLBP. However, the physiotherapist should be aware of these signs and symptoms.

2.1.2. Assessment of movement dysfunctions

Movement and stability are dependent on normal function of the articular, nervous, and myofascial system. Dysfunction in one of these systems may lead to dysfunction in another system, and as a consequence the quality of movement may be altered leading to movement dysfunctions.[29,33]

Movement dysfunctions are often present in NS-CLBP and may lead to dysfunctional sensorimotor control.[34-35] Assessment of the articular, nervous and myofascial system is needed to understand the movement dysfunction, if present.

2.1.2.1. Articular dysfunctions

2.1.2.1.1. Relevance in NS-CLBP

A painful low back may be related to restricted, excessive, or poorly controlled lumbar motion.[36-38] Altered mobility can be characterized as general (mobility of the trunk as a whole) or segmental (between two consecutive vertebra).[39] Articular dysfunctions, such as hypo- or hypermobility, are often described in NS-CLBP. Causes of articular dysfunctions could be multiple (congenital, degenerative, traumatic, muscular ...).[29] Altered spinal joint mobility can influence other spinal levels, and could lead to altered quality of movement and production of symptoms[29,40-43] and should therefore be assessed.[38]

2.1.2.1.2. Testing

Trunk mobility can be assessed generally (mobility of the trunk as a whole) or on a segmental level (between vertebra). General trunk mobility has been quantified in the clinical setting using methods of linear or angular displacement.[44] General movement of the trunk or lower back related to the pelvis can be assessed three-dimensionally using ultrasonic[45] or magnetic resonance (MRI)[46] or high-speed camera devices.[47] However, most clinical rehabilitation centers use less sophisticated assessments by devices (e.g. Tergumed and David Back devices). These measurements, however, do not capture the existence of altered mobility at a single segment.

In contrast, different segmental mobility tests are described.[39,48-49] Clinical methods to evaluate segmental motion include manual application of a posterior to anterior (PA) force on the vertebral spinous process or palpation of movement between spinous processes during localized motion of the trunk in different directions.[50] In both cases, the amount of motion, or resistance to force, is assessed using subjective categories (hypomobile, normal or hypermobile) judged by the therapist. Presence, absence or change in pain resulting from the test is also noted. Consequently, therapist's experience will influence the interpretation.

In NS-CLBP regional range of motion tests seem more reliable than segmental range of motion judgement.[1] However, European guidelines for the management of CLBP indicate that spinal range of motion tests are not primordial in the diagnosis of CLBP.[1]

2.1.2.2. Neurogenic dysfunctions

2.1.2.2.1. Relevance in NS-CLBP

Patients with NS-CLBP may complain about associated leg pain. Since the causes of leg pain could be very different, a physiotherapist should differentiate between peripheral nerve sensitization (radicular syndrome), pseudoradicular syndrome and referred musculoskeletal pain.

A radicular syndrome occurs when a nerve root is irritated. In this case, differentiation between radicular pain and radiculopathy is needed. In the former, only radiating pain is present, while in the latter there is an objectively observed sensorial and/or motor deficit (numbness, tingling or muscle weakness). Both occur often together, and radiculopathy could be a continuum of radicular pain. Causes could be multiple, such as a protruding disc, an arthritic spur of the spine, stenosis, etc. Radiculopathy should be detected as a red flag.

Other patients could have similar complaints, but the origin of their pain may not be located at the nerve root, but more peripherally, for example an irritation of the ischiadicus nerve as result of a hypertonic piriformis muscle.

Leg pain can also be referred pain arising from the back. Referred pain is pain perceived at a location other than the site of the painful stimulus. This pain is caused by segmental concordance of the innervation of different structures and should be seen as a perception error of the central nerve system.[51]

2.1.2.2.2. Testing

Symptom quality and behavior are key defining features of pain with neurogenic origins.[52] The pain characteristics reported by the patient (localization, intensity, type, frequency) are important in the history-taking. For instance, pain localization must be taken into account, as it often constitutes the first clinical information that may lead to suspect radicular pain.[11,29] In patients with leg symptoms (certainly if lower than the knee), a focused neurologic examination based on history and clinical examination is needed.[29,53] This neurological examination should be performed on a regular basis during follow-up. Traditionally, it encompasses the osteo-tendinous reflexes testing, motor and sensory testing (nerve function tests) and nerve provocation tests (neurodynamic tests and nerve palpation tests).[54-55] All of the physical examination findings should be consistent with subjective examination information that revealed the features of the symptomatic complaint and its history.

If history taking and clinical examination suggest the presence of a radiculopathy (indicators for nerve root problems: unilateral leg pain > LBP; radiating to foot or toes; numbness and paraesthesia in the same nerve distribution; positive straight leg raising test (Lasègue); localised neurology (limited to one nerve root)) or cauda equina syndrome (bilateral leg weakness, urinary retention, saddle anaesthesia) further medical examination (imaging procedures) should be performed.[56-57] However, these patients do not fit in the diagnosis of NS-CLBP and their symptoms should be detected as red flags.[57]

2.1.2.3. Myofascial dysfunctions

2.1.2.3.1. Relevance in NS-CLBP

The myofascial system is composed of the skeletal muscles and the associated fascia. Possible myofascial dysfunctions are reduced muscle strength,[58-61] reduced muscular endurance,[62-64] altered muscle length, changes in muscle tone[65] and myofascial pain. These changes in muscle function could influence the whole motion patterns and could induce changes in movement. For example, shortened muscles will reduce joint movement and will produce compensatory movements in other joints.[29] This can lead to maladaptive movement patterns and persistence of pain syndromes. Assessing the myofascial system (muscle strength, muscle tone …) is therefore primordial in the management of NS-CLBP.

As endurance and strength are highly relevant for this work, they are extensively described below.

Endurance

Decreased endurance of the trunk muscles, both flexor and extensor muscles, can be an important factor related to LBP.[66-67] Lack of endurance of the trunk muscles has been described as both a predictive factor for developing LBP[68-70] as well as a discriminating factor between subjects with a history of back pain and subjects who have not.[71-72] Several trunk muscles act as postural muscles and are, with respect for their function, built to be effective in low load contraction over a longer period of time. They must be able to maintain the erect posture of the spine throughout sitting, standing, walking, etc.[64]

Strength

Trunk muscle strength has been extensively studied in relation to NS-CLBP. Although some contradictions exist, the majority of researchers have found trunk muscle strength to be an important factor in NS-CLBP.[58] It has been demonstrated that patients with CLBP have weaker trunk muscles than healthy subjects[58-61,73-74], and that generally extensor strength is affected more than flexor strength.[58,61,74-75] Trunk muscle strength could be affected by the chronic pain state as a consequence of disuse (deconditioning syndrome)[76-77], but trunk muscle strength seems also important in the prevention of LBP.[68,75,78-79] Therefore, trunk muscle strengthening exercises are not only recommended for patients, but also for healthy subjects to prevent LBP.

2.1.2.3.2. Testing

Endurance tests

An endurance test of the trunk muscles analyses the localized ability of the trunk muscles to maintain an activity. Endurance can be tested in static and dynamic conditions[66,80] and can be defined as the point of isometric fatigue where the position can no longer be maintained or as the point of dynamic fatigue when repetitive work can no longer be sustained at a certain force level.[81] Different static and dynamic endurance tests are described to evaluate the abdominal and back muscle endurance.[66,80] Of all available assessment strategies, isometric endurance testing seems to be most cost-effective and requires little equipment for testing.[80] In addition, static protocols may be more appropriate for testing in LBP populations because of the standardized and relatively pain-free experimental protocols.[82]

To measure back muscle endurance, the Biering-Sorensen test (B-S test)[68] is most frequently investigated and reported in the literature. It measures the time the subject can keep the unsupported trunk (from the upper border of the iliac crest) horizontal while prone on an examination table.[68,80] Demoulin et al.[83] concluded in their literature review that the B-S test enables a quick, easy and reproducible method to investigate the isometric endurance of the back extensors. In addition, this test appears capable of differentiating LBP patients from healthy controls and might detect persons at risk to develop LBP in the near future.[68] In the report of the Belgian Federal Knowledge Centre of Health Care concerning CLBP, this is the only test with a positive connotation in the evaluation of

physical fitness.[11] The discriminative validity, reproducibility and safety are reported to be good in patients with CLBP.[11]

Until now, less attention was given to endurance of abdominal muscles, although these muscles also play an important role in maintaining the upward position of the trunk during different positions and movements.[82] Isometric sit-up positions are the most frequently used techniques to study abdominal muscle endurance in a static condition.[82,84]

Muscle strength tests

Muscle strength can be tested manually or with devices. Devices allow to obtain more objective measures in contrast to the therapist's interpretation of the force sensation on a scale (0 – 5).

A method often used to assess trunk muscle strength is isokinetic testing.[58,85-91] Devices exist to measure this in a standardized way (Cybex, Biodex, MedX, etc. …). The Cybex dynamometer with the trunk extension-flexion modular component has been developed for testing sagittal plane movements of the trunk and is widely used in the evaluation and rehabilitation of CLBP.[60,92] The Cybex device allows testing isokinetic movements at different velocities. This is important since research has shown that velocity of movement has an impact on the force produced.[93-96]

2.1.2.4. Sensorimotor control

2.1.2.4.1. Relevance in NS-CLBP

Myofascial, articular and neurogenic dysfunctions cannot be separated from sensorimotor control dysfunctions.[29-31,33]

Sensorimotor control is defined as the strategy of the central nervous system (CNS), based on the continuous interplay between input (visual, vestibular, and somatosensory information) and output (coordinated muscle action), to maintain a position or to produce movement. The CNS must interpret the afferent input from the peripheral mechanoreceptors and other sensory systems, compare these requirements against an "internal model of body dynamics," and then generate a coordinated response of the muscles so that the muscle activity occurs at the right time, at the right amount, and in the right sequence.[97] Consequently, the sensorimotor control system interacts with both proprioception (joint position sense, kinesthesia and sensation of force) and neuromuscular control

(the commands of the CNS to generate a coordinated response of the muscles to keep the body in a desired position and orientation or to move in a controlled way). Disturbances in the sensorimotor system may compromise the sensorimotor control function and lead to changes in proprioception and neuromuscular control.

Proprioception is defined as the afferent information, arising from peripheral areas of the body that contributes to the sensorimotor control. Pain and inflammation can affect the sensory acuity and lead to changes in proprioception.[29] Coordination of the muscles to keep the body in a desired position and orientation or to move in a controlled way is described as neuromuscular control. Neuromuscular control is under the commands of the CNS, and pain can influence the strategies used by the muscles.[98]

In summary, sensorimotor control involves the ability to activate muscles in a selected pattern (muscle recruitment patterns) in response to demands of a voluntary posture or movement.[99] In order to provide optimal control of the dynamic stability of the lumbar spine finely-tuned coordination of the spinal muscles is required.[100] In this context, motor control concerns interplay between feedback and feedforward control mechanisms (sensorimotor control) to modulate muscle activity to control changing internal and external spine forces during lumbar movement, in order to maintain sufficient spinal stability and to move in an efficient way.[33]

The trunk muscles may play different roles during movement and in the provision of spinal functional stability. In this context, Bergmark[101] proposed the presence of two separate muscle systems, acting together, in particular the global muscle system (e.g. m. obliquus externus, m. iliocostalis, …) and the local stability system (e.g; m. transversus abdominis, m. multifidus). The global muscle system refers to global torque producing muscles, which are used to provide general trunk stability.[101-102] The local stability muscle system refers to deep stabilizing muscles that play a role in controlling intervertebral motion. [101-102]

There is emerging evidence demonstrating that changes in the amplitude and the timing of trunk muscle activation are associated with NS-CLBP and may result in motor control impairment (MCI).[103-106] Strategies used by the CNS to control the trunk muscles may be altered following a painful experience or in a painful situation.[107] In addition, inadequate sensorimotor control could lead to

spinal injury and pain.[38,108] Therefore, people with a history of LBP have an elevated risk of encountering additional LBP episodes[108-109] and even becoming chronic pain patients. Furthermore, in patients with NS-CLBP with MCI, treatment with movement control exercises results in a significant decrease in functional disability[110-111] and suggests that altered muscle recruitment strategies are reversible.[35] Therefore, trunk muscle recruitment patterns and sensorimotor control should be assessed and treated in patients with NS-CLBP, if this seems to be relevant within the clinical context.

2.1.2.4.2. Testing

Sensorimotor control can be assessed in different ways. Clinicians and researchers can evaluate the way the patient moves in a subjective way[102,110,112], or more objective methods as kinematic variables[42,113] (joint ranges, trunk displacements, ...) can be used. Sensorimotor control can also be evaluated indirectly by assessing trunk muscle recruitment patterns using for example sEMG[114-115] magnetic resonance imagery (MRI)[116] or ultrasonography (US).[117]

The concept of Kinetic Control, as proposed by Comerford and Mottram[102], and the O'Sullivans' classification system[35,112] are examples of subjective methods used to assess sensorimotor control by the way the patients moves. These subjective methods are tools to define MCI in function of the direction of the movement dysfunction (e.g. flexion related movement dysfunction).[102,112,116]

Kinematic measures, as example of objective methods to analyze sensorimotor control, can give more objective details (such as changes in joint angle or trunk displacements) on how the patients are moving during a task.[42,113] But sensorimotor control can also be evaluated in terms of trunk muscle recruitment patterns. sEMG, for example, allows to analyze the timing of onset of the different trunk muscles[117-119] or to calculate the amplitudes of muscle activity in different trunk muscles[120-121] in order to observe trunk muscle recruitment patterns. These objective methods are mainly used by researchers, but are currently not recommended in clinical practice.[1]

2.1.3. Assessment of restriction in activity/participation

2.1.3.1. Relevance in NS-CLBP

Structure impairments and movement dysfunction could lead to a restriction in activity (= difficulty in executing activities) and participation (problems with involvement in life situations such as work, family

duties or leisure).[29] This is often defined as the patient's functional disability (=difficulty with simple physical activities).[122] Disability is a complex phenomenon, reflecting the interaction between features of a person's body and features of the society (environment) in which he or she lives.[28] Functional disability is a major concern in patients with NS-CLBP, because it has an important impact on the quality of life (QOL). Restoration of an acceptable QOL is, after all, the first concern in the rehabilitation of NS-CLBP.[31]

2.1.3.2 Testing

The most standardized way to assess functional disability and QOL is the use of validated self-report questionnaires. These tools are able to evaluate changes in the patient's condition and to assess the effectiveness of rehabilitation programs. Different instruments have been developed for measuring the functional status and the QOL of patients with LBP and selecting the most useful scale may appear difficult. Choices can be made upon the variability in examined content, the difference in questions, the type of scale, and the variable length of time needed for administration of the different instruments.[123-124] In addition, some of the available instruments have been developed without a well-defined conceptual model and not all of them have been thoroughly investigated with regard to reliability, validity, and responsiveness.

Therefore, in the current dissertation, the Quebec Pain Disability Index (QBPDI)[123] and the Short Form 36 Health Survey (SF-36)[124] were preferred to assess functional disability and QOL respectively. The QBPDI is a 20-item self-administered instrument designed to assess the level of functional disability in individuals with back pain exploring the limited area of 'simple' physical activities. The concepts used in the QBPDI are consistent with the definition of disability in the ICF.[28] The scale is an acceptable, reliable and valid measure used for monitoring the progress of individual patients participating in treatment or rehabilitation programs.[122-123] The SF-36[124] is a widely used instrument reporting on QOL. This relatively brief and simple questionnaire comprising eight subscales enables the patient to report on his health status, both on physical as well as on mental components of health. The scores on the different subscales give an idea of the patient's perception of health and thus on his QOL.

2.2. Pain mechanisms and psychosocial factors

2.2.1. Relevance in NS-CLBP

In CLBP, the treatment should be directed towards reducing of the patient's pain and disability. Pain cannot be purely understood in terms of impairment of structure and movement dysfunctions, but should be placed in a context of emotions, cognitions, beliefs, experiences, etc.[125] Certainly NS-CLBP, and the resulting functional disability, is a complex multidimensional phenomenon. A wide range of psychosocial factors could influence pain and functioning. The biopsychosocial view provides an integrated model that incorporates purely mechanical processes as well as psychological (behavior, emotions, beliefs) and social-contextual variables (work-related factors, social network support, cultural norms), which all play a significant role in the development and perpetuation of pain and interact all with each other.[126]

Because a NS-CLBP patient will often seek health care even after diagnostic testing has failed to identify a clear nociceptive source, it is important as clinician to be aware of different possible pain mechanisms. In addition, during the long period since the onset of the pain, psychological factors had the opportunity to influence the pain processing and thereby the patient's suffering.

The assessment of pain mechanisms and psychosocial factors is therefore not redundant in NS-CLBP.

Pain mechanisms

Pain results from a complex processing mechanism.[127-129] It is important to differentiate nociception and the perception of pain. Nociception refers to the peripheral and CNS processing of information about the internal or external environment, as generated by the activation of nociceptors. Noxious stimuli (tissue injury) activate nociceptors that are present in peripheral structures and that transmit information to the spinal cord dorsal horn (or the nucleus caudalis).[130] Consequently, the information continues to the brainstem and the cerebral cortex, where the perception of pain is generated. Three pain mechanisms are in continuous interaction: afferent input (nociception and neurogenic input), central processes (pain processing in the brain) and efferent output (pain, motor system, endocrine system…) (Figure 3).

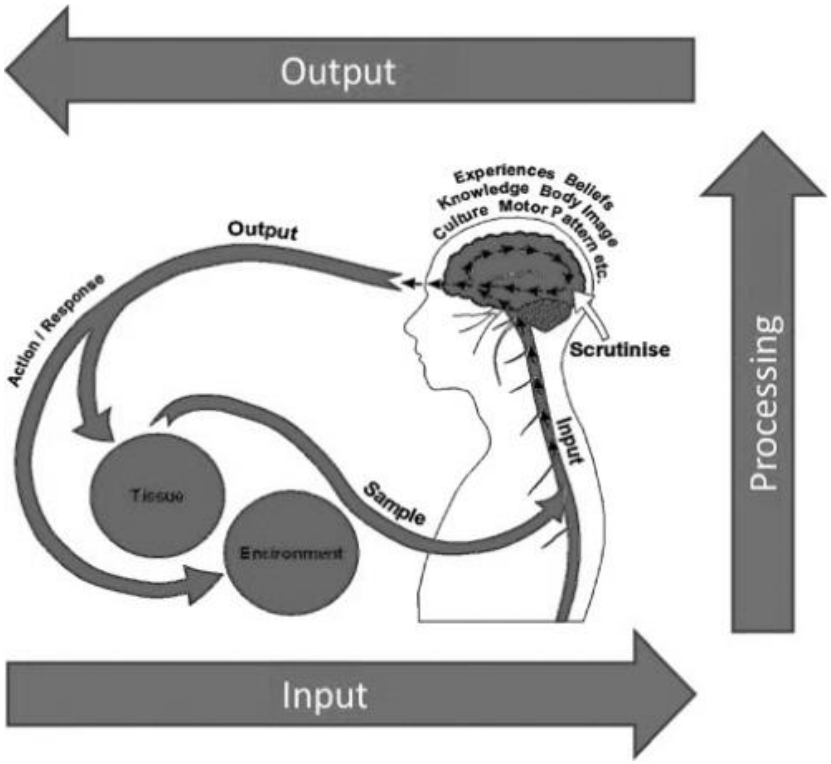

Figure 3 Pain, the Tissues and the Nervous System:

A conceptual model. (Gifford, 1998)

The central processing (affective, cognitive, emotional ...) is multidimensional and occurs in different area of the brain.[131-132] The sensory dimension is the awareness of the intensity, location and quality of pain. The cognitive dimension relates to what the patient thinks about the problem. His thoughts are influenced by previous experiences (e.g. pain experience in the past) and knowledge about the problem (e.g. diagnosis, medical background, …). Finally, the affective dimension implies the emotional response, usually negative, that motivates or governs responses to the pain (e.g., fear, anxiety or anger).

In summary, pain perception is not only a sensory experience, but also an emotional experience, affected by psychological factors such as past experiences, beliefs about pain, fear or anxiety. Pain experience should therefore be linked with psychosocial factors. Furthermore, the mechanisms that contribute to the development of persistent pain are far more complicated than the rather simple anatomical and physiological underpinnings of momentary pain. They arise in the context and

environment of tissue or nerve injury and involve changes in the properties not only of nociceptors but also of the circuits that these receptors engage in the spinal cord and at other levels of the neuraxis.[133-134] Therefore, in NS-CLBP, clinicians should be aware of possible abnormal central pain mechanisms (e.g. central sensitization).

Psychosocial Factors

The experience of pain is thus complex and subjective, as it is influenced by a magnitude of factors. Pain should therefore be interpreted in the light of influencing psychosocial factors.

The pain experience, and the resulting functional disability and decreased QOL observed in patients with NS-CLBP, could be linked with inter alia kinesiophobia and pain catastrophizing.[151-153] Kinesiophobia and catastrophizing both involve irrational thoughts about pain. Kori et al. (1990) defined kinesiophobia as a condition in which a patient has "an excessive, irrational, and debilitating fear of physical movement and activity resulting from a feeling of vulnerability to painful injury or reinjury". Sullivan et al. (2001)[135] defined catastrophizing as "an exaggerated negative mental set brought to bear during actual or anticipated painful experience". Catastrophizing means that pain is erroneously interpreted as a sign of serious injury or pathology over which one has little or no control.[136] It is characterized by feelings of helplessness, active rumination and excessive magnification of cognitions and feelings toward the painful situation.

Kinesiophobia and catastrophizing can both lead to avoidance of movements or activities resulting in functional disability and reduced QOL. Longstanding physical inactivity could have a detrimental impact on the musculoskeletal and cardiovascular systems and this may worsen the pain problem. Thus treating pain related fear and catastrophizing – and the resulting avoidance behavior – is important to improve functioning, reduce affective distress and decrease pain and interference with activities of daily living.[137-138] Kinesiophobia and catastrophizing should therefore be assessed preceding the therapy.

Avoidance behavior also involves a lack of positive experiences increasing mood disturbances such as irritability, frustration and depression.[139] Both depression and disuse are known to be associated with decreased pain tolerance,[140-141] and hence they might promote the painful experience. Depression has even been identified as a determinant of poor rehabilitation outcomes in individuals with musculoskeletal conditions.[142-143] A study of Sullivan et al.[162] highlights the importance of early

screening and treatment for depressive symptoms in patients with NS-CLBP, because depressive symptoms become treatment resistant over a longer time and hinder the pain reduction. In other words, depression could be a consequence of NS-CLBP,[144-145] but plays also a role in maintaining the chronic pain state.[144,147]

In addition, depression and anxiety disorders are often associated with multiple somatic symptoms.[148-149] These medically unexplained somatic symptoms may negatively influence patients by affecting treatment outcomes, reducing QOL and causing functional impairment. Somatic symptoms are also an important indicator of subsequent mood disorders, demonstrating the importance of appropriate and early intervention to treat these symptoms. Self-report questionnaires for mood disorders as well as for multiple somatic symptoms should therefore be used as screening tools and as outcome instruments in patients with NS-CLBP.

Not only endogenous factors, such as psychological disturbance, have an impact on the patient's functioning, but also some exogenous/environmental factors (work-related aspects, social support, familial concerns …) could influence the degree of disability of the patient. All these psychosocial factors (endogenous and exogenous) have been conceptualized as "yellow flags" indicating a possible hindrance for recovery. Taken in isolation, their prognostic value is low, emphasizing the need for a multidimensional assessment.

2.2.2. Testing

As indicated in the previous paragraphs, evaluation of these pain mechanisms and psychosocial factors is recommended for each patient in order to 'tailor' a treatment plan to the specific needs of that patient.[1]

Evaluating pain mechanisms specifically, as for example the recognition of central sensitization, is a complex process. Because this is not the aim of this dissertation, it is not described extensively in this introduction. However, as pain reduction is a goal in the treatment of NS-CLBP, measures of pain (in terms of pain perception) should be used to enable continuous reassessment of the patient. As the experience of pain is influenced by a magnitude of factors, pain should be assessed in a multidimensional way. The first part of the Multidimensional Pain Inventory[150] ($MPI_{part\ 1}$) enables the

physician to measure pain-relevant psychosocial aspects (such as subjectively experienced pain-intensity, interference in daily life occasioned by the pain, perceived pain control, etc.) and is made up of 5 scales: pain severity, interference with the daily life due to pain, perceived life control, affective distress and social support.

A more detailed assessment of psychosocial factors in patients with NS-CLBP requires an interview as well as the administration of several self-report measures. The interview is used to evaluate the patients' suffering and the factors that may influence their complaints. But standardized tools for evaluation are necessary because primary health care is often poorly equipped (lack of personnel, training, time) to assess these variables. Further, many psychological variables have been identified, making interview assessments difficult and time consuming. Finally, interview techniques are subject to several biases and their predictive ability is not known yet. Standardized self-report measures exist to evaluate psychosocial variables in patients.[151] The choice of a specific tool depends on the psychosocial aspect that should be measured. The tools that were used in the current dissertation will be described in the following paragraphs.

Kori et al.[152] developed the Tampa Scale for Kinesiophobia (TSK). This 17-item questionnaire determines the level of a person's fear to perform physical movement and activities resulting from a feeling of vulnerability to painful injury or re-injury. In a clinical setting, the TSK can provide the practitioner a tool to identify pain-related fear in patients with LBP.[153] Another measure often used to indicate pain-related fear is the Fear-avoidance beliefs questionnaire (FABQ).[154] The TSK and the FABQ are both reliable measures of pain-related fear in acute LBP patients[153], but the TSK is a more specific measure of pain-related fear[155] and its validity and reliability have been widely studied in the NS-CLBP population.[155-156] Therefore the TSK was preferred in this dissertation.

As described above, avoidance behavior can also be linked with pain catastrophizing. Therefore, it may be useful to measure this aspect of pain behavior separately. The Pain Catastrophizing Scale (PCS)[157] is a valid and reliable instrument to assess the tendency of the patient to focus excessively on pain sensations (rumination), to magnify the threat value of pain sensations (magnification) and to perceive himself as unable to control the intensity of pain (helplessness). Consequently, the PCS was applied in the current dissertation as a measure for pain catastrophizing.

Different self-report questionnaires for mood disorders as well as for multiple somatic symptoms are developed to screen and follow-up patients with NS-CLBP. The Hospital Anxiety and Depression Scale (HADS) is a valid and reliable scale screening for depression and anxiety, independent of somatic symptoms.[158] Although a review evaluating common outcomes for measuring treatment success for CLBP indicated that the Beck Depression Inventory is most used to assess depression [159], the HADS has the advantage to indicate not only depression, but also anxiety. The Hopkins Symptom Checklist-25 analyses also both depression and anxiety, but is mainly used in eastern countries, and its sensitivity and specificity of depression is lower than the HADS.[160] The Distress Risk Assessment Method (DRAM) was developed to assess the degree of psychological disturbance in patients with LBP. It consists of two subscales: the Modified Zung Depression Index (MZDI) and the Modified Somatic Perception Questionnaire (MSPQ).[161-162] This combination assesses depression and somatic complaints and has been shown to be accurate in patients with LBP.[161,163] The Symptom Checklist– 90 (SCL–90)[164] and the State University of New York at Albany (SUNYA) Psychosomatic Symptom Checklist[165] are other examples of self-report questionnaires used to assess current multiple somatic symptoms. These scales have been developed to measure current somatic distress and are useful for research into the treatment outcomes of somatoform disorders. However, it takes a relatively long time to complete these scales, making analysis difficult within an actual clinical or community setting.[166] Recently, a new questionnaire was developed, which was proven reliable and valid, and which is much easier to use, namely the Patient Health Questionnaire with 15-items (PHQ-15). This scale inquires about 15 somatic symptoms or symptom clusters that account for more than 90% of the physical complaints (excluding upper respiratory tract symptoms) reported in the outpatient setting.[167] The HADS, as a measure for depression and anxiety, and the PHQ-15 as a measure for multiple somatic complaints were selected in this dissertation. The DRAM was included as external criterion for multiple somatic complaints to establish a valid cut-off score (COS) for the PHQ-15 in chapter 4 of this dissertation.

The Orebro Musculoskeletal Pain Screening Questionnaire (OMPQ),[168] as used in this project, was developed to help identifying patients at risk for developing persistent back pain problems and related disability. The OMPQ may be recommended as a tool in the early identification of patients who risk developing long-term functional problems in relation to their pain. The questionnaire intends application in individuals who are experiencing regional pain problems that are affecting their

performance at work, who are taking repeated short spells of sickness absence or who are currently off work and have been so for up to 12 weeks. There are 21 scored questions concerning attitudes and beliefs, behavior in response to pain, affection, perception of work and activities of daily living. A COS of 105 and below has been found to predict, with 95% accuracy, those who will recover and, with 81% accuracy, those who will have no further sick leave, in the next 6 months. This assists the clinician to apply interventions (including the use of activity programs based on cognitive behavioral strategies) to reduce the risk of long-term pain-related disability.

3. Outline and aims

The planetary model clearly illustrates the need for a complete biopsychosocial assessment of patients with NS-CLBP. However, some physical and psychosocial components of the assessment of NS-CLBP remain unclear and further investigations are needed. The aim of this dissertation was to improve a part of this assessment; more specifically, this work focuses on trunk muscle recruitment pattern evaluation and the use of self-report questionnaires. In Figure 4, the present dissertation is situated within the planetary model.

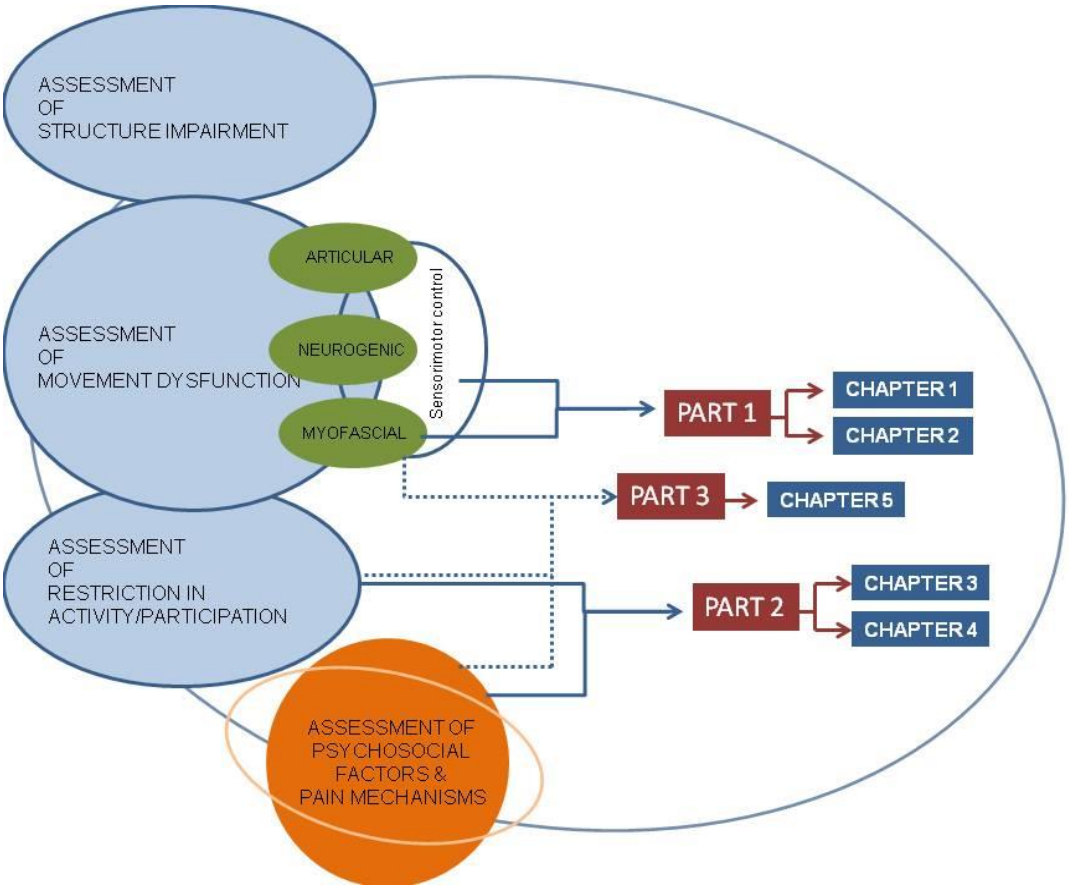

Figure 4 A flow-chart to situate the present dissertation in the planetary model

3.1. Trunk muscle recruitment patterns

3.1.1. Trunk muscle recruitment patterns during isokinetic strength testing

The use of Cybex isokinetic dynamometers is valid to measure strength in terms of Newton per meters.[169-170] However, this kind of measure does not give information about the used trunk muscles and on the trunk muscle recruitment patterns to obtain this strength. As explained below, information about trunk muscle recruitment patterns can give interesting enlightenment of the sensorimotor control in NS-CLBP. Combining isokinetic testing with simultaneous sEMG recording could give insights in the trunk muscle patterns used during these exercises.

With regards to the different modalities during strength testing and training, the velocity of movement has an impact on trunk muscle recruitment patterns.[171-172] Therefore one of the aims of this dissertation was to analyze trunk muscle recruitment patterns during different velocities of isokinetic testing in healthy subjects. Before evaluating these recruitment patterns during isokinetic tests in patients, it is important to understand the mechanisms of muscle function in healthy subjects. Therefore, within the *first chapter* of this dissertation the influence of different velocities of isokinetic movements on trunk muscle recruitment patterns in healthy subjects will be investigated. The results of this study were extensively described in the following publication:

> *Van Damme B, Stevens V, Van Tiggelen D, Duvigneaud N, Neyens E, Danneels L. Velocity of isokinetic trunk exercises influences back muscle recruitment patterns in healthy subjects. Journal of Electromyography and Kinesiology 2013:23(2):378-86*

3.1.2. Trunk muscle recruitment patterns during sensorimotor control assessment

Evaluation of sensorimotor control by observation of the way the patient moves is very subjective, and objective measurements to validate these concepts are scarce. However, a study of Dankaerts et al.[113] provides evidence that statistical models based on kinematic measures and sEMG may correctly classify subjects within three subgroups (no-LBP, active extension patterns and flexion patterns). These findings suggest that the sub-group classification based on MCI is reflecting 'real phenomena'. However, the ground of this classification model[113] was limited to the activity of superficial muscles[112] during sitting postures and forward bending. Combining a range of low load exercises (as used in the observational subjective classification methods) and increasing the number of measured muscles will

probably improve such classification models. A main focus of this dissertation was to assess sensorimotor control in an objective way, using sEMG amplitude analysis of both deep stabilizing and global torque producing muscle groups during a range of motor control exercises in order to be able to define specific trunk muscle recruitment patterns.

In order to create a statistical model, trunk muscle recruitment patterns were analyzed both in healthy and NS-CLBP subjects. This study is presented in *chapter 2* of the current dissertation:

> *Van Damme B, Stevens V, Perneel C, Van Tiggelen D, Neyens E, Duvigneaud N, Moerman L, Danneels L. A surface electromyography based objective method to identify patients with nonspecific chronic low back pain, presenting a flexion related movement control impairment. Journal of Electromyogaphy and Kinesiology 2014:24(6):954-64*

3.2. Psychosocial factors: self-report questionnaires

As described in the introduction, a lot of self-report questionnaires exist to plan and evaluate treatment in a standardized way, but clinicians encounter some practical problems due to language-related problems and to the lack of criteria in function of an appropriate clinical interpretation.

A first problem is the availability of standardized questionnaires in the appropriate language. A lot of questionnaires are not available in the French or Dutch language, and if they are, the translated version is not always validated. Moreover, some questionnaires present some cultural issues, for which cross-cultural adaptations are needed with respect to the psychometric properties of the questionnaires.

A second concern related to the use of self-report questionnaires is the clinical interpretation of the scores. To facilitate the clinical interpretation of a score and to objectify the real clinical importance of a change in score during intervention, clearly defined information is needed about screening thresholds (COS) and clinical relevant changes. COS and minimal clinical important changes (MCIC) are population depended and should therefore be established for the NS-CLBP population.

The aim of the second part of this dissertation was to improve the clinical use of several self-report questionnaires. In *chapter 3*, cross-cultural adaptation of several questionnaires (PHQ-15, MPI_{part1}, QBPDI, TSK and OMPQ) was performed to the Dutch and French languages applied in Belgium, the

Netherlands and France. Test-retest reliability of these adapted questionnaires and of other existing translations of questionnaires (PCS, DRAM, HADS, SF-36) was investigated over a long time interval.

Van Damme Benedicte, Stevens Veerle, Van Tiggelen Damien, Perneel Christiaan, Crombez Geert, Danneels Lieven. Cross-cultural adaptation and reproducibility of a battery of self-report questionnaires for French and Dutch speaking patients with non-specific chronic low back pain. Journal of Back and Musculoskeletal Rehabilitation, manuscript submitted

In *chapter 4*, COS (TSK, OMPQ, PHQ-15) and MCIC (TSK, OMPQ, QBPDI, MPI-PS, SF-36_{PCS} and SF-36_{TS}) were established for the questionnaires described in the introduction. This was done to facilitate the clinical interpretation of the questionnaire scores before and after therapy. The COS and ranges of MCIC are presented in:

Van Damme Benedicte, Stevens Veerle, Crombez Geert, Van Tiggelen Damien, Perneel Christiaan, Nathalie Roussel, Christophe Demoulin, Danneels Lieven. Cut-off scores and minimal clinical important changes for screening and primary outcome self-report questionnaires in non-specific chronic low back pain. Manual Therapy, manuscript submitted

3.3. Endurance testing: Linking physical and psychosocial assessment

As explained extensively in this general introduction, biological, psychological and social factors are interacting in NS-CLBP. This means that also in the assessment of NS-CLBP attention should be paid to the influence of these factors on the outcome measures. Psychosocial factors could for example influence the outcome of physical tests. For example, Geisser et al.[173] demonstrated that pain-related fear shows a significant inverse correlation with lumbar flexion and a direct correlation with the EMG amplitude in full flexion in CLBP patients.

Endurance tests, which are widely used in the assessment and in research of NS-CLBP, seem also highly influenced by psychosocial factors.[174] Clinicians should be aware of the interaction between psychosocial components and outcome of physical tests. The outcome measure used during endurance tests, such as the B-S test, is often expressed as the time that the subject can maintain the sustained activity. However, this kind of measure is known to be largely influenced by pain and motivational factors.[174] Combining these tests with surface electromyography (sEMG) measures have

been validated as tools to objectively monitor local muscle fatigue in both healthy and LBP populations.[175-176] The use of self-report questionnaires in addition to sEMG monitored endurance tests can provide insight in the amount of impact of pain-related factors and psychosocial components on the outcome of physical endurance tests.

Therefore, in the *last chapter* of the current dissertation we were interested in the correlation between the physical performance and the outcome of the psychosocial evaluation. It was hypothised that psychosocial aspects influence the performance on back and abdominal endurance tests.

> *Van Damme Benedicte, Stevens Veerle, Van Tiggelen Damien, Perneel Christiaan, Crombez Geert, Danneels Lieven. Performance based on sEMG activity is related to psychosocial components: differences between back and abdominal endurance tests. Journal of Electromyography and Kinesiology 2014:24*(5):636-44

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RESEARCH PART 1:

TRUNK MUSCLE RECRUITMENT PATTERNS

CHAPTER 1

Velocity of isokinetic trunk exercises influences back muscle recruitment patterns in healthy subjects.

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ABSTRACT

Isokinetic exercises at different angular velocities on Cybex devices are often used for assessment and therapy in chronic low back pain patients. Little is known about the effect of velocity of movement on the muscle activity during these exercises. The purpose of this study was to investigate both relative muscle activity and ratios of local to global muscle activity at the different velocities of isokinetic movements on a Cybex dynamometer. Fifty-three healthy employees of Belgian Defence (26 male and 27 female) aged between 20 and 57 years old voluntarily performed isometric and isokinetic exercises at 4 different velocities. Surface electromyographic signals of different abdominal and back muscles were recorded on both sides. Both the relative muscle activity and the local to global muscle activity ratio of the back muscles were affected by changes in velocities of isokinetic exercises. The global muscle system was more influenced by changes in velocity, than the local muscle system. Abdominal relative muscle activity and ratios were not influenced by velocity of movement. This study revealed that the velocity of isokinetic extension exercises influences the recruitment of the back muscles, meaning that protocols of training programs should be adapted in function of the focus of the therapy.

Keywords*:* Electromyography, Trunk muscle activity, Ratios, Isokinetic exercises, Velocity

INTRODUCTION

There is considerable evidence that trunk muscle strength (Newton and Waddell, 1993; Nachemson and Lindh, 1969; Takemasa et al., 1995; Thorstensson and Nilsson, 1982) and trunk muscle activation patterns (O'Sullivan et al., 1998; Stevens et al., 2006; Van Dieën, 2003a,b; Hodges, 2001; Hodges and Richardson, 1999) are important in relation to low back pain (LBP). It has been hypothesized that trunk muscle recruitment patterns may be altered in patients with LBP to compensate for reduced spinal stability (Panjabi, 1992; Van Dieën et al., 2003a,b; O'Sullivan et al., 1998). However, debate about most optimal muscle recruitment patterns in healthy subjects continues. Marshall and Murphy (2005) considered higher local muscle activity in comparison to global activity as preferably in healthy subjects. In contrast, Van Dieën et al. (2003a,b) found that in healthy subjects, ratios of local to global muscle activity were lower than in LBP patients. Specific exercise therapy could alter this ratio (O'Sullivan et al., 1998; Stevens et al., 2007) and improve spinal stabilization. Therefore the trunk muscle recruitment pattern needs an important focus in the evaluation and rehabilitation program of the LBP patient. Trunk muscle recruitment is often defined in terms of local to global muscle activity (Bergmark, 1989). Deep local stabilizing muscles like the lumbar multifidus (LMF), the transversus abdominis (TrA) and the inferior fibres of the internal obliques (IO) mainly contribute to segmental spinal stability. Global muscles, such as the external obliques (EO) and iliocostalis pars thoracis (ICLT) are larger superficial muscles responsible for more general stabilizing of the trunk and for torque production. Marshall and Murphy (2005) accentuate the importance of the synergistic relation between the local and the global stability system in rehabilitation exercises.

Although trunk muscle recruitment has been investigated in all kinds of exercises, information on trunk muscle activation and recruitment patterns during isokinetic exercises on Cybex devices is scarce. The Cybex dynamometer with the trunk extension-flexion (TEF) modular component has been developed for testing sagittal plane movements of the trunk and is widely used in the evaluation and rehabilitation of chronic LBP (Newton and Waddell, 1993; Almekinders and Oman, 1994). The Cybex device allows testing isokinetic movements at different velocities. This is important since research has shown that velocity of movement has an impact on the force produced. Muscles generate greater concentric force at slow angular velocities and this force decreases as the velocity increases (Rahnama and Bambaeichi, 2008; Thorstensson et al., 1976; Bobbert and Harlaar, 1993; Perrine and

Edgerton, 1978). This is important in the choice of therapeutic exercises and is based on the force velocity relationship described by Hill (1938). Hill (1938) identified a hyperbolic relationship between force and velocity. Many theories have been proposed to explain this relationship. For example, Grimby (1985) suggests that there are different patterns of motor unit recruitment at different speeds in isokinetic measurements, which cause reduced torque output. The reason for this is dedicated to the different recruitment capabilities of the different muscle fibres. At lower speeds, both type I and II fibres can be activated maximally, while with increasing angular velocity the slow-twitch type I fibres will initially remain passive (Kannus, 1994). The Hill equation was based on laboratory measurements of the muscle fibres and other internal (anatomical structure of the muscle, fibre type distribution, fatigue, muscle length) and external factors (contraction type) play a role in the force production (Rahikainen et al., 2012). The effect of the force-velocity relationship on the activation of muscles has been studied by Welter et al. (2000) in arm-movements. They found that the force-velocity relationship could not be the main explanation for changes in the electromyography (EMG) and suggest that other muscle contractile properties, such as history dependence, could have a role in muscle activation levels.

Much information about isokinetic testing on Cybex devices in healthy people and LBP is available (Bayramoğlu et al., 2001; Takemasa et al., 1995); however, all data concern peak torque. Research shows lower muscular peak torque performance on all isometric and isokinetic measures for patients with LBP compared to normal asymptomatic subjects (Newton et al., 1993; Bayramoğlu et al., 2001; Takemasa et al., 1995). The impact of velocity of movement on muscle recruitment has not yet been investigated in isokinetic testing of the back and abdominal muscles.

Moreover, the relative contribution of different trunk muscles (expressed as a ratio of both local and global muscles) in isokinetic exercises on Cybex devices remains unanalyzed. To understand trunk muscle recruitment patterns in patients with LBP during isokinetic movements, evaluation of healthy subjects is needed. Therefore, the aim of this study was to analyse the relative muscle activity of four trunk muscles and the ratio of local to global muscle activity at different velocities of isokinetic exercises in healthy subjects.

MATERIALS AND METHODS

Subjects

Twenty-six healthy men (mean age of 38.2 ± 9.91 years, mean BMI of 24.6 ± 2.20) and twenty-seven healthy women (mean age of 36.5 ± 11.30 years, mean BMI of 22.6 ± 2.74), employees of the Belgian Defence (military and citizen, from different work settings) participated voluntarily in this study.
Criteria for selection included: aged between 20 and 57 years old and never having had a medical or paramedical consult for LBP. Persons with known neurological or other important disorders and pregnant women were excluded. This study was approved by the Ethics Committee of the Ghent University Hospital and all subjects give a signed written consent.

Cybex device

The Cybex Norm Isokinetic dynamometer (CSMI, Stoughton, USA), with the TEF modular component, was used for the assessment of isometric and isokinetic trunk flexion and extension. Isokinetic dynamometry has been shown to be a reliable method for measuring strength in healthy individuals, both in young and elderly subjects (Karataş et al., 2002), and also in LBP patients (Newton et al., 1993; Newton et al., 1997; Hutten and Hermens, 1997). Isokinetic dynamometers produce reliable data when testing the spine in flexion and extension (Almekinders and Oman, 1994) up to 120°/s (Newton and Waddell, 1993).
The subject was placed on the TEF modular component in a standing position (Fig. 1) (Karataş et al., 2002; Bayramoğlu et al., 2001; Madsen, 1996; Tan et al., 1993). The rotation axis was set at the intersection point of the midaxillary line and the lumbosacral junction (L5-S1) (Cohen et al., 2002; Karataş et al., 2002; Jerome et al., 1991; Langrana and Lee, 1984; Madsen, 1996; Marras and King, 1984; Mayer et al., 1985; Smith et al., 1985; Tan et al., 1993; Calmels et al., 2004; Hermann and Barnes, 2001; Langrana et al., 1984), approximately 3.5 cm below the top of the iliac crest (Karataş et al., 2002). The heels were placed against the footplate heel cups. The lumbar pad was moved forward or backward to obtain 15° of flexion in the knees (Karataş et al., 2002; Smith et al., 1985; Calmels et al., 2004) and the lower limbs were fixed with a tibial and a tight pad (Karataş et al., 2002; Bayramoğlu et al., 2001; Calmels et al., 2004). The pelvic belt was tightened across the top of the anterior superior iliac spines. The scapular pad was positioned across the centre of the scapula and

the chest pad was fixed parallel to the scapular pad (Karataş et al., 2002; Smith et al., 1985; Calmels et al., 2004).

The anatomical zero position and the range of motion (ROM) were determined before the isometric and isokinetic exercises. Data were sampled at a frequency of 1000 Hz and stored using HUMAC software. Peak torque of the different exercises was registered in the subject report.

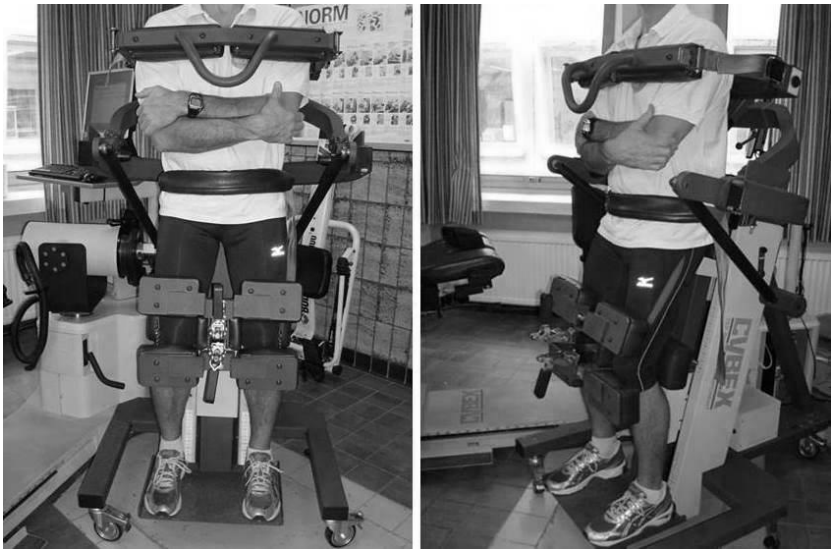

Fig. 1 Positioning of the subject on the TEF modular component of the Cybex device.

Electromyography

For the recording of the EMG signals, an 8-channel surface EMG system was used (Myosystem 2000, Noraxon U.S.A. Inc., Scotssdale, AZ). All raw EMG signals were band pass-filtered between 10 and 500 Hz and amplified. The collection rate was 1000 Hz and the common mode rejection ratio was greater than 110 dB. The signals were converted from an analogue voltage to a digital signal at 1000 Hz (A/D conversion) before being stored in a personal computer.

The input impedance of the system was greater than 100 mega-ohms. After appropriate skin preparation in order to reduce the skin impedance (typically ≤ 10 kilo-ohms) (Hermens et al., 2000; Danneels et al., 2001), 8 pairs of circular Ag/AgCl sensor surface electrodes (Ambu® Blue Sensor M, Ambu A/S, Ballerup, DK)) were placed parallel to the muscle fibres (Ng et al., 1998), bilaterally, of a local and a global abdominal and back muscle as follows: The inferior fibres of the IO (midway between the anterior iliac spine and the symphysis pubis, above the inguinal ligament) (Stevens et al., 2008), the EO (just below the rib cage, on the line between the most inferior point of the costal margin

and the contra-lateral pubic tubercle) (Ng et al., 1998), the LMF (lateral to the midline of the body, above and below a line connecting both posterior superior iliac spines) (Danneels et al., 2002; Stevens et al., 2008), the thoracic part of the ICLT (above and below the L1 level, midway between the midline and the lateral aspect of the body) (Danneels al, 2002; Stevens et al., 2008).

Experimental procedure

All the tests were performed on the CYBEX NORM. Peak torque and EMG values of the trunk musculature, as described above, were registered.

Isometric testing was performed first for flexion, then for extension, to record the maximal voluntary isometric contraction (MVIC). The isometric exercises were performed at the zero position (Tan et al., 1993; Hermann and Barnes, 2001; Ross et al., 1993). For each direction there was first a familiarization trial, followed by two test repetitions. The subject was asked to perform the maximal contraction within the first two seconds and maintain this contraction at that level for another 5 seconds. Between both repetitions, there was a pause of 45 seconds.

Isokinetic trunk flexion and extension were assessed at 4 different velocities, in following order: 60°/s (Karataş et al., 2002; Bayramoğlu et al., 2001; Cohen, 2002; Corin et al., 2005; Smith et al., 1985), 30°/s (Smith et al., 1985; Weissland et al., 2002), 90°/s (Karataş et al., 2002; Smith et al., 1985), and 120°/s (Smith et al., 1985; Bayramoğlu et al., 2001). The velocity of 60°/s is usually chosen to start with due to the average force needed. The ROM was set at 15° extension and 45° flexion. For each velocity the subject performed first 3 submaximal familiarization trials (Calmels et al., 2004; Hermann and Barnes, 2001), followed by a 10 second pause and 5 test repetitions (Karataş et al., 2002; Bayramoğlu et al., 2001; Weissland et al., 2002). At 30°/s only three test repetitions were performed, in order to reduce the influence of fatigue. When the velocity was changed, the subject received a pause of 60 seconds (Tan et al., 1993; Ross et al., 1993). For each test, the starting position was the maximal extension position (Karataş et al., 2002). The subject was asked to move as fast as possible, and he was verbally encouraged during the test session to exert the maximal force.

Signal Processing and Data Analysis

The stored EMG data were full-wave rectified and smoothed with a root mean square (RMS) with a time window of 50ms. ECG reduction was performed with the Noraxon software. RMS values were calculated to quantify the amplitude of the EMG signals. Accordingly, the peak torque of each isokinetic test was registered.

For the MVIC, the RMS of the first three seconds of the maximal activity level of the isometric exercise was calculated for each trial. The analysis of the intraclass correlation coefficients (ICC) showed a good reliability (>0.7) between the different trials, consequently the average RMS of the different trials was calculated for each muscle side.

For the isokinetic testing, the mean RMS amplitude was calculated for each trial, over the period that the subject moved at the asked velocity. The ICC's were calculated to assess the reliability of the measurement between the different trials for each task. Since the ICC's showed a good correlation (>0.7) between the different trials, the average of the trials was calculated for each muscle at each velocity.

To provide a basis for EMG signal amplitude normalization for the isokinetic exercises, the MVIC's were used. A relative value was calculated by dividing the average RMS of the isokinetic phase by the respective average RMS of the MVIC. So for the extension movement the relative muscle activity were calculated for the LMF and the ICLT at respectively 30°/s (LMF_{30}, $ICLT_{30}$), 60°/s (LMF_{60}, $ICLT_{60}$), 90°/s (LMF_{90}, $ICLT_{90}$), 120°/s (LMF_{120}, $ICLT_{120}$). For the flexion movement the relative muscle activity were calculated for the IO and the EO at respectively 30°/s (IO_{30}, EO_{30}), 60°/s (IO_{60}, EO_{60}), 90°/s (OI_{90}, EO_{90}), 120°/s (IO_{120}, EO_{120}).

To emphasize the relationship between local segmental stabilizing muscles and global torque producing muscles, the relative activity was expressed as ratios (Van Dieën et al., 2003a,b; Marshall and Murphy, 2005; Stevens et al., 2006) of local to global muscle activity. For the extension phase of the isokinetic flexion-extension exercises the ratio LMF/ICLT was analysed, for the movement into flexion the ratio IO/EO was analysed.

Statistical analysis

Statistical analysis was performed using SPSS 18.0 software package for Windows. The level for statistical significance was set at 0.05. First a General Linear Model (GLM) for repeated measures was conducted on the relative muscle activity of each of the four muscles to analyse the effect velocity and side (within factors). Age and gender were set as between factors. Side did not show any significant effect, so for the further analysis the average of the right and left muscle side was used. Then a General Linear Model (GLM) for repeated measures was conducted to analyse the effect of the different factors on the global to local muscle ratios described above and on the peak torque. Velocity was set as within factor. Gender and age were set as between factors. These variables with significant interaction were subject to post-hoc Least Significant Difference test (LSD) with Bonferonni adjustments.

RESULTS

The relative muscle activity

The relative muscle activity of both the LMF and the ICLT (Fig. 2) are significantly lower for the highest velocity, 120°/s. LMF_{120} is significantly lower than LMF_{30} (p=.008) and LMF_{90} (p=.005). $ICLT_{120}$ is significantly lower than $ICLT_{30,60,90}$ (p<0.001). $ICLT_{60}$ is significantly lower than $ICLT_{30}$ (p=0.009). Statistics show no significant difference of the relative muscle activity of the IO and EO (Fig. 3) between the 4 velocities. Gender and age do not significantly affect the relative muscle activity of the back muscles or the abdominal muscles.

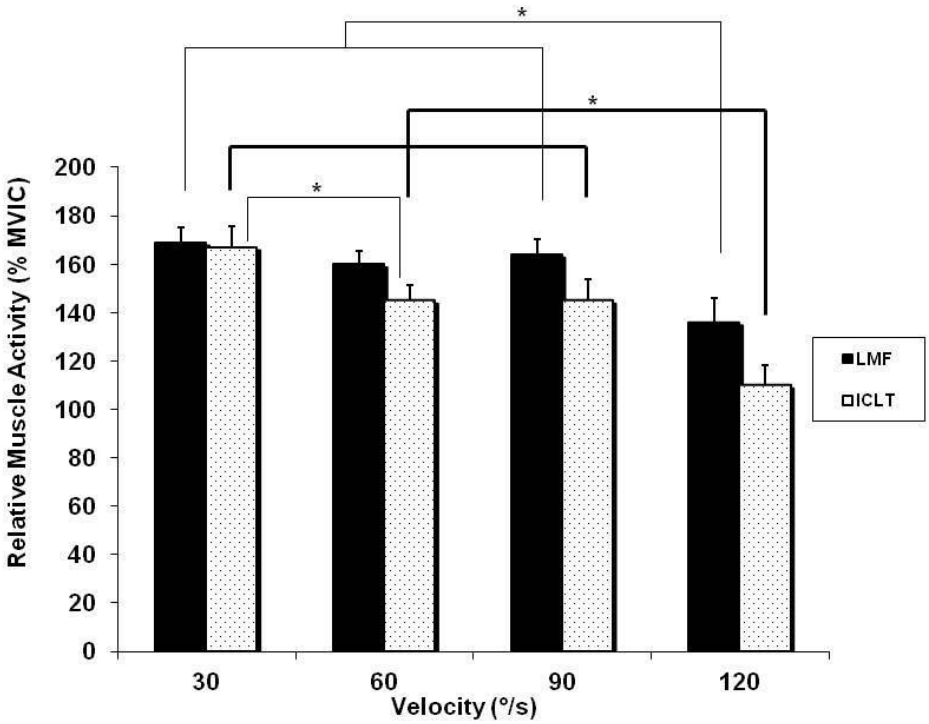

Fig. 2 Mean relative muscle activity of the back muscles during isokinetic extension exercises at four different velocities (*p<0.05).

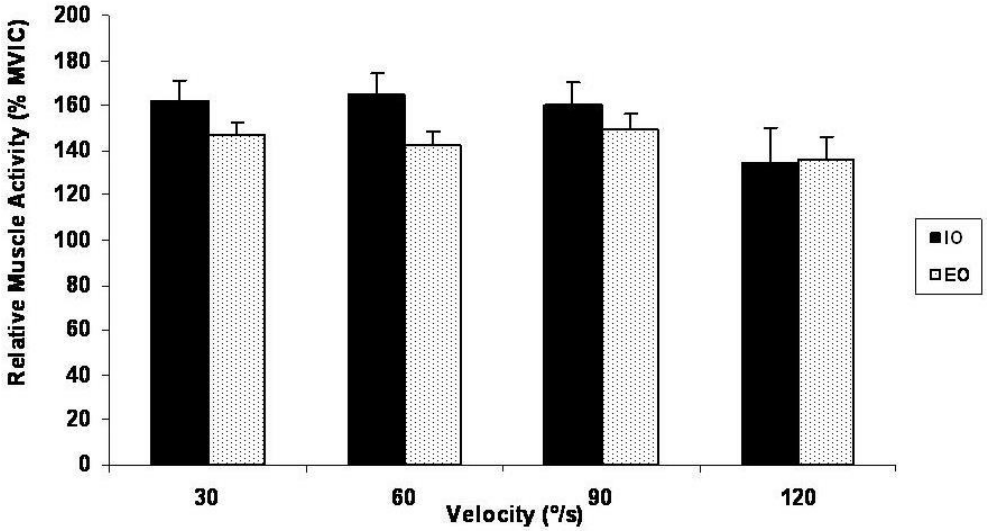

Fig. 3 Mean relative muscle activity of the abdominal muscles during isokinetic flexion exercises at four different velocities (*p<0.05).

The local to global muscle ratios

Statistics show a significant effect of velocity (p=0.012) on the back muscle ratios. The ratio LMF/ICLT during extension is significant lower for the velocities 30°/s and 90°/s, compared to the ratio at 120°/s (p≤0.027) (Fig. 4). This is independent from the age and the gender of the subject. The velocity has no significant impact on the ratio of the abdominal muscles during the flexion movement on the Cybex dynamometer.

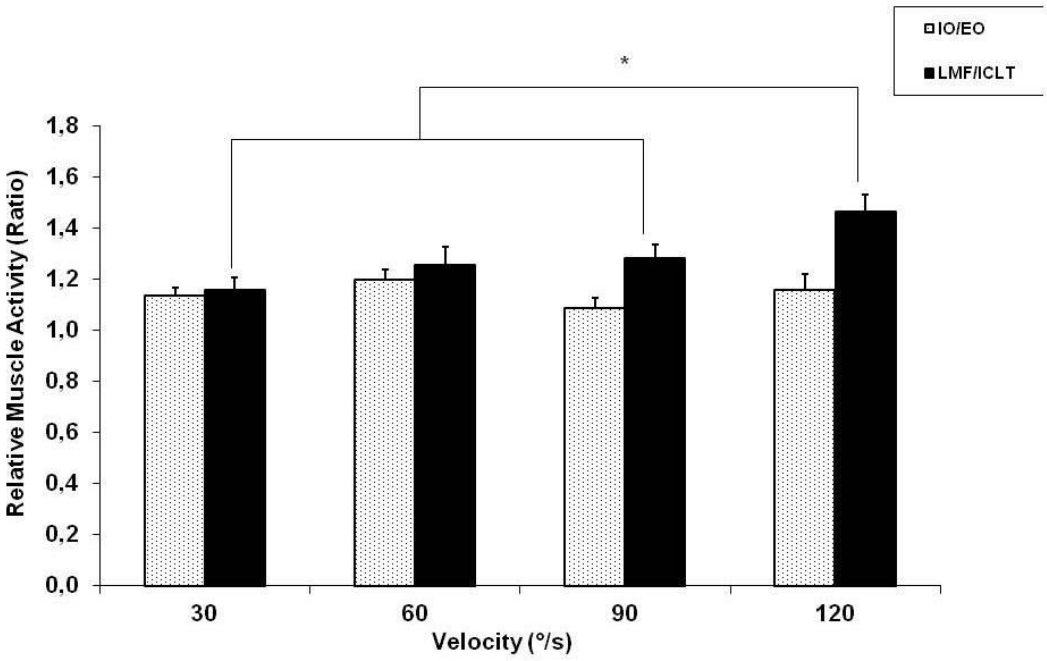

Fig. 4 Differences in back and abdominal muscle ratio at four different velocities during flexion and extension (*p<0.05).

Also gender (Fig. 5) is significant (p=0.016) for the ratio of the back muscles. Independent of the age of the subjects and the velocity of the isokinetic exercise, the ratio LMF/ICLT is significantly higher for the men (p<0.001), in comparison to the women. The ratio IO/EO is higher for the women, in comparison to the men. However, for this last statement the level of significance was not achieved.

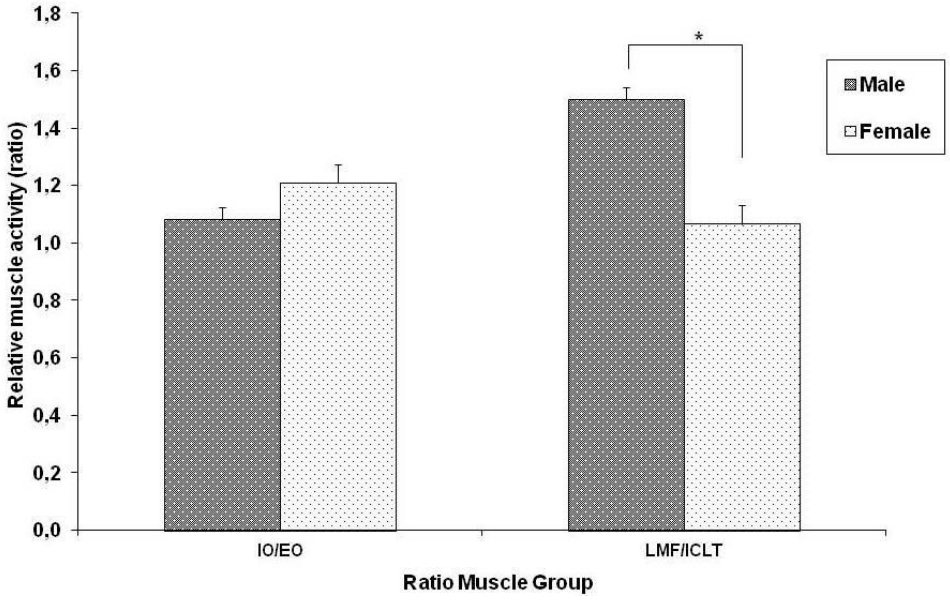

Fig. 5 Mean local to global muscle ratios for male and female subjects for back and abdominal muscles (*p<0.05).

The peak torque

Statistics show a significant interaction *Velocity*Gender* (p<0.05) on the peak torque value. Figs. 6 and 7 illustrates the peak torque in Newton-meters (N m) at the different velocities, for both flexion and extension in male and female subjects. The peak torque of the females is significantly lower (p<0.001) than those of the males at all velocities for both flexion and extension. For male and female subjects, the peak torque for both flexion and extension is decreasing with ascending velocities, but not all values are significantly different. In male subjects the peak torque at 120°/s is significantly lower than at 30°/s and 60°/s (p≤0.01) for flexion. At 30°/s the peak torque is significantly higher than at 60°/s, 90°/s and 120°/s (p<0.001) in extension. In females the peak torque at 120°/s is significantly lower than at 30°/s, 60°/s and 90°/s (p<0.001) in flexion and at 30°/s it is significantly higher than 60°/s, 90°/s and 120°/s (p<0.001) in extension.

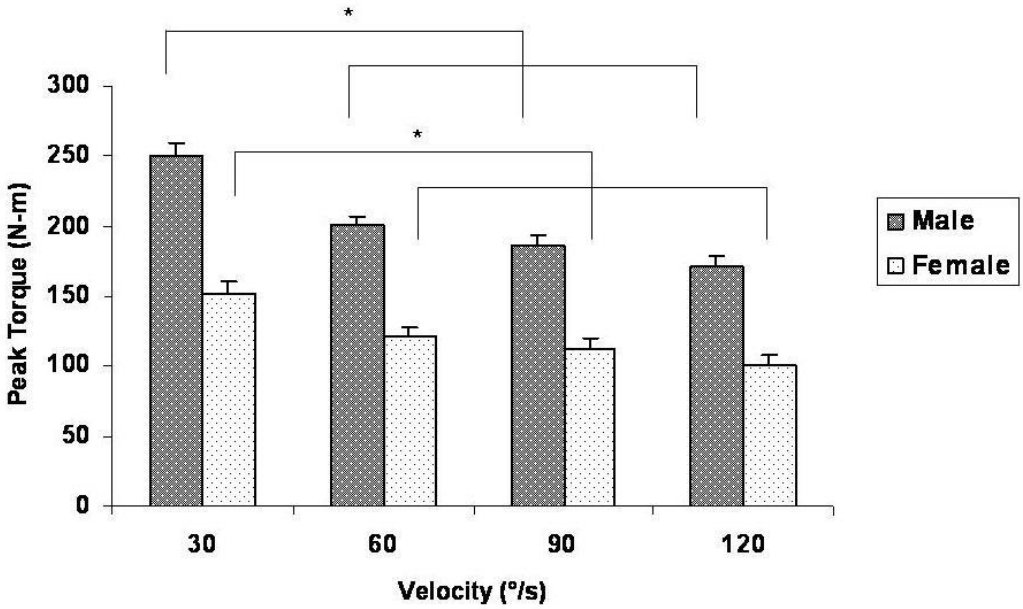

Fig. 6 Peak torque (N-m) at four different velocities in extension exercises for male and female subjects (*p<0.05)..

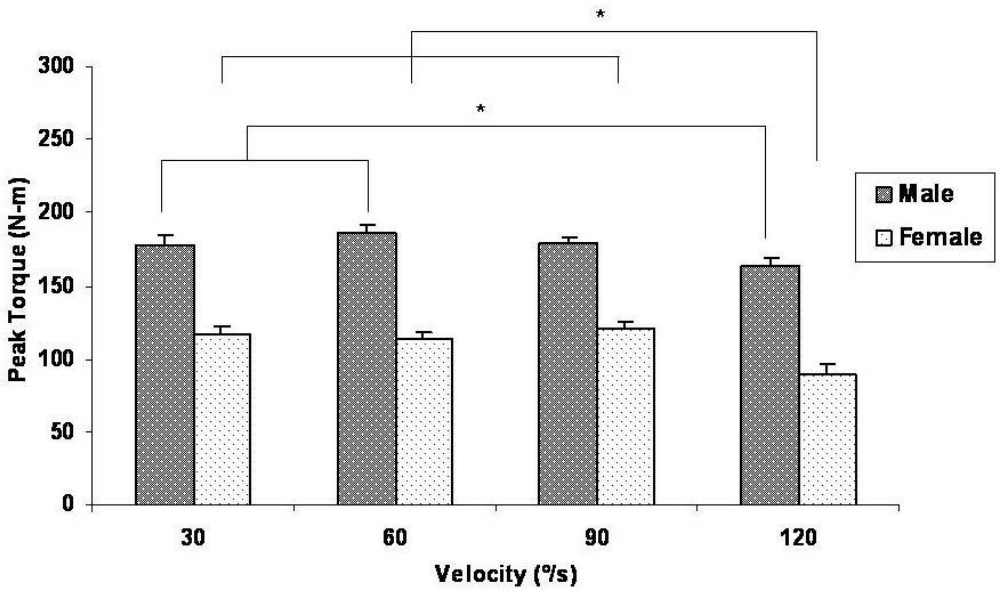

Fig. 7 Peak torque (N-m) at four different velocities in flexion exercises for male and female subjects (*p<0.05).

DISCUSSION

The present study investigated the influence of velocity on both the relative muscle activity and the ratio local to global muscle activity of the back and abdominal muscles. Interaction with gender and age was studied. Accordingly, peak torque was analysed.

While testing at different velocities it may be preferable to randomize the sequence of the velocities, in order to diminish undesirable effects (i.e. learning effect, fatigue …) on the study outcome. In this study, standardization of the sequence was chosen for practical reasons inter alia. 60°/s was set as first velocity, because the total ROM was 60° and this seemed most optimal to fully familiarize with the test. Pilot testing showed that 30°/s was too difficult as first exercise. 90°/s and 120°/s was set at the end, because less force is needed and fatigue - although expected to be minimal - due to the other trials will have less influence on these trials. In addition, Brown (2000) reported contradictory statements about the influence of the sequence of the velocities on peak torque. Fatigue seems to be an important factor, so the number of repetitions and the number and duration of the pauses could be more important.

Influence of velocity on extension movements

The peak torque gradually decreases with increasing velocity. This is in accordance with the finding that with increasing velocity, the relative EMG activity level of the back extensor muscles decreases. However, the decrease in LMF activity along with increased velocity is less pronounced than in the ICLT. This results in a significant higher LMF to ICLT ratio at higher velocities. Adding the analysis of the ratio of local to global muscle activity, highlights the difference between both extensor muscle groups; solitary analysis of the individual activity levels would have missed this important difference in recruitment pattern.

There is considerable evidence for the important role played by the LMF in segmental stabilization (Danneels et al., 2001, 2002). Biomechanical studies have highlighted the role of the LMF muscle in provision of segmental stiffness, control of the spinal neutral zone and its capacity to stabilize the spine when spinal stability is challenged (Van et al., 2006). The LMF has a unique architectural design to function as a dynamic stabilizer of the human spine: very short fibre length, large physiological cross-sectional area and specialized sarcomere length operating range (Ward et al.,

2009a,b). This could explain why this muscle is less sensitive to changes when the task is modified. Segmental stabilization is always needed, independent of the task.

The activity of the ICLT is more influenced in function of the task. ICLT is considered as a torque-producing muscle, with a general trunk stabilizing function (Danneels et al., 2001, 2002). In contrast to a higher presence of slow-twitch fibres in the local muscle system, the amount of fast-twitch fibres is higher in global muscle systems (Akuthota et al., 2008). During lighter load there is a preferential recruitment of fast-twitch motor units (Newton et al., 1997). With heavier loads the movement is slower and requires greater force production with longer duration of activation, thus a greater proportion of the motor unit pool is recruited with the use of both fast- and slow-twitch motor units as suggested in the study of Robert Newton et al.. (1997). Force capability of a muscle in concentric actions decreases with increasing velocity of shortening (Van et al., 2006). The findings of this study are in accordance to the theories described above, but according Mac Donald et al. (2006) the theory about the distribution of slow and fast twitch fibres requires further evaluation.

Influence of velocity on flexion movements

This current study demonstrates that the PT during flexion movements is also affected by the velocity of the isokinetic exercises. In flexion, PT_{120} is significantly lower for both female and male subjects compare to all other velocities. However, the abdominal muscle activity does not change in the same way as the back muscle activity with different velocities. The EMG activity of the IO and EO demonstrate no significant changes in function of the velocities. Consequently, no significant differences are found in the abdominal local to global muscle ratio.

In contrast to the ICLT, the EO has been shown to fulfil an important role in the stability of the lumbar spine. Together with the IO and the Transversus Abdominis (TrA), the EO increases the intra-abdominal pressure via the thoracolumbar fascia, thus imparting functional stability of the lumbar spine (Akuthota and Nadler, 2004). McGill (1996) suggest that the EO plays a role in controlling spinal flexion and extension. The EO has a torque producing role in rotation of the trunk (Creswell et al., 1994), but his role as a torque producing muscle during flexion movements is not clear. It could be hypothesized that the EO is not a torque producing muscle during flexion on the Cybex device, but that the changes observed in $PT_{flexion}$ are generated by the RA. Nevertheless, McGill (1996) indicates

that the contribution of the obliques to flexion may be underestimated and that these muscles may play a greater role in flexion than previously suggested.

Cordo et al. (2003) analyzed the patterns of muscle activity during the sit-up movement. They found that the RA and the EO reach their peak relative EMG activity in the same phase of the movement, during the lower-trunk curling, suggesting EO and RA are both torque producing muscles during the flexion movement. But EO is activated at 40-50% of the MVIC, while RA is working at 80% of the MVIC. So it is not clear if the EO acts as a stabilizer or as a torque producing muscle. Secondly, this study concerns an exercise in lying position, against gravity force, while the tests on the Cybex device are performed in a standing position. The main role of the different muscles may vary in function of the influence of gravity forces. A study of Vezina et al. (2000) supports the stabilizing role of the EO. During different dynamic stability exercises higher activation of the EO was shown compared to the activation of RA, erector spinae and LMF. Creswell et al. (1992) suggest that the coordinative patterns between the muscles of the ventrolateral wall are task specific and based on the demands of movement, torque and stabilisation. Further analysis of the IO/RA during flexion on the Cybex device might clarify this.

The influence of different velocities on abdominal muscle activity has not yet been described, but research on the effect of stable versus unstable surfaces during different exercises showed similar outcome for the abdominal muscle activity levels. Marshall and Murphy (2005) demonstrated that the EO activity was unaffected by the task performed and that the ratio of TrA and IO to the RA activity did not change between different surfaces.

The role of Gender and Age

Results reveal an important role of gender, but no influence of age is observed in this study.

The evaluation of the peak torque demonstrates they are significantly higher in males than in females. In contrast, analysis of the relative individual muscle activity levels shows no influence of gender. However, the evaluation of the ratios of local to global muscle activity demonstrates also the importance of gender. The gender difference in peak torque is unaffected by the movement direction or velocity. The peak torque is higher for male subjects than female subjects for both muscle groups and at the 4 velocities. Epidemiological research indicates that females suffer twice the risks of occupationally related musculoskeletal and low-back injuries (Granata et al., 2001; Granata and

Wilson, 2001). There is consistent evidence that both for healthy subjects and patients with LBP, males show higher performance on all strength measures than females (Newton and Wadell, 1993). Gender differences in passive joint stiffness have also been established and recent measurements indicate gender differences in muscle-controlled active joint stiffness. To compensate for reduced active muscle stiffness, it is hypothesized that females may perform lifting tasks with greater co-activation to augment trunk stiffness and stability (Granata et al., 2001; Granata and Wilson, 2001).

However, the evaluation of the ratios of local to global muscle activity marks a difference in gender influence according to the movement direction: a higher local to global back muscle activity ratio is shown in males than females, but the local to global abdominal muscle activity ratio is higher in females than in males. However, for this last statement the level of significance was not achieved. Males have been shown to demonstrate significantly greater LMF cross-sectional area than females (Stokes, 2005; Hides et al., 2008). Thickness changes in the muscle during activation correlate well with EMG activity of the muscle (Mannion et al., 2008). In contrast, no differences have been described for the ICLT.

Concerning the difference in back muscle activity ratio to abdominal muscle activity ratio, research demonstrated that the TrA in women represent a greater proportion of the total lateral abdominal muscles (Springer et al., 2006). This may explain why the ratio IO/EO is higher in women than in men. In flexed postures, female subjects recruit greater activity than males in the ES and the EO and recruit lower activity from the RA and IO muscles than males (Granata et al., 2001; Granata and Wilson, 2001). Arokoski et al. (2001) suggest that women activate better their stabilizing trunk muscles than men. As suggested by Granata et al. (2001), control of LBP may require gender specific preventative measures and more intensive research efforts focusing on gender specific biomechanical factors in musculoskeletal injury.

Relative Muscle Activity and MVICs

The relative muscle activity levels reached more than 100% of the MVICs at all velocities. Such high relative activity levels may suggest inadequate MVICs. However, most of the studies evaluating exercises on devices use MVICs performed on these devices for the amplitude normalization of the EMG (Stevens et al., 2008; San Juan et al., 2005; Udermann et al., 1999). In a study of Stevens et al. (2008) manually resisted maximal exertions were compared to resisted maximal exertions on a

Tergumed device. In general, no significant differences were found between manually resisted and device resisted MVIC's; for two muscles, the device resisted MVICs were even significantly higher than the manually resisted MVICs. However, we acknowledge that performing a similar study on the Cybex device would have been useful. Though isometric exercises are often used to normalize dynamic movements (Cholewicki et al., 1997; Gallagher, 1997; Udermann et al., 1999; Walsworth, 2004), length-force properties may have caused high relative activity levels. Analysis of EMG signals over the full ROM may ignore the differences in EMG-force relationships and this could be regarded as a limitation of the present study. However, other procedures often fail to maintain the dynamic character of the exercises.

Clinical implications

The greater values in ratio LMF/ICLT by higher velocity during isokinetic extension, as described in this study, may have an impact on training programs. If the aim of the training is to improve back muscle activity in general, lower velocities can be used, because LMF as well as ICLT demonstrates significantly higher relative muscle activity levels. If the aim of the treatment is to improve the muscle recruitment patterns, for example to improve the activity of the LMF more than the ICLT, training is needed at higher velocities, such as 120°/s. In contrast, the ratio IO/EO is not affected by the different velocities. And the relative muscle activity of the IO and the EO is not significantly affected by the changes in velocity. Further exploration could be useful to analyse the EMG activity of the RA, a torque producing muscle for flexion, and the ratio IO/RA. For athletes it is certainly useful to choose the velocity in function of the exerted sports discipline. The gender differences in back and abdominal muscle activity ratios emphasize the need to interpret muscle recruitment patterns of males and females differently in isokinetic tests. Further research is needed to establish norm data.

CONCLUSION

It is well established that specific training is important in patients with LBP in function of the needs. Isokinetic devices are frequently used in the assessment and rehabilitation of low back pain patients. This study reveals that the velocity of isokinetic extension exercises influences the use of the back muscles. No impact has been demonstrated for the abdominal muscles and further exploration is

needed. Training programs on Cybex devices should be adapted in function of the focus of the therapy and further exploration of the gender differences is needed.

These conclusions are made for controlled flexion-extension exercises in standing position with the lower limbs fixed. Similar results may be present in daily life activities at high velocities and in exercises without the need of devices.

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CHAPTER 2

A surface electromyography based objective method to identify patients with nonspecific chronic low back pain, presenting a flexion related movement control impairment.

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ABSTRACT

Movement control impairments (MCI) are often present in patients with non-specific chronic low back pain (NS-CLBP). Therefore, movement control exercises are widely used to rehabilitate patients. However, the objective assessment remains difficult.

The purpose of this study was to develop a statistical model, based on logistic regression analysis, to differentiate patients with NS-CLBP presenting a flexion-related MCI from healthy subjects. This model is based on trunk muscle activation patterns measured by surface electromyography (sEMG), during movement control exercises.

Sixty-three healthy male subjects and 36 male patients with a flexion-related MCI participated in this study. Muscle activity of the internal obliques, the external obliques, the lumbar multifidus and the thoracic part of the iliocostalis was registered. Ratios of deep stabilizing to superficial torque producing muscle activity were calculated to examine trunk muscle recruitment patterns during 6 different exercises. Logistic regression analyses were performed (1) to define the ratios and exercises that were most discriminating between patients and non-patients, (2) to make a predictive model. K-Fold cross-validation was used to assess the performance of the predictive model.

This study demonstrated that sEMG trunk muscle recruitment patterns during movement control tests, allows differentiating NSCLBP patients with a flexion-related MCI from healthy subjects.

***Keywords**:* Electromyography, Trunk muscle activity, Ratios, Movement Control Impairment, Flexion

INTRODUCTION

Maladaptive movements can provide a basis for ongoing peripherally driven nociception sensitization leading to a chronic pain state in mechanical low back pain (LBP) [O'Sullivan, 2005; Sahrmann, 2002; Comerford & Mottram, 2001; Mottram & Comerford, 2008]. These movement control impairments (MCI) are often described as a painful loss or impairment of normal physiological movement in one or more directions (lumbar flexion, lumbar extension or lumbar rotation) or in a combination of these movement directions [O'Sullivan, 2005; Van Dillen et al, 2003; Mottram & Comerford, 2008]. MCI is estimated to appear in 30% of patients with LBP [O'Sullivan, 2005] and flexion-related MCIs are the most common disorders observed in clinical practice [O'Sullivan, 2000].

Different movement control tests and standardized examinations, based on the clinician' subjective inspection of the patient movement, have been reported and allow to classify patients with MCI in different subcategories related to the direction of their MCI [Van Dillen et al, 1998; Dankaerts et al, 2006b; Van Dillen et al, 2003; Mottram & Comerford, 2008]. These tests are also able to differentiate between patients with non-specific chronic low back pain (NS-CLBP) and healthy subjects [Luomajoki et al, 2008]. Although several of these tests have been proven reliable [Dankaerts et al, 2006b; Luomajoki et al, 2010; Van Dillen et al, 2003], the scoring is very subjective. Objective golden standards to assess MCI are lacking.

There is strong evidence linking motor control deficiency with inefficient deep stabilizing muscle groups [Hodges & Moseley, 2003; Jull, 2000; Richardson et al, 2004; Silfies et al, 2005]. More generally, many authors suggest that there is a link between pain being provoked by a particular direction of movement and deficiency in the muscles that have to control that movement [Comerford & Mottram, 2001; Dankaerts et al, 2006a; O'Sullivan, 2005; Sahrmann, 2002]. However, research using electromyography (EMG) activation patterns to evaluate altered control strategies leads to contradictory findings [Danneels et al, 2002; Van Dieën et al, 2003]. Surface EMG (sEMG) measurement of different trunk muscles during specific movement control exercises might be a way to objectify differences between patients and healthy subjects and to explain the MCI present in patients with NS-CLBP.

Furthermore, in patients with NS-CLBP with MCI, treatment with movement control exercises results in a significant decrease in functional disability [Luomajoki et al, 2010; Saner et al, 2011] and suggests that altered muscle recruitment strategies are reversible [O'Sullivan, 2005]. These

rehabilitation programs would certainly benefit from an objective measure to identify trunk muscle recruitment patterns; moreover, it would be valuable to obtain an objective tool to objectify changes after therapy.

The aim of this study was a first step in the development of a statistical method, to differentiate patients with NS-CLBP with a MCI diagnosis (flexion-related MCI) from healthy subjects, based on trunk muscle recruitment patterns measured by sEMG during a battery of movement control tests, This method should enable to detect patients in a reliable and objective way.

MATERIALS AND METHODS

Subjects

Medical doctors specialized in rehabilitation and sports medicine screened 116 male patients with NS-CLBP at the Military Hospital Queen Astrid (Brussels, Belgium) in the period of January to September 2013. Patients were eligible for the study according to the following inclusion criteria: age of less than 65 years and NS-CLBP with a history of more than three pain episodes during the past year or pain persisting for at least three months. NS-CLBP included local LBP, or radiating pain, but without neurological findings [muscle weakness, loss of sensibility or reflexes]. Patients under the age of 18, female patients, patients with a BMI >33, patients with previous spinal surgery or spinal fractures, patients with nerve root entrapment with neurological deficit and patients with specific LBP diseases were excluded from this study. All patients were employees of the Belgian Defence [military and civilian personnel]. After screening for yellow flags with the Orebro Musculoskeletal Pain Questionnaire (OMPQ) [Linton & Boersma, 2003], 13 patients were excluded from the study. Eighteen patients did not complete the self-reporting screening questionnaires and were also excluded. Five patients stopped therapy at the military hospital [changed work location, mission abroad, lack of motivation], and 12 patients did not perform the clinical assessment in the time frame of this study. For the 69 remaining patients, further standardized clinical assessment was done by a physiotherapist trained and experienced in the concept of kinetic control [Comerford & Mottram, 2001; Sahrmann, 2002] to assess MCI in these patients. The testing based on the Kinetic Control principles is very similar to the method used by O'Sullivan [2005], but offers a more structured evaluation model. Table 1 presents an overview of the main features related to the possible MCIs. Combinations of flexion,

extension and rotation MCIs are possible and are referred to as flexion-rotation, extension-rotation or multidirectional MCIs. However, a malperformance on certain series of tests indicates a specific or multidirectional MCI.

Thirty-six male patients with flexion related MCI (flexion, flexion-rotation or multidirectional MCI with a dominant flexion pattern) accepted to participate in this study. Sixty-three healthy male subjects were recruited in the same setting to participate voluntarily in this study. Criteria to be selected as a healthy subject were: male sex, aged between 18 and 65 years old and never having had a medical or paramedical consult for LBP. People with known neurological or other important disorders and a BMI >33 were excluded.

Finally, 36 male patients with NS-CLBP and a flexion related MCI and 63 healthy men agreed to be included in the study. This study was approved by the local Ethical Committee.

Table 1 Main features in patients with a lumbar flexion, extension or rotation related motor control impairment based on the concept of Kinetic Control

	Main features for flexion-related MCI	Main features for extension-related MCI	Main features for rotation-related MCI
History	Work, leisure, … inducing many flexion related positions/activity	Work, leisure, … inducing many extension related positions/activity	Work, leisure, … inducing many rotation related positions/activity
	Flexion related symptoms in the lumbar spine	Extension related symptoms in the lumbar spine	Rotation related symptoms in the lumbar spine
	Flexion related disability	Extension related disability	Rotation related disability
Inspection of natural movement	Excessive ROM to flexion at the site of patient's symptoms The lumbar spine has greater give into flexion relative to the hips or thoracic spine under flexion load Abnormal initiation of flexion at the site of patient's symptoms	Excessive ROM to extension at the site of patient's symptoms The lumbar spine has greater give into extension relative to the hips or thoracic spine under extension load Abnormal initiation of extension at the site of patient's symptoms	Excessive ROM to rotation at the site of patient's symptoms The lumbar spine has greater give into rotation relative to the hips or thoracic spine under rotation load Abnormal initiation of rotation at the site of patient's symptoms
Inspection of habitual position	Observation of a flexed standing position	Observation of a hyper extended standing position	
	Observation of a slumped sitting position	Observation of a hyper extended sitting position	
Dissociation tests[4] (control of direction)	*Give[1] to flexion during the following exercises:*	*Give[1] to extension during the following exercises:*	*Give[1] to rotation during the following exercises:*
	Forward bending in standing position	Backward bending in standing position	Single heel slide in crook lying
	Standing bow test	Thoracic extension in standing position	Bent knee fall out in crook lying
	Backward rocking in 4 point kneeling	Thoracic extension in sitting position	Top leg turn out in side lying
	Sitting bow test	Hip extension with knee extended in prone position	Single leg hip rotation in prone lying
	Double bent leg lift (bilateral) in crook lying	Supine double leg lowering in crook lying	Unilateral knee extension in sitting with a straight back
	Thoracic flexion in sitting	Sitting bow test	Hip extension with knee extended in prone lying
	Bilateral knee extension with a straight back in sitting position	Double knee bend in prone position	Single knee flexion with hip extension in prone lying
	Ischial weight-bearing (straight back) from stand to sit	Hip extension with knee extended in standing	Single leg extension in bridging position
	Hip flexion in sitting position	Bilateral arm elevation in sitting position	Knees swing in standing (with small knee bend)
			Thoracic rotation in standing

	Trunk side bend in standing
	Pelvic side shift in standing
	Hip flexion in sitting position
	Unilateral arm elevation in sitting position

[1] The give is related to the patients complaints or provokes the symptoms and can be a segmental hinge[2]or a multisegemental give[3].

[1] During the attempt to dissociate the lumbar spine from independent hip or thoracic movements, the subject either cannot control the give or has to concentrate too hard

[2] A hinge is observed as an excessive translation shear during motion testing or a pivot point

[3] A multisegmental give is a hypermobile range to flexion or an exaggeration of the spinal curve

[4] These tests are described by Comerford M 1996 Dynamic Stability and Muscle Balance of the Lumbar Spine and trunk. Course notes. Copyright Kinetic Control.

Experimental Procedure

In all participants, weight and height were measured and the activity level was questioned by the number of hours of sport activities per week, to ensure that no significant differences were found between the healthy population and the patients with NS-CLBP.

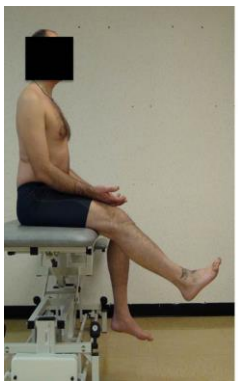
All subjects performed 6 movement control tests (concept of dissociation) [Comerford & Mottram, 2001; Mottram & Comerford, 2008]. They were asked to maintain the neutral position of the lumbar spine while performing movements with the arms, legs or trunk. The neutral position of the lumbar spine is a relative region within the mid-range (Panjabi's 'neutral zone'), where there is minimal support or restraint from the passive structures. The neutral position of the lumbar spine was set about halfway between full extension and a flat spine in the sitting position [Danneels et al., 2002; Stevens et al., 2008]; in standing position, the anterior and posterior iliac spines were in line [Richardson et al., 2004]. The subject was asked to maintain this position with minimal effort. Each movement comprised three phases of 3 seconds (rhythm indicated by a metronome): a pre-phase (movement to the end position), a static phase (holding the end-position) and a post-phase (movement back to starting position). The quality of the lumbar lordosis was visual inspected by the physiotherapist during the whole movement. After consensus with experts, the following movement control tests were chosen:

- Seated uni- and bilateral knee extension (Figure 1) (Exercise 1 (Ex1)): The subject was sitting on a table with both feet off the floor and was instructed to straighten the knees to within 10° of full extension, keeping the spine in neutral position. This test was performed two times with each leg separately, and two times with both legs together. The hands were placed on the thighs with the palms turned upwards, to avoid balance assistance through the upper extremities.
- Standing unilateral hip extension with extended knee (Figure 2) (Exercise 2 (Ex2)): The subject was standing with the lumbo-pelvic region in neutral position and was asked to extend the hip till 15° of extension, maintaining the foot in contact with the floor. The subject performed this exercise two times with each leg separately.
- Seated uni- and bilateral shoulder flexion with extended elbow (Figure 3) (Exercise 3 (Ex3)): The subject was sitting with the spine and pelvis in neutral alignment, the acromion vertically positioned

over the greater trochanter. The feet were supported with the hips in 80° of flexion. The subject was asked to elevate his arm to maximal shoulder flexion, maintaining the spine in a neutral position.

- Seated hip flexion (Figure 4) (Exercise 4 (Ex4)): The subject was sitting with the spine and pelvis in neutral alignment. The feet were supported on the ground with the hips in 80° of flexion. The subject was asked to flex one hip till the foot was 10.5 cm off the ground. The arms could not be used for support and were positioned alongside the trunk. This exercise was done twice for each hip separately.
- The sitting and standing bow test (Figure 5) (Exercises 5 and 6 (Ex5 and Ex6)): The subject, in sitting position, was instructed to lean forward from the hips to 30° of flexion, keeping the spine in neutral position. This exercise was done 2 times, while keeping the arms alongside the trunk. Then, the subject, in standing position, was instructed to bend forward from the hips to 45° of flexion, keeping the back in a neutral position. This exercise was also done twice, while keeping the arms alongside the trunk.

In sitting, the neutral spine position was determined as the position halfway between full extension and a flat position of the lumbar spine; in standing, a horizontal alignment between the anterior superior iliac spine and the posterior superior iliac spine was the reference [Danneels et al, 2002; Stevens et al, 2006a]. In addition, the acromion was positioned vertically to the greater trochanter.



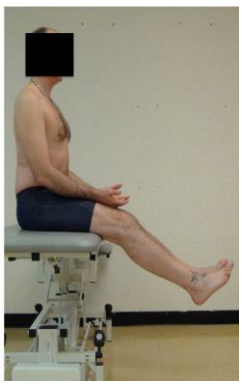


Figure 1 (Ex1): Seated uni- and bilateral knee extension

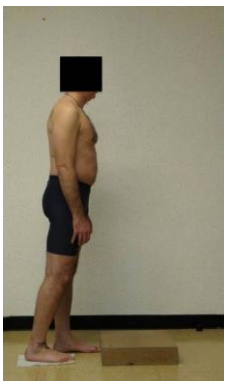


Figure 2 (Ex 2): Standing unilateral hip extension with extended knee

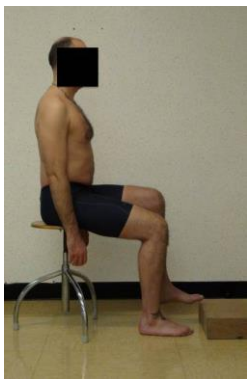


Figure 4 (Ex 4): Seated unilateral hip flexion

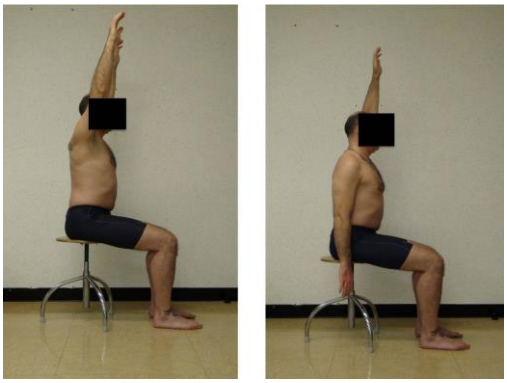


Figure 3 (Ex 3):

Seated uni- and bilateral shoulder flexion with extended elbow

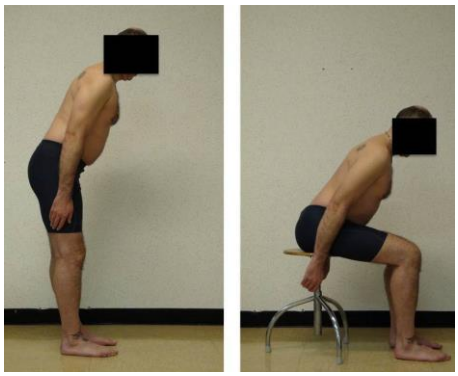


Figure 5 (Ex 5 and 6):

The sitting and standing bow test

The subjects also performed 2 submaximal isometric contractions of 5 seconds, to have a base sEMG activity for normalization of the data. An isometric submaximal contraction of the abdominal muscles was performed in a straight-knee sitting position with 45° of hip flexion while the trunk was unsupported and the thighs were fixed to the table. An isometric submaximal contraction of the back muscles was performed in prone lying, with the pelvis and ankles fixed on the table. The subject had to hold a horizontal position of the trunk, while this was unsupported and the arms were crossed in front of the chest.

Surface Electromyography

During the tests, sEMG was recorded. A TeleMyo 2400T G2 (Noraxon Inc, Scottsdale, U.S.A.) system was used. All raw EMG signals were band pass-filtered between 10 and 500 Hz and amplified. The collection rate was 1000 Hz and the common mode rejection ratio was greater than 110 dB. The signals were converted from an analogue voltage to a digital signal before being stored in a personal computer.

After appropriate skin preparation [Hermens et al, 2000; Danneels et al, 2001], 8 pairs of circular Ag/AgCl sensor surface electrodes (Ambu® Blue Sensor M, Ambu A/S, Ballerup, DK) were placed parallel to the muscle fibres [Ng et al, 1998], bilaterally, of deep stabilizing and superficial torque producing abdominal and back muscle as follows: The inferior fibres of the internal obliques (IO) (midway between the anterior iliac spine and the symphysis pubis, above the inguinal ligament) [Stevens et al, 2008], the external obliques (EO) (just below the rib cage, on the line between the

most inferior point of the costal margin and the contra-lateral pubic tubercle) [Ng et al, 1998], the lumbar part of the multifidus (LMF) (lateral to the midline of the body, above and below a line connecting both posterior superior iliac spines) [Danneels et al, 2002; Stevens et al, 2008], and the thoracic part of the iliocostalis lumborum (ICLT) (above and below the L1 level, midway between the midline and the lateral aspect of the body) [Danneels al, 2002; Stevens et al, 2008].

Signal Processing and Data Analysis

The stored EMG data were full-wave rectified and smoothed with a root mean square (RMS) (time window = 100ms). Electrocardiogram reduction was performed with the Noraxon software. RMS values were calculated to quantify the amplitude of the EMG signals.

For the submaximal voluntary contraction, the RMS of the first three seconds of the isometric exercise was calculated. The submaximal voluntary contraction value of the LMF and ICLT was obtained during the isometric submaximal back muscle contraction exercise; the IO and EO submaximal level was achieved during the isometric submaximal abdominal contraction exercise.

For the movement control tests, the mean RMS amplitude of each muscle was calculated for each trial, over the pre-phase of the trial. The average RMS of the two trials was calculated for each task, for each muscle, for each side separately.

Normalization of trunk flexor and extensor muscle activity was completed using submaximal isometric contractions [Silfies et al, 2005]. A relative value was calculated by dividing the average RMS of the movement control exercises by the respective average RMS during the submaximal contraction.

To emphasize trunk muscle recruitment patterns, the relative activity was expressed as ratios of deep stabilizing muscle activity to superficial torque producing muscle activity (IO/EO; LMF/ICLT) [Van Dieën et al, 2003; Marshall & Murphy, 2005; Stevens et al, 2006a; Van Damme et al, 2012]. Left and right muscle groups were analysed separately (Table 2a and Table 2b).

Table 2a Presentation of the logarithmic transformed (Log10) ratios (based on the Root Mean Squared values measured by sEMG) of deep stabilizing muscle groups to the superficial torque producing muscle groups during several motor control exercises in healthy subjects . Left and right muscle groups are presented separetaly.

	Healthy subjects			
	IO/EO(Left)	IO/EO(Right)	LMF/ICLT(Left)	LMF/ICLT(Right)
	Mean (min-max) ± SD	Mean (min-max) ± SD	Mean (min-max) ± SD	Mean (min-max) ± SD
Standing unilateral hip extension w ith extended knee (left leg)	0,1 (-0,8 - 1,0) ± 0,4	0,1 (-0,5 - 1,1) ± 0,4	0,0 (-0,5 - 0,4) ± 0,2	0,1 (-0,3 - 0,6) ± 0,2
Standing unilateral hip extension w ith extended knee (right leg)	0,1 (-0,6 - 1,2) ± 0,4	0,0 (-0,7 - 1,3) ± 0,4	0,2 (-0,2 - 0,5) ± 0,2	-0,1 (-0,6 - 0,3) ± 0,2
Sitting bow test	-0,3 (-0,9 - 1,7) ± 0,4	-0,2 (-0,8 - 1,0) ± 0,4	-0,1 (-0,9 - 0,5) ± 0,3	-0,1 (-0,7 - 0,4) ± 0,2
Standing bow test	0,0 (-1,0 - 1,1) ± 0,4	-0,1 (-0,7 - 1,1) ± 0,4	0,0 (-0,5 - 0,3) ± 0,2	-0,1 (-0,5 - 0,3) ± 0,2
Seated unilateral knee extension (left leg)	-0,1 (-0,7 - 1,4) ± 0,4	-0,2 (-0,8 - 0,8) ± 0,3	-0,1 (-0,9 - 0,6) ± 0,3	-0,2 (-0,7 - 0,5) ± 0,3
Seated unilateral knee extension (right leg)	-0,2 (-0,8 - 1,0) ± 0,3	-0,2 (-0,7 - 0,7) ± 0,3	-0,2 (-1,1 - 0,3) ± 0,3	-0,2 (-0,7 - 0,4) ± 0,3
Seated bilateral knee extension	-0,1 (-0,7 - 1,0) ± 0,4	-0,2 (-0,7 - 0,9) ± 0,3	-0,2 (-0,9 - 0,4) ± 0,3	-0,2 (-0,7 - 0,4) ± 0,3
Seated unilateral shoulder flexion w ith extended elbow (left arm)	-0,2 (-1,0 - 0,9) ± 0,4	-0,2 (-0,9 - 0,8) ± 0,4	-0,3 (-1,0 - 0,3) ± 0,3	-0,4 (-1,3 - 0,1) ± 0,3
Seated unilateral shoulder flexion w ith extended elbow (right arm)	-0,2 (-0,9 - 0,9) ± 0,4	-0,3 (-0,9 - 0,9) ± 0,4	-0,5 (-1,2 - 0,2) ± 0,3	-0,3 (-0,8 - 0,4) ± 0,3
Seated bilateral shoulder flexion w ith extended elbow	-0,2 (-1,1 - 0,9) ± 0,4	-0,3 (-1,0 - 0,7) ± 0,4	-0,4 (-1,1 - 0,3) ± 0,3	-0,3 (-0,9 - 0,2) ± 0,2
Seated unilateral hip flexion (left)	0,0 (-0,6 - 0,9) ± 0,3	0,0 (-0,8 - 1,0) ± 0,4	-0,1 (-0,5 - 0,6) ± 0,2	0,1 (-0,4 - 0,6) ± 0,2
Seated unilateral hip flexion (right)	0,0 (-0,6 - 1,1) ± 0,4	-0,1 (-0,5 - 0,9) ± 0,3	0,1 (-0,4 - 0,6) ± 0,2	-0,1 (-0,5 - 0,3) ± 0,2

IO= internal obliques; EO=external obliques; LMF=lumbar multifidus; ICLT=thoracic part of the iliocostalis lumborum

Table 2b Presentation of the logarithmic transformed (Log10) ratios (based on the Root Mean Squared values measured by sEMG) of deep stabilizing muscle groups to the superficial torque producing muscle groups during several motor control exercises in patients with NS-CLBP . Left and right muscle groups are presented separetaly.

	Patients			
	IO/EO(Left)	IO/EO(Right)	LMF/ICLT(Left)	LMF/ICLT(Right)
	Mean (min-max) ± SD	Mean (min-max) ± SD	Mean (min-max) ± SD	Mean (min-max) ± SD
Standing unilateral hip extension w ith extended knee (left leg)	0,0 (-0,9 - 1,3) ± 0,4	0,0 (-0,8 - 1,0) ± 0,4	0,1 (-0,4 - 1,3) ± 0,3	0,2 (-0,7 - 0,6) ± 0,2
Standing unilateral hip extension w ith extended knee (right leg)	0,0 (-0,7 - 1,4) ± 0,4	0,0 (-0,8 - 1,0) ± 0,4	0,2 (-0,2 - 1,5) ± 0,3	0,1 (-0,3 - 0,5) ± 0,2
Sitting bow test	-0,4 (-1,3 - 1,2) ± 0,5	-0,3 (-0,9 - 0,6) ± 0,3	-0,1 (-0,7 - 1,2) ± 0,4	-0,1 (-0,7 - 0,5) ± 0,3
Standing bow test	-0,3 (-1,2 - 1,2) ± 0,4	-0,2 (-1,0 - 0,8) ± 0,4	0,0 (-0,4 - 1,3) ± 0,3	-0,1 (-0,5 - 0,3) ± 0,2
Seated unilateral knee extension (left leg)	-0,2 (-0,9 - 1,2) ± 0,4	-0,2 (-0,7 - 0,8) ± 0,3	0,0 (-0,7 - 2,0) ± 0,5	0,1 (-1,2 - 2,1) ± 0,5
Seated unilateral knee extension (right leg)	-0,4 (-1,2 - 0,8) ± 0,4	-0,1 (-0,6 - 0,7) ± 0,3	-0,1 (-0,9 - 2,0) ± 0,5	0,0 (-1,1 - 2,1) ± 0,5
Seated bilateral knee extension	-0,3 (-1,1 - 1,1) ± 0,4	-0,1 (-0,6 - 0,9) ± 0,3	0,0 (-0,8 - 2,0) ± 0,5	0,1 (-1,1 - 2,1) ± 0,5
Seated unilateral shoulder flexion w ith extended elbow (left arm)	-0,5 (-1,5 - 1,0) ± 0,5	-0,3 (-0,8 - 0,4) ± 0,3	-0,3 (-1,5 - 0,8) ± 0,4	-0,4 (-1,1 - 0,5) ± 0,4
Seated unilateral shoulder flexion w ith extended elbow (right arm)	-0,5 (-1,5 - 1,1) ± 0,5	-0,4 (-0,9 - 0,3) ± 0,3	-0,4 (-1,2 - 0,7) ± 0,5	-0,4 (-1,2 - 0,3) ± 0,3
Seated bilateral shoulder flexion w ith extended elbow	-0,5 (-1,5 - 0,8) ± 0,4	-0,4 (-1,0 - 0,3) ± 0,3	-0,4 (-1,4 - 0,8) ± 0,4	-0,4 (-1,2 - 0,1) ± 0,3
Seated unilateral hip flexion (left)	-0,1 (-0,7 - 1,1) ± 0,4	-0,1 (-0,7 - 0,9) ± 0,3	0,0 (-1,0 - 1,6) ± 0,4	0,2 (-0,5 - 0,7) ± 0,3
Seated unilateral hip flexion (right)	-0,2 (-0,9 - 1,2) ± 0,4	0,0 (-0,4 - 0,7) ± 0,3	0,2 (-0,4 - 1,4) ± 0,3	0,0 (-0,6 - 0,5) ± 0,3

IO= internal obliques; EO=external obliques; LMF=lumbar multifidus; ICLT=thoracic part of the iliocostalis lumborum

Statistical analysis

SPSS version 22 was used. All data were logarithmic transformed (Log10), because they showed positive skewness.

Principal Component Analysis (PCA)

A PCA was done on the data of the healthy population, for each movement control exercise, to reduce the number of variables (correlation method, no rotation). Factors -principal components (PC)- were retained when $\lambda \geq 1$ or, if based on the scree plot, additional factors were justified. Afterwards, the retained factors were calculated for the data of the group of patients.

Defining a classifier based on logistic regression analysis

A logistic regression classifier was built to estimate the probability for each subject to be patient or not. The factors retained in the PCA were set as independent variables.

A logistic regression model was used twice:

- During phase 1: A Forward Wald logistic regression analysis (FWD-Wald method) was used, in which the predictor variables (factors used in the classifier) were selected based upon the Wald statistics (F-to-enter: 0.05; $p<0.05$).
- During phase 2: A logistic regression analysis with the ENTER-method was applied, in which the predictor variables were fixed in advance.

Cross-validation (K-Fold)

A K-fold cross-validation procedure (K=10) was used to analyze the performance of the classifier. The total sample was randomly divided in K subsamples; K-1 subsamples were used as training set and 1 subsample was used as validation data. Each sample contained data from healthy subjects as well as from patients. Since the ratio of patients to healthy subjects was similar for each subsample, the logistic regression analysis was performed K times; each subject appeared one time in the validation data.

Performance of the classifier was measured by Receiving Operating Characteristics (ROC)-curves. The null-hypothesis was tested by meaning of the area under the ROC-curve and the significance difference ($p<0.05$) with the no-discrimination line.

The analysis was performed in two phases:

- The aim of phase 1 (FWD-Wald) was to estimate the performance of the logistic regression as a classifier, using the K-Fold cross-validation; as well as to make an inventory of the significant predictive factors in each loop of the cross-validation. Based on the inventory, the factors that appeared as a significant predictor in minimum 50% of the K-Fold loops were retained for phase 2.
- The aim of phase 2a (ENTER-method) was to analyze the performance of the logistic regression as a classifier, in which the factors selected in phase 1 were entered as fixed factors in the logistic regression. The objective was to measure the performance of a model where the predictive factors did not vary in function of the training/validation set.
- In order to obtain a useful interpretation for further exploitation, the logistic regression (ENTER-method) was performed finally on the whole sample (phase 2b).

Although it would be preferable to include the PCA within the cross-validation analyses to ensure the best performance of our model, the PCA was performed prior to the cross-validation procedures to facilitate the exploitation of the results.

RESULTS

The demographic data of the sample are presented in Table 3.

Table 3 Descriptive statistics on the study population and group differences

	Healthy subjects (n=63)	**NS-CLBP with flexion MCI (n=36)**	**Unpaired T-test for Equality of Means**
Characteristics	**Mean+/-SD (min-max)**	**Mean+/-SD (min-max)**	p-value*
Age	39.84 ± 10.61 (20-63)	43.78 ± 8.14 (25-57)	.057
BMI[1]	25.08 ± 2.28 (21.30 -29.88)	25.60 ± 2.28 (19.27-31.70)	.335
Sport hrs/week	4.07 ± 3.60 (0-14)	3.81 ± 3.73 (0-15)	.735

[1]Body Mass Index

*Significance level: $p<0.05$

Principal Component Analysis (PCA)

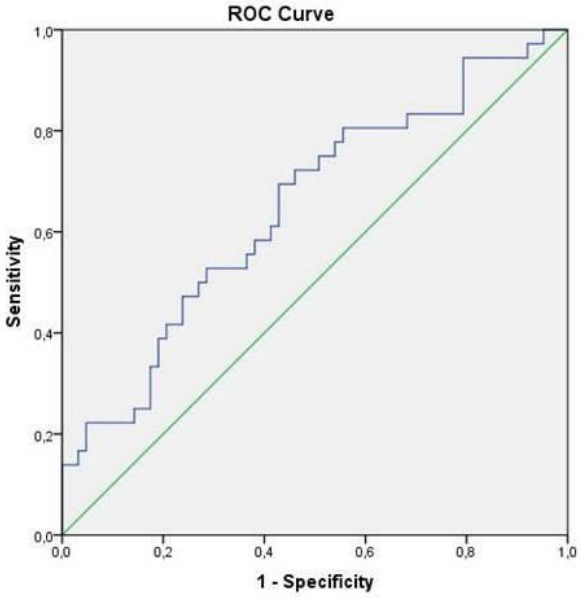
After PCA analysis, 14 factors were obtained: 3 factors (λ≥1) for Ex1 (a weighted mean of all ratios, a contrast between the IO/EO ratios and the LMF/ICLT ratios and a contrast between the right LMF/ICLT ratios and the left LMF/ICLT ratios), 3 factors (λ≥0.99) for Ex2 (a weighted mean of the IO/EO ratios, a weighted mean of the LMF/ICLT ratios and a contrast between the right LMF/ICLT ratios and the left LMF/ICLT ratios), 4 factors (λ≥0.99) for Ex3 (a weighted mean of all ratios, a contrast between the IO/EO ratios and the LMF/ICLT ratios, a contrast between the right LMF/ICLT ratios and the left LMF/ICLT ratios and a contrast between the right IO/EO ratios and the left IO/EO ratios), 2 factors (λ≥1) for Ex4 (a weighted mean of all ratios and a contrast between the IO/EO ratios and the LMF/ICLT ratios) and 2 factors (λ≥1) for Ex5 (a weighted mean of the IO/EO ratios and a weighted mean of the LMF/ICLT ratios).

Phase 1: Forward Wald Method

In figure 6, a ROC-curve (due to the fact that the 10 subsamples are chosen randomly, the ROC curve is changing slightly for each new analysis) established on a K-10 Fold cross-validation of the Forward Wald Logistic regression classifier is presented. The presented ROC-curve has an area under the curve of 0.749 and is significantly different from the line of no-discrimination (p=0.001).

During the K-Fold process, 4 factors appeared frequently (>50%) as significant predictors in the classifier. These factors were:

- Factor 1 of Ex1 (PC1Ex1): a weighted mean of all ratios during Ex1
- Factor 2 of Ex2 (PC2Ex2): a weighted mean of the LMF/ICLT ratios during Ex2
- Factor 1 of Ex3 (PC1Ex3): a weighted mean of all ratios during Ex3
- Factor 4 of Ex3 (PC4Ex3): a contrast between the right IO/EO ratios and the left IO/EO ratios during Ex3



Area Under the Curve

Test Result Variable(s): ProbPatientValData

Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
,649	,058	,014	,535	,762

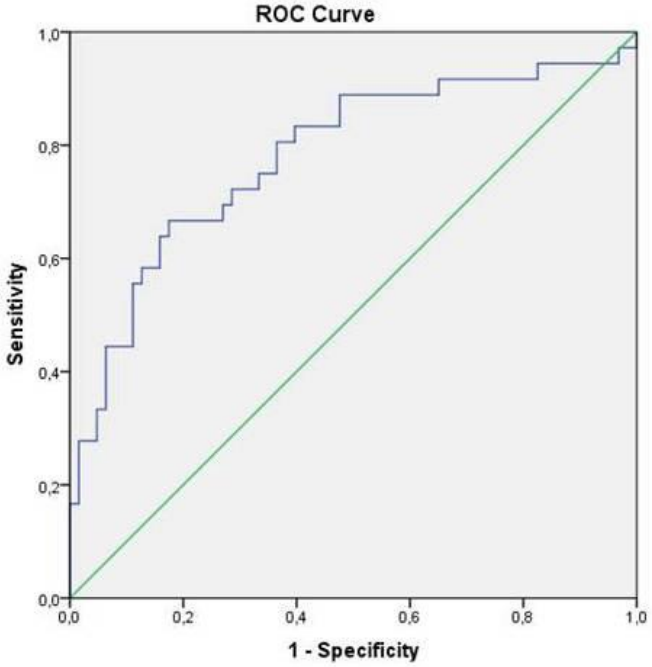
a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

Figure 6 A ROC-curve established on a K-10 Fold cross-validation of the Forward Wald Logistic regression classifier

Phase 2a: ENTER Method (Cross validation)

Figure 7 is giving an example of a ROC-curve established on a K-10 Fold cross-validation of the ENTER method (area under the curve of 0.78 - significantly different from the line of no-discrimination ($p<0.001$)).



Area Under the Curve

Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
,754	,054	,000	,648	,860

Figure 7 A ROC-curve established on a K-10 Fold cross-validation of the ENTER method

Phase 2b: ENTER-method (whole sample)

The predictive model, based on the logistic regression (ENTER-method), was able to classify 75.8 % of the subjects correctly (Table 4). The four factors found to be significant predictors in this final model were: PC2Ex2 (Exp(β)=1.821; p=0.009), PC1Ex1 (Exp(β)=3.86; p=0.001), PC1Ex3 (Exp(β)=0.232; p=0.001) and PC4Ex3 (Exp(β)=1.777; p=0.026) (Table 4).

Table 4 Results of the logistic regression analysis performed with the ENTER-method

Variables in the Equation

		β	S.E.	Wald	df	Sig.	Exp[β]
Step 1a	PC2Ex2	0.6	0.23	6.778	1	0.009	1.821
	PC1Ex1	1.351	0.421	10.307	1	0.001	3.86
	PC1Ex3	-1.462	0.424	11.913	1	0.001	0.232
	PC4Ex3	0.575	0.259	4.937	1	0.026	1.777
	Constant	-1.351	0.317	18.127	1	0	0.259

Variable[s] entered on step 1: PC2Ex2, PC1EXT1, PC1EX3 and PC4EX3.
Significance level: p<0.05

DISCUSSION

The present study suggests that with the current statistical method patients with MCI might be distinguished from healthy subjects in an objective way based on trunk muscle recruitment patterns measured by sEMG (phase 2a). This method enables to calculate a probability to be patient in a reliable way. Unfortunately, the model developed is not a perfect model and further investigation is needed to improve the discriminative value of this model.

Forward-Wald method: selection of the predictive factors

Changes in trunk muscle recruitment may be very task-dependent [Van Dieën et al, 2003; Sherman, 1985], which indicates that the choice of exercise is very important. Of the 6 investigated movement control tests, only 3 seem to be significant in the discrimination between flexion-related MCI patients and healthy subjects. This list is not exhaustive, and additional exercises may assist in improving the predictive model. This underlines that both in clinical setting and in research, the choice of exercises is very crucial to detect differences between populations.

Since changes in trunk muscle recruitment patterns are highly variable between individuals [Van Dieën et al, 2003], and a NS-CLBP population is heterogeneous [Dankaerts et al, 2006; O'Sullivan, 2005; Sheeran, 2012], classification in subgroups (direction of MCI) could be very useful [Dankaerts, 2006; O'Sullivan, 2005; Sheeran et al, 2012; Saner, 2011]. The selection of the 3 predictive factors mentioned above only refers to the flexion-related MCI. The 3 other exercises did not appear in the predictive model, but these exercises might be discriminative for other directions of MCI. The present study focused on flexion-related disorders because these are the most common in patients with NS-CLBP and also most frequently observed in a male population [O'Sullivan, 2000].

Enter-method: differences between healthy subjects and patients

Changes in trunk muscle recruitment patterns in patients seem functional to enhance spinal control [Van Dieën et al, 2003]. The Exp(β)-coefficient (Table 4) of the predictive model in this study showed that higher ratios (IO/EO and LMF/ICLT) in Ex1 (PC1Ex1) and higher LMF/ICLT ratios during Ex2 (PC2Ex2) enhance the probability to be a patient. This suggests that, in these exercises, patients

activate the deep stabilizing muscle groups relatively more compared to the superficial torque producing muscle groups to maintain the neutral position of their lumbar spine. Patients with LBP may need additional muscular stabilization of the lumbar spine to compensate for reduced stiffness as reported by Van Dieën et al [2003], in accordance to the model of Panjabi.

Another explanation might be that, leaving aside possible differences in passive stiffness, the NS-CLBP patients presenting a flexion-related MCI just have more difficulties to actively control the neutral lumbopelvic position and need to activate more their deep stabilizing muscle groups compared to healthy subjects. D'Hooge et al [2013] demonstrated altered muscle coordination during rapid trunk flexion to enhance spine protection in subjects with recurrent LBP. Patients co-contract more flexor and extensor trunk muscles, with lesser agonist flexor muscle activity and greater extensor muscle activity than controls. They found a higher activity of the LMF and even a lower activity of the EO in patients. These changes might be functional in LBP patients, since they would stiffen the trunk, thus precluding the chance patients would feel perturbations they could not adequately respond to. Because of the leg movement in Ex1 and Ex2, the balance of the subject is compromised, and this could explain why patients prepare themselves for eventual loss of control by overactivating the deep stabilizing muscle groups. Hanada et al [2011] investigated abdominal and low back muscle activation during walking in older adults with NS-CLBP and found similar results. Patients with NS-CLBP activated the LMF significantly more than did the control group. Sheeran et al [2012] demonstrated for a group NS-CLBP patients with a flexion pattern a significantly higher activation of the IO and EO (sitting and standing), LMF (standing) and a similar activation of the ICLT (sitting and standing) compared to asymptomatic controls.

In contrast, during Ex3, higher ratios (IO/EO and LMF/ICLT) (PC1Ex3) diminish the probability to be a patient. In this sitting exercise, with a simple arm movement, the balance is less compromised and therefore patients may consider increasing lumbar muscle activity redundant. An interesting comparison can be made with the study of Dankaerts et al [2006] about the usual and slumped sitting position. The average back muscle activity during usual sitting in the flexion pattern patients was non-significantly less when compared to healthy subjects. These results seem similar to the results concerning Ex3, in contrast with Ex1 and Ex2, but it has to be pointed that the two study protocols differed. In the present study, in order to be able to compare the muscle activity between all patients

and healthy controls in identical positions, the neutral position was maintained during these exercises. However, for several subjects, this was not their usual sitting position. In the study of Dankaerts et al [2006], subjects were sitting in their usual position, which was a more flexed position. The study of Dankaerts et al [2006] suggested that increased co-contraction of local stabilizing muscles was only present in extension patterns, but this was also based on usual sitting and not on sitting in the neutral position.

In addition, the current predictive model indicated also that more asymmetry between left and right abdominal muscle ratio during Ex3 (PC4Ex3) increases the likelihood to be a patient. This is not surprising, since left/right asymmetries in movement control are often described in relation to NS-CLBP [Alexiev A, 1994; Hoyt et al, 1981; Cram & Steger, 1983; Triano & Luttges, 1985; Van Dieën et al, 2003].

The choice of the ratios was based on preliminary analyses of the data. Models based on relative muscle activity and models based on ratios of abdominal to back muscle activity were not discriminating between patients and non-patients. This underlines the importance of considering trunk muscle recruitment patterns in terms of activity of deep stabilizing muscle groups to torque producing muscles, as applied also in previous studies [Van Damme et al, 2012; Stevens et al, 2006b].

There is considerable recognition of the need to develop a method of subclassifying NS-CLBP [Mc Carthy et al., 2004]. Mc Carthy et al [2004] proposed an overview of different subclassification systems used, organized into four themes: patho-anatomical sources, clinical features, psychological features and finally work and health status. Subclassification based on clinical features is the most common method, but the range of methodological score is wide. In accordance to the present study, Van Dillen et al [1998] focused on movement impairment, but they used a highly subjective physical assessment developed on judgmental issues, which compromise the validity, the generalizability and the clinical usefulness of the system. Classification systems combining judgmental approaches and statistical methodology are the most optimal to ensure reliability and validity of the system. The method proposed in the present study combines a judgmental approach (by detecting the patients with flexion related MCI) and a statistical method based on objective EMG data. Although EMG

recording is not feasible in every clinical setting, the proposed method could help to develop and support classification based on MCI.

In addition, the described method is helpful to objectify classification based on clinical features. Patient evaluation should also include more than just motor control exercises. Consequently, this is only a part of the patient evaluation. In subgrouping NS-CLBP patients assessment of biomedical, psychological and social domains should be combined [Mc Carthy et al, 2004].

Limitations

Absolute EMG amplitudes depend on many factors unrelated to the level of muscle activation, such as thickness of tissues overlying the muscles. To obtain a signal independent of such factors, normalization of EMG amplitude to the EMG amplitude during maximal voluntary contraction (MVC) is often used. However, when measuring patients, this procedure is not reliable, since patients are often unwilling or unable to perform MVC. Van Dieën et al. [2003] plaid for non-normalized EMG amplitudes in clinical studies, because normalization to submaximal contraction could bias the results. Therefore the different groups should be perfectly matched. However, in clinical practice it is difficult to work with perfectly matched groups, so in this study normalization to a submaximal contraction was used [Silfies et al, 2005; Dankaerts et al, 2006a]. Submaximal voluntary isometric contractions have been reported to be more reliable in a pain population [McGill, 1991; O'Sullivan et al, 2002] and appear more sensitive when assessing low levels of muscle activity [Allison et al, 1998; O'Sullivan et al, 2002; Snijders et al, 1995]. Evidence was provided that in clinical outcome studies, submaximal voluntary isometric contractions are more appropriate for normalization of trunk muscle EMG [Dankaerts et al, 2004]. In addition, data analysis comparing submaximal voluntary isometric contractions and MVC in the present study showed that submaximal voluntary isometric contractions, in contrast to MVCs, were not significantly different between healthy subjects and patients with CLBP. The submaximal voluntary isometric contractions reached a level of about 40% of MVIC in the healthy subjects. However, the exercises used to record the submaximal voluntary contraction can be discussed.

Although the exercises were very standardized, the neutral position of the spine was controlled visually. No video registration, neither other kinematic measurements were performed to ensure the

neutral position of the spine during the exercises to maintain the practical clinical situation. The neutral position of the spine is often debated, because lack of consensus exists to define precisely where this point is. In addition, it is exposed to subjectivity, because it is often arbitrary chosen by the clinician. However, the control of a single static position or point in the range is not representative for normal functioning, where stability is required dynamical. Function requires control of more than only one isolated point [Comerford and Mottram, 2012]. Although a synchronized kinematic assessment would have been more optimal, the main intention was to create a model to test and detect patients in a clinical setting, requiring as less time, equipment and analysis time as possible, without compromising the objectivity. In addition, previous research on a position-reposition test measuring neutral spine position accuracy using an ultrasound movement analysis system (Zebris CMS70P, Isny, Germany) showed good reliability [Stevens et al., 2006].

At this moment, the results of the current study do not yet entirely support the idea that subclassification is feasible based on trunk muscle activation patterns during a small battery of movement control exercises. To ensure this, other patient groups including patients with other MCI (e.g. extension related patterns) as well as patients without MCI should also be assessed. However, the selection of flexion-related patterns was not very strict, because also multidirectional patterns were included. The authors were aware that this could bias the results and consequently, the same analysis was repeated, removing the data of the multidirectional patterns (n=17). Since the results were similar to these of the strictly flexion-related ones, the authors opted to describe the group in its entirety, which facilitates clinical use. In addition, this study focused only on a male population, which is the most representative military population; however, female subjects should also be tested.

CONCLUSION

In the current study a statistical model, based on sEMG ratios of relative amplitudes of trunk muscle activity during movement control exercises was developed to discriminate between healthy subjects and patients with NS-CLBP presenting a flexion related MCI. Further research in other LBP populations is needed to study the idea of subclassification based on trunk muscle activation patterns during a small battery of movement control exercises. In addition, it would be interesting to assess

whether retraining movement control, may induce significant changes in trunk muscle recruitment patterns and if these changes could be detected with the current statistical model.

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RESEARCH PART 2:

PSYCHOSOCIAL ASSESSMENT

CHAPTER 3

Cross-cultural adaptation and reproducibility of a battery of self-report questionnaires for French and Dutch speaking patients with non-specific chronic low back pain.

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ABSTRACT

Objectives: A cross-cultural adaptation of a battery of questionnaires to French and Dutch and investigation of the reproducibility of these questionnaires over a long period of time in patients with non-specific chronic low back pain.

Methods: Several screening and outcome self-report questionnaires and their subscales were assembled. The Quebec Pain Back Disability index, the Multidimensional Pain Inventory part 1, the Tampa Scale for Kinesiophobia and the Patient Health Questionnaire with 15 items were cross-cultural adapted to French and Dutch and the Orebro Musculoskeletal Pain Questionnaire was cross-cultural adapted to Dutch. Existing translation of the Pain Catastrophizing Scale, the Distress and Risk Assessment Method, the Hospital Anxiety and Depression Scale and the Short Form 36 were used. Forty-eight French-speaking and 43 Dutch-speaking patients completed twice all questionnaires, with a time interval between 3 weeks and 4 months. Reproducibility (reliability and agreement) of each questionnaire was analyzed using two-way ANOVA for repeated measures. The reliability of the questionnaires was assessed with the intraclass correlation coefficient for agreement (two-way random effects model, single measure) ($ICC_{2,1}$). To indicate agreement, the standard error of measurement for agreement was defined. The minimum detectable change for the different questionnaires and their subscales was calculated.

Results: Cross-cultural adapted French and Dutch version were developed for the questionnaires described above. In general, the reliability was satisfactory ($ICC_{2,1} \geq 0.6$) to good ($ICC_{2,1} \geq 0.7$), except for some subscales of the SF-36.

Discussion: The developed battery of questionnaires is reliable for French- and Dutch speaking patients. Test-retest reliability was comparable to the literature.

Keywords: Non-specific chronic low back pain, self-report questionnaires, cross-cultural adaptation, reproducibility

INTRODUCTION

The experience of chronic pain is more than the experience of the intensity of pain. Chronic pain is a biopsychosocial experience, where psychosocial and physical components play an inseparable role [1]. Extensive evaluation of both physical aspects and psychosocial dimensions is required to tailor the therapy in order to break down the vicious circle of pain and disability in patients with non-specific chronic low back pain (NS-CLBP). This assessment is not only needed before starting therapy, but also after a certain treatment period to monitor changes and to organize follow-up.

NS-CLBP could be influenced by a wide range of psychological (fear-avoidance, kinesiophobia, depression …) and social variables (work-related issues, familial problems…) feeding the chronicity of the problem [2]. By assessing only one aspect, e.g. kinesiophobia, one may miss another one, e.g. catastrophizing. Therefore, the psychosocial assessment should be extensive enough and combine a range of screening and outcome measurements.

A wide range of self-report questionnaires exist to assess psychosocial factors in patients with LBP. However, there are a number of issues. Questionnaires are not always available in the required language, and when they are, the way the questionnaire was translated and validated in its adapted form is not always clear. The cross-cultural adaptation of a health status self-administered questionnaire for use in a new country, culture, and/or language necessitates adherence to a well-defined method, to reach equivalence between the original source and target versions of the questionnaire.

A project was conducted to obtain a cross-cultural adaptation of a battery of questionnaires for patients with NS-CLBP in two of Belgium's national languages: French and Dutch. The first aim of this project was to translate a battery of questionnaires from the original language in a standardized way [3]. Secondly, the reproducibility of these translated versions was assessed [4] over a long period of time.

MATERIALS AND METHODS

Battery of questionnaires

The subjects responded to some sociodemographic questions and a numeric pain rating scale and they were asked to fill in an electronic version of a battery of questionnaires. The battery consisted of several screening and outcome self-report questionnaires: The Quebec Pain Back Disability index (QBPDI) [5,6]; an adapted version of the MPI_{part1} (24 items) and its 5 subscales: pain severity (MPI-PS), interference with the daily life due to pain (MPI-I), perceived life control (MPI-LC), affective distress (negative mood) (MPI-AD) and social support (MPI-S) [7]; the Tampa Scale for Kinesiophobia (TSK) [8]; the Orebro Musculoskeletal Pain Questionnaire (OMPQ) [9,10]; the Patient Health Questionnaire [11]; the Pain Catastrophizing Scale (PCS) [12]; the Distress and Risk Assessment Method (DRAM) as a combination of the Modified Zung Depression Index (MZDI) and the Modified Somatic Perception Questionnaire (MSPQ); the Hospital Anxiety and Depression Scale (HADS) and its two subscales for anxiety and depression ($HADS_{AX}$ and $HADS_{DP}$) [13-14] and the Short Form 36 (SF-36) [15] and its different subscales (Physical Functioning ($SF\text{-}36_{PF}$), Role Physical ($SF\text{-}36_{RP}$), Bodily Pain ($SF\text{-}36_{BP}$), General Health ($SF\text{-}36_{GH}$), Vitality ($SF\text{-}36_{VT}$), Social Functioning ($SF\text{-}36_{SF}$), Role Emotional ($SF\text{-}36_{RE}$) and Mental Health ($SF\text{-}36_{MH}$), the Physical Component Summary ($SF\text{-}36_{PCS}$) and the Mental Component Summary ($SF\text{-}36_{MCS}$)).

Cross-cultural adaptation

An existing validated French version (FV) and Dutch version (DV) of the PCS [12], the DRAM, the HADS [13-14] and the SF-36 [15] were used in the battery of questionnaires. A validated FV of the OMPQ [9] was used, but with some minor adaptations.

Questionnaires which were not available in French or Dutch (PHQ-15, adapted MPI_{part1}), or questionnaires that were available in these languages but with some potential bias related to specific cultural issues (FV and DV of the QBPDI, FV and DV of the TSK and the DV of the OMPQ) were all translated and adapted from the original English version. The FV of the QBPDI [6] and of the TSK [16] were developed in Canada and had some language-specific issues. This was also the case for the DV of the TSK [17], QBPDI [5] and the OMPQ [21] which were developed in The Netherlands. FV and DV [18] of the MPI existed, but were based on an older version of the MPI. The authors of the original

MPI proposed to use a newer version of the questionnaire to avoid some comprehensive issues. The translation and cross-cultural adaptation were carried out in accordance with previously published guidelines [3]. These guidelines describe the process currently recommended by the American Academy of Orthopedic Surgeons Outcomes Committee. An overview of the translation procedure is presented in Figure 1.

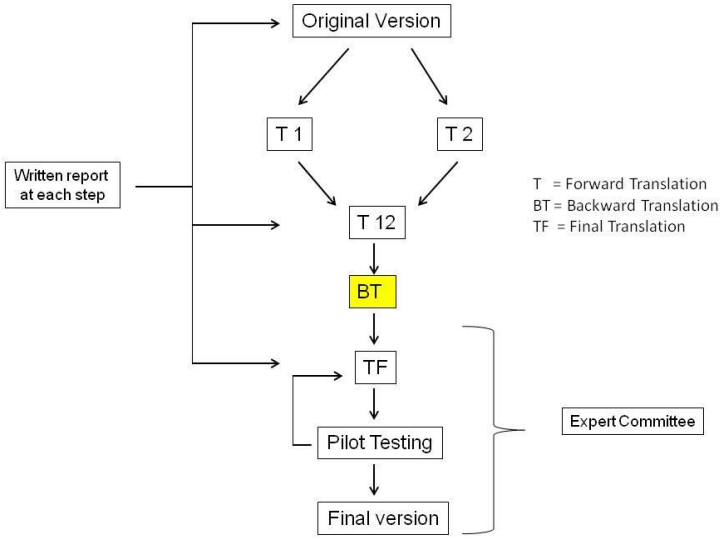

Figure 1 An overview of the translation procedure

The French and Dutch translations were performed by separate groups of translators. An initial translation was performed by two independent translators from English to the target language. After discussion, the 2 translators produced a consensus version of the translated questionnaire. A back translation of the consensus version was done by a native English speaker. An expert committee reviewed all translations, discussed with the original translators possible discrepancies and developed the final versions. Based on the findings of a pilot testing on patients with LBP, the expert Committee produced a final version of each adapted questionnaire. The translators as well as the patients who participated in the pilot testing originated from Belgium, The Netherlands and France. This was done to avoid dialect issues specific to one country and to make the adaptations of these questionnaires applicable in different European Dutch and French speaking countries.

Reproducibility study

Patient population

In the period of December 2012 to February 2014, 97 patients with NS-CLBP accepted to participate to the reproducibility study. All these patients were enrolled in a specific multidisciplinary program for NS-CLBP by a medical doctor specialized in rehabilitation and sports medicine at the national Military Hospital. Patients were eligible for the study according to the following inclusion criteria: a minimum age of 18 years, NS-CLBP with a history of more than three pain episodes during the past year or pain persisting for at least three months and never having completed these self-report questionnaires before. Patients with specific diseases causing LBP (cancer, rheumatoid arthritis, fractures …), psychiatric disease, alcohol problems or patients with another native language were excluded from this study. After their visit by the medical doctor, they completed an electronic version of the battery of questionnaires for the first time. On average, 45 minutes were needed to complete all questionnaires. The patients could fill in the questionnaires electronically at home, at office or at the hospital. If questions remained unanswered, an alert was given at the termination of the questionnaires to ask the patient to complete the remaining questions. If patients asked questions about the content of the questionnaires, they were instructed to answer as quickly as possible, without too much thinking and to take the answer which was the nearest to their situation. Physiotherapists did just help for practical reasons (searching of unanswered questions, saving the answers, etc.).

A same version of the test battery was completed a second time more than three weeks (min: 21 days, max: 119 days, mean: 58.63 days for the FV; min: 21 days, max: 104 days, mean: 53.63 days for the DV) after the first version, before starting physiotherapy. One patient was excluded because of a serious psychiatric disorder with great inter-day variability in mood state, 3 patients were excluded because they followed psychotherapy in between the interval period, and 1 patient reported an important change in pain status compared to the first test session and was excluded. One person was excluded because there were problems with the completed second questionnaire form which hindered score calculation. Finally 48 French and 43 Dutch valid questionnaires were used for analysis.

The study was approved by the local Ethics Committee and informed consent was obtained from each participant of this study.

Statistical analysis

All statistical analyses were performed with SPSS version 22. Statistical significance was accepted at the $p<0.05$ level. The different analyses were done for French and Dutch data separately.

The differences in mean values for the repeated trials were examined using two-way ANOVA (single factor, within subjects) for repeated measures. Reproducibility of the questionnaires and their subscales was analyzed using a measure for agreement and a measure for reliability [4,18,19].

Agreement refers to the absolute measurement error (expressed in the unit of the measurement) to indicate the proximity of the scores on repeated measures. A small error is needed to distinguish clinical important changes [4]. To indicate agreement, the standard error of measurement for agreement (SEMagreement) was defined. For both measures the 95% confidence intervals (CI) were determined. The minimum detectable change (MDC95%) for the different questionnaires and their subscales was calculated as follows: $1.96 \times \sqrt{2} \times SEM$ (95% confidence level). MDC95% reflects the degree of change required in individual scores, in order to establish real change above measurement error.

Reliability of a measurement concerns the degree to which patients can be distinguished from each other despite measurement errors. It concerns the proportion of inter-individual variance to the total variance (inter- and intra-individual variance). High reliability is important for discriminative purposes [4]. The reliability of the questionnaires was assessed with the intraclass correlation coefficient for agreement (two-way random effects model, single measure) ($ICC_{2,1}$). An ICC ≥0.70 reflects a good reliability [4,19] and an ICC ≥0.60 is often set as satisfactory.

RESULTS

Cross-cultural adaptation

The questionnaires that were translated from the original English version to DV and FV are shown in the Appendices.

The MPI was translated from an adapted version of the original MPI, as proposed by the authors of the original MPI. This explains why the DV presented in this study is different from the version presented by Lousberg et al. [20] which was derived from the original version.

The version of the TSK and the QBPDI obtained in this study, are quite similar to the existing translations of these questionnaires. Some differences were retained as response to some cultural problems present in the existing DV's [5,16] and FV's [6,17], which had been translated in the past respectively in the Netherlands and in French-speaking Canada. For example, in item 9 of the QBPDI "miles" was converted to "kilometers". Also in the original Dutch translation of the TSK [16], which was widely examined on psychometric properties in the Netherlands and in Belgium [22,23], some language-related problems persisted. The sentences used in items 8, 10 and 16 were difficult to understand for patients. The words "blessure" (items 7,9 and 13), "ongeluk" (item 6) and "oefeningen" (item 1 and 17) led to some ambiguity in the interpretation of the statement. The new translations result in some minor changes in the existing translations.

The DV and FV of the PHQ-15 were translated from the English version of the PHQ-15 and were not derived from the FV and DV of the total PHQ, because no information existed about the translation protocol.

The most important differences obtained in the current DV of the OMPQ compared to the existing DV developed by Kole-Snijders et al. [21] were the additional choices in questions 4 and 13 that enabled persons who did not have a job to answer to the questions. In question 16 "work" was replaced by "all day activities", so that people who are unemployed can also answer to this question. In the FV proposed by Nonclercq et al. [9] some minor adaptations were applied to make the DV and FV comparable.

Reproducibility study

Data of 48 French-speaking (44 men and 4 women; mean age 41.22) patients and 43 Dutch-speaking (37 men and 6 women; mean age 42.5) patients were analyzed in this study (Table 1a and b). The median duration between the first and the second questionnaire was 56 days, with an interquartile ranging from 31.5 (P25) to 70 (P75) days for the French-speaking population and 42 days, with an interquartile ranging from 30 (P25) to 80 (P75) days for the Dutch speaking population.

Results from the $ICC_{2,1}$, the $SEM_{agreement}$ and the MDC are presented in Table 2 for the French-speaking population and in Table 3 for the Dutch-speaking population ($p<0.05$).

The $ICC_{2,1}$ for the questionnaires were good (≥0.7) to satisfactory (≥0.6) ($p<0.05$), except for the $SF\text{-}36_{EM}$ and $SF\text{-}36_{RP,}$ the FV of the $SF\text{-}36_{BP}$ and the DV of the $SF\text{-}36_{VT}$.

Table 1a Demographic data of the final French-speaking patient population

	French Speaking Patients (n=48)			
	Men (n=44)		Women (n=4)	
	Military (n=39)	Civilian (n=5)	Military (=2)	Civilian (=2)
	Mean ± SD (min-max)	Mean ± SD (min-max)	Mean ± SD (min-max)	Mean ± SD (min-max)
Age	41.97 ± 7.8 (23-53)	46 ± 7.18 (37-54)	34.5 ± 6.36 (30-39)	46 ± 4.24 (43-49)
Weight	85.13 ± 12.1 (61-117)	74.8 ± 14.25 (59-96)	67.5 ± 0.71 (67-68)	63 ± 1.41 (62-64)
Length	179.69 ± 5.1 (170-193)	174.2 ± 5.17 (169-182)	166.5 ± 3.54 (164-169)	164.5 ± 7.78 (159-170)
BMI	26.34 ± 3.4 (21-35)	24.58 ± 3.92 (19-29)	24.37 ± 1.29 (23-25)	23.33 ± 1.68 (22-25)
Pain Duration (months)	50.08 ± 77.84 (3-340)	105.6 ± 122.169 (3-256)	4 ± 1.41 (3-5)	13.5 ± 2.12 (12-15)

Table 1b Demographic data of the final Dutch-speaking patient population

	Dutch Speaking Patients (n=43)			
	Men (n=37)		Women (n=6)	
	Military (=36)	Civilian (=1)	Military (n=5)	Civilian (n=1)
	Mean ± SD (min-max)	Mean ± SD (min-max)	Mean ± SD (min-max)	Mean ± SD (min-max)
Age	42.67 ± 9.46 (18-55)	44	41.8 ± 12.19 (27-51)	42
Weight	88 ± 13.71 (63-117)	74	70.8 ± 9.09 (60-82)	84
Length	181.39 ± 6.47 (63-117)	180	165.2 ± 4.55 (158-170)	172
BMI	26.59 ± 6.47 (170-194)	22.84	25.87 ± 2.27 (23-28)	28.39
Pain Duration (months)	69.08 ± 3.57 (20-35)	76	82.8 ± 110.99 (8-276)	3

Table 2 Reproducibility results for a battery of questionnaires (adapted to French) in patients with non-specific chronic low back pain

Questionnaire	N° items	Possible Range	Mean (SD) Time 1; *min-max*	Mean (SD) time 2; *min-max*	Mean difference (95%CI)	$ICC_{2,1}$ (95% CI)	$ICC_{2,1}$ p-value	$SEM_{agreement}$	SEM % mean	$MDC_{95\%}$
DRAM MSPQ	22	0-39	5.6 (5.09) *0-25*	4.98 (4.41) *0-20*	0.63	0.668	<0.001	2.74	25.9 %	7.59
DRAM MZDI	23	0-69	18.98 (8.29) *7-38*	17.92 (7.57) *4-37*	1.06	0.737	<0.001	4.05	11.0 %	11.22
HADS Anxiety	7	0-21	5.71 (3.12) *0-13*	5.38 (2.56) *1-13*	0.33	0.719	<0.001	1.51	13.6 %	4.19
HADS Depression	7	0-21	4.60 (3.47) *0-13*	4 (3.26) *0-14*	0.60	0.64	<0.001	2.00	23.3 %	5.55
MPI affective	3	0-18	6.38 (3.94) *0-16*	5.46 (3.71) *0-14*	0.92	0.695	<0.001	2.06	17.4 %	5.72
MPI control	2	0-12	7.79 (2.713) *1-12*	8.35 (2.65) *2-12*	-0.56	0.6	<0.001	1.73	10.7 %	4.80
MPI interference	9	0-54	18.65 (9.44) *0-37*	17.96 (9.61) *0-40*	0.69	0.725	<0.001	5.01	13.7 %	13.90
MPI pain	3	0-18	7.10 (2.77) *2-13*	6.42 (3.47) *0-13*	0.69	0.707	<0.001	1.66	12.3 %	4.61
MPIsupport	3	0-18	11.33 (3.88) *3-18*	12.19 (3.76) *1-18*	-0.85	0.736	<0.001	1.91	8.1 %	5.29
OREBRO	21	2-210	77.73 (23.564) *24-138*	71.60 (20.79) *20-117*	6.13	0.827	<0.001	8.43	5.6 %	23.38
PCS	13	0-39	16 (8.28) *3-43*	14.69 (8.26) *2-36*	1.31	0.767	<0.001	3.94	12.8 %	10.93
PHQ 15	15	0-30	6.25 (3.63) *1-16*	5.69 (3.43) *1-17*	0.56	0.786	<0.001	1.61	13.5 %	4.46
QBPDS	20	0-100	22.71 (13.66) *0-55*	21.98 (13.24) *1-51*	0.73	0.875	<0.001	4.77	10.7 %	13.23
$SF\text{-}36_{BP}$	2	0-100	53.45 (16.83) *22-84*	57.36 (14.65) *22-84*	-3.91	0.381	0.003	12.35	11.1 %	34.22
$SF\text{-}36_{RE}$	3	0-100	77.78 (35.953) *0-100*	87.5 (27.18) *0-100*	-9.72	0.158	0.132	29.16	17.6 %	80.82
$SF\text{-}36_{GH}$	5	0-100	66.06 (17.29) *30-100*	67.21 (16.91) *30-97*	-1.15	0.838	<0.001	6.90	5.2 %	19.14
$SF\text{-}36_{PF}$	10	0-100	69.69 (15.99) *35-100*	71.15 (18.14) *25-100*	-1.46	0.775	<0.001	8.12	5.8 %	22.51
$SF\text{-}36_{RP}$	4	0-100	45.83 (40.06) *0-100*	55.73 (39.36) *0-100*	-9.90	0.552	<0.001	26.23	25.8 %	72.71
$SF\text{-}36_{SF}$	2	0-100	79.68 (17.41) *38-100*	82.55 (15.2) *50-100*	-2.88	0.679	<0.001	9.17	5.6 %	25.41
$SF\text{-}36_{Vit}$	4	0-100	56.88 (17.76) *25-85*	58.85 (17.39) *25-95*	-1.98	0.657	<0.001	10.31	8.9 %	28.57
$SF\text{-}36_{MH}$	5	0-100	64.50 (17.613) *32-100*	67.75 (18.14) *20-100*	-3.25	0.67	<0.001	10.17	7.7 %	28.18
$SF\text{-}36_{PCS}$	25	0-100	58.38 (14.53) *27-87*	62.06 (13.93) *35-93*	-3.68	0.723	<0.001	7.21	6.0 %	19.98
$SF\text{-}36_{MCS}$	19	0-100	68.96 (15.73) *33-90*	72.77 (13.89) *28-94*	-3.81	0.639	<0.001	8.71	6.1 %	24.15
$SF\text{-}36_{TS}$	36	0-100	64.21 (14.62) *30-90*	68.51 (13.12) *31-94*	-4.30	0.7	<0.001	7.36	5.5 %	20.41
TSK	17	17-68	39.65 (8.82) *23-59*	39.35 (8.14) *23-56*	0.29	0.791	<0.001	3.91	4.9 %	10.83

SD: standard deviation; ICC:intraclass correltation coefficient; SRM: standard error of the mean; MDC: minimum detectable change

Table 3 Reproducibility results for a battery of questionnaires (adapted to Dutch) in patients with non-specific chronic low back pain

Questionnaire	N° items	Possible Range	Mean (SD) Time 1; *min-max*	Mean (SD) time 2; *min-max*	Mean difference (95%CI)	$ICC_{2,1}$ (95% CI)	$ICC_{2,1}$ p-value	$SEM_{agreement}$	SEM % mean	$MDC_{95\%}$
DRAM MSPQ	22	0-39	5.88 (4.62) *0-21*	4.65 (4.35) *0-15*	1.23	0.743	<0.001	2.16	20.56 %	6.00
DRAM MZDI	23	0-69	13.58 (7.63) *1-38*	12.95 (7.61) *2-36*	0.63	0.824	<0.001	3.20	12.08 %	8.88
HADS Anxiety	7	0-21	4.3 (2.83) *0-11*	3.98 (2.93) *0-11*	0.33	0.855	<0.001	1.09	13.14 %	3.02
HADS Depression	7	0-21	3.35 (2.88) *0-12*	2.77 (2.78) *0-11*	0.58	0.842	<0.001	1.07	17.51 %	2.97
MPI affective	3	0-18	5.65 (3.82) *0-15*	5.42 (3.91) *0-13*	0.23	0.714	<0.001	2.08	18.80 %	5.77
MPI control	2	0-12	9.28 (2.44) *3-12*	9.81 (1.95) *3-12*	-0.53	0.705	<0.001	1.17	6.12 %	3.24
MPI interference	9	0-54	18.81 (10.81) *2-43*	17.4 (11.41) *0-47*	1.42	0.761	<0.001	5.41	14.93 %	14.99
MPI pain	3	0-18	7.3 (3.08) *3-14*	6.56 (3.4) *2-14*	0.74	0.600	<0.001	2.04	14.73 %	5.66
MPIsupport	3	0-18	12.95 (3.6) *0-18*	11.79 (3.99) *0-18*	1.16	0.745	<0.001	1.80	7.27 %	4.99
OREBRO	21	2-210	77.05 (21.15) *37-142*	72.44 (22.64) *29-129*	5.43	0.762	<0.001	10.15	6.79 %	28.13
PCS	13	0-39	15.7 (7.94) *1-34*	14.77 (7.18) *2-34*	0.93	0.649	<0.001	4.49	14.72 %	12.44
PHQ 15	15	0-30	6.51 (3.1) *1-17*	5.74 (3.13) *1-12*	0.77	0.642	<0.001	1.82	14.90 %	5.06
QBPDS	20	0-100	25.09 (13.12) *2-61*	21.02 (13.34) *0-47*	4.07	0.784	<0.001	5.65	12.25 %	15.65
$SF\text{-}36_{BP}$	2	0-100	48.06 (16.67) *12-84*	53.35 (16.86) *22-84*	-5.29	0.629	<0.001	9.84	9.70 %	27.27
$SF\text{-}36_{RE}$	3	0-100	86.05 (29.31) *0-100*	89.15 (25.94) *0-100*	-3.10	0.457	0.001	20.45	11.67 %	56.70
$SF\text{-}36_{GH}$	5	0-100	65.51 (17.2) *25-95*	67.14 (18.88) *30-100*	-1.63	0.753	<0.001	8.99	6.78 %	24.92
$SF\text{-}36_{PF}$	10	0-100	68.72 (18.03) *30-95*	74.88 (15.02) *35-100*	-6.16	0.642	<0.001	7.43	5.18 %	20.61
$SF\text{-}36_{RP}$	4	0-100	40.7 (39.72) *0-100*	54.65 (41.64) *0-100*	-13.95	0.489	<0.001	28.43	29.81 %	78.79
$SF\text{-}36_{SF}$	2	0-100	74.64 (21.56) *13-100*	81.98 (19.15) *38-100*	-7.34	0.650	<0.001	10.92	6.97 %	30.27
$SF\text{-}36_{Vit}$	4	0-100	62.44 (15.33) *25-90*	63.14 (13.23) *40-90*	-0.70	0.443	0.001	10.73	8.55 %	29.75
$SF\text{-}36_{MH}$	5	0-100	73.67 (19.52) *32-100*	75.91 (18.53) *24-104*	-2.23	0.750	<0.001	9.51	6.36 %	26.35
$SF\text{-}36_{PCS}$	25	0-100	57.09 (13.98) *33-86*	62.63 (15.29) *33-92*	-5.55	0.695	<0.001	8.25	6.89 %	22.87
$SF\text{-}36_{MCS}$	19	0-100	72.13 (15.2) *33-94*	75.46 (13.8) *36-99*	-3.34	0.689	<0.001	7.92	5.37 %	21.95
$SF\text{-}36_{TS}$	36	0-100	64.73 (14.13) *29-90*	70.02 (14.05) *33-95*	-5.29	0.754	<0.001	6.24	4.63 %	17.29
TSK	17	17-68	38.58 (7.81) *22-57*	36.4 (7.25) *22-51*	2.19	0.757	<0.001	3.50	4.66 %	9.69

SD: standard deviation; ICC:intraclass correltation coefficient; SRM: standard error of the mean; MDC: minimum detectable change

DISCUSSION

In this article a battery of cross-culturally adapted (DV and FV) questionnaires is suggested that enables a broad evaluation of patients with NS-CLBP. A reproducibility study with a long time interval was conducted on a NS-CLBP population.

Cross-cultural adaptation

A wide range of questionnaires exists, but most questionnaires were developed in English-speaking countries. With the increase in the number of multinational research projects, the need to adapt health status measures for use in other than the source language has also grown rapidly [3]. For some of the questionnaires used in the battery, cross-cultural adaptation was needed, even though Dutch and/or French translations sometimes already existed. The Dutch language used in the Netherlands does not completely correspond to the Dutch in Flanders and there are also differences between the Canadian and the Belgian French language. Although people will understand each other, some words or expressions may cause confusion. Confusion or uncertainty about the meaning of words may threaten the clinical relevance of a questionnaire. For example “running” in Dutch of the Netherlands sometimes means “walking”. However, if one person considers it as walking and another as running, the outcome may be very different. In the current study, collaboration with several countries allowed creating questionnaires that avoided regional characteristics. Although some of these questionnaires were widely examined on psychometric properties in the past, even in a Belgian population, e.g. the TSK [22,23], they were submitted to a new translation procedure, because some problems with words/sentences persisted.

The cross-cultural adaptation of a health status self-administered questionnaire for use in a new country, culture, and/or language necessitates use of a unique method, to reach equivalence between the original source and target versions of the questionnaire [3]. A poor translation process may lead to an instrument that is not equivalent to the original questionnaire and this limits the comparability of responses across populations divided by language or by culture [24]. It was decided to follow the guidelines proposed by Beaton et al. [3] for the cross-cultural adaptation procedures in order to have a standardized approach, even if only minor changes were needed. Only for the FV of the OMPQ [9] some adaptations were made without following the whole process. This version of the OMPQ was

developed in Belgium, but some adaptations were made to have accordance between de DV and FV of the OMPQ.

The method used in this article is a process of translating and, if necessary, replacing items to make it relevant in a new culture. After this cross-cultural adaptation there is a need for psychometric testing and normative data collection using the new instrument, because a translation does not automatically provide a valid measure.

Reproducibility study

The different questionnaires and their subscales showed satisfactory to good reliability over a longer period of time in the two languages, except for some subscales of the SF-36. Overall, these results are in line with results described in the literature, but some important methodological differences should be pointed to explain possible differences in the results.

Reproducibility studies of self-report questionnaires with a long time interval between the two trials (> 1 month) have not often been reported. In this study, the interval between the repeated administrations is between 1 and 4 months. This is much longer than in most of the reproducibility studies where a 1 to 2 week interval is common [4] to prevent recall and to ensure that no clinical changes have occurred. However, in clinical practice longer periods are often found [25]. Due to factors such as waiting lists there may be a delay of weeks to months between screening and a first rehabilitation session. Screening instruments with diagnostic consequences or outcome questionnaires designed to monitor for clinical changes need therefore to be stable over periods of time that are in accordance with this interval between screening and start of treatment. A longer period implicates more difficulties to monitor for clinical or social changes in patients and could therefore compromise good reliability results. Because of the chronic state of the patients in the current study, no sudden clinical changes were expected. However, in order to diminish the risks of the effects of day to day variability, changes were monitored by short questioning (pain, social life, work) and patients who demonstrated important changes or who had any kind of therapy within the interval were excluded from this study. Although the risk of a longer time interval was chosen, the current results are similar to studies using shorter intervals. For the QBPDI, the OMPQ and the TSK a good reliability index (ICC>0.7) was found in both the FV and DV ($p<0.05$). This is in line with studies investigating reproducibility over 1 to 2 weeks interval in patients with CLBP. Concerning the QBPDI,

ICC's ranging from 0.696 to 0.92 were reported [5,26,27,28]. For the OMPQ an $ICC_{2,1}$=0.89 was found [9] and for the TSK an ICC > 0.9 is often reported [29,30]. Concerning the PCS, ICC >0.7 [31] and even >0.8 [32] are reported in CLBP patients. Kopec [6] reported an ICC of 0.93 for the original English version and an ICC of 0.88 for the original French version in LBP patients over a median interval of 3.8 days (range 1-14 days). This is somewhat higher than the present results found in the FV, but corresponds to the ICC of the DV. The reliability varies among the subscales of the MPI, with MPI-LC (FV) and MPI-PS (DV) demonstrating the lowest values. Kerns et al. [7] demonstrated that the test-retest reliabilities of these scales over a 2-week interval range from satisfactory to excellent (range from 0.62 to 0.91). The ICC of the FV is somewhat lower in this study, but remains satisfactory.

Caution should be taken when generalizing results of test-retest studies to other language versions and certainly to other patient populations. For example, the reliability of the subscales of the SF-36 can be questioned in this study. The ICC's are very low for some of the subscales. In contrast, Steffen & Seney [37] found good test-retest reliability (0.80) for the subscales of the SF-36, except for the Social Functioning subscale, but this was a study in patients with a Parkinson disease. For the PHQ-15 a not defined ICC of 0.65 [33] was found in a psychiatric Korean population and an ICC for consistency of 0.83 was found in a Dutch primary care population [34]. In this study we also found a difference in the ICC of the DV and FV, but generally the reliability of the PHQ-15 is acceptable.

In most of the studies concerning the reproducibility of questionnaires, no information was found about the ICC used. Test-retest reliability could be overestimated if the wrong ICC is used [4,20]. So when reporting on reproducibility, the statistical techniques that are used, should be explained extensively. Differences found between the current study and other studies could be explained by the method used. Over an average 4-week time interval, the ICC for a German version of the MPI in patients with chronic musculoskeletal pain was 0.57 for the subscale $MCI_{control}$ and ≥0.72 for the other subscales [35]. The ICC's are better than in the present manuscript, but no information is available over the type of ICC being used in the German version. As in the present study, test-retest stability of a DV of the HADS and its subscales was found high in a general population of young adults (mean test-retest interval of 22 days) [13], but a Pearson product-moment correlation coefficient was used. Retest reliability of a German version of the HADS showed a high correlation (r>0.80) over a 2-weeks

interval, which decreased with longer time intervals [36], but the applied correlation coefficient was not defined.

The test-retest reliability described as ICC is often presented in publications. However, less information is available on the standard error of the measurement and minimum detectable changes, which are essential for the interpretation of important clinical changes. However, the present results are similar to the little information found in the literature, except for the SF-36. Steffen and Seney [37] found for the $SF\text{-}36_{PF}$, the scale most often used by physical therapists, an $MDC_{95\%}$ value of 28%. This differs from our results, but again, the study was performed on a group of patients with Parkinson disease. The Norwegian version of the PCS showed a SEM of 4.6 points and a $MDC_{95\%}$ minimum detectable change estimation of 12.8 points [31], which is similar to our results. In a previous study, the FV of the OMPQ had a $SEM_{agreement}$ of 10.12 (10% of the mean) and a $MDC_{95\%}$ of 28.1 points [9], which is close to the present DV. The Hungarian version of the QBDS had a SEM of 5.2 (11% of the mean) and a $MDC_{95\%}$ of 14 points [27]; close to the current results. The Italian version of the PCS demonstrated a MDC of 10.45 [32], similar to the outcome in this study.

The most surprising result in this study is the unsatisfactory test-retest reproducibility of some subscales of the SF-36 showed. The subscales of the FV and DV of the $SF\text{-}36_{RP}$ and of the $SF\text{-}36_{EM}$ demonstrated very low ICC-values. Also the FV $SF\text{-}36_{BP}$ and the DV $SF\text{-}36_{VT}$ showed very low ICC-values. This is not so surprising because these subscales are based on a very low number of items. A small change in the response could induce a big change in the total score. Differences with results of other studies, as explained above, could be a consequence of the longer time interval, the specificity of the population, but also by the fact that this questionnaire was part of a group of questionnaires (which makes it also harder for the patient to recall what the previous answer was). To confirm or reject this low ICC, these specific scales should be tested on a larger group of NS-CLBP patients.

Limitations

The combination of a wide range of questionnaires provides the therapist with a complete screening and follow-up of for the French and Dutch-speaking patients. However, filling in the battery of questionnaires is taking about 45 minutes of the patients' time. This is quite long and could influence the concentration. The electronic version may overcome this problem. The patients can fill in the

questionnaire at home, at the office or at the hospital and can choose when it best suits. For the clinicians the electronic version saves a lot of time, because the calculation of the scores and the reporting of these can be automatically generated. The system implies that all questions should be answered - otherwise the questionnaires cannot be saved - consequently, no data will be missed. If no electronic device is available, the patient could fill in a paper version of the series of questionnaires. Although this will imply a lot of additional work to the clinician, extensive research showed that paper and electronic version of self-report questionnaires are generally equivalent [38, 39].

Another limitation of this study is the absence of known minimum important changes (MCIC) for most of the questionnaires included in the battery. Further research should compare the $MDC_{95\%}$ with the MIC [4] to determine with certainty that the MDC is small enough.

The proportion of males to females, which is not balanced in this study, could question the validity of the results. In the French speaking population only 9% were female; in the Dutch speaking groups 16% were female. However, this proportion is common in a military population mainly consisting of men. In the Belgian military population, only about 8% are female. Accordingly, about 7% females are reported in the armies of the United Kingdom, the Netherlands and France and Jahnke et al. [39] mentioned about 14% females on active duty in the US. The subsample of women in our study was too small to investigate the influence of gender on test-retest reliability. Research about the influence of gender in this regard is lacking and future studies should consider examining the test-retest reliability of self-report questionnaires separately for these two groups.

In conclusion, given the good reliability observed in the self-report questionnaires used in this study, this battery can be used for French- and Dutch speaking patients in future research. The clinical usefulness of the battery of questionnaires, specific to the NS-CLBP population will be further explored by establishing cut-off scores for the screening questionnaires and by investigating responsiveness of the outcome questionnaires.

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Inventaire multidimensionnel de la douleur

(MPI partie 1)

Avant de commencer, veuillez répondre aux 2 questions préliminaires ci-dessous :

1. Certaines questions de ce questionnaire font référence à votre "personne de confiance". Une "personne de confiance" est une personne avec qui vous vous sentez très proche. Ce terme inclut toute personne que vous côtoyez régulièrement ou peu fréquemment. Il très important d'identifier quelqu'un comme étant votre "personne de confiance". Veuillez indiquer ci-dessous qui est votre personne de confiance (cochez une proposition) :

- ☐ *Conjoint / partenaire / compagnon*
- ☐ *Colocataire / camarade de chambre*
- ☐ *Ami / voisin*
- ☐ *Enfant / autre membre de la famille*
- ☐ *Autre (veuillez préciser)*

2. Vivez-vous actuellement avec cette personne? Oui / Non

Quand vous répondrez aux questions des pages suivantes qui concernent votre "personne de confiance", répondez toujours en vous référant à la personne spécifique mentionnée ci-dessus.

Dans les 20 questions suivantes, décrivez votre douleur et la façon dont elle affecte votre vie. En-dessous de chaque question se trouve une échelle pour indiquer votre réponse. Lisez attentivement chaque question et entourez un chiffre sur l'échelle se trouvant sous cette question pour indiquer la proposition qui correspond le mieux à votre situation.

1. Evaluez le niveau de votre douleur en ce moment. 0 1 2 3 4 5 6 *Aucune douleur* — *Douleur très intense*	
2. En général, à quel point votre douleur nuit-elle à vos activités quotidiennes? 0 1 2 3 4 5 6 *Pas d'interférence* — *Interférence extrême*	
3. Depuis qu'elle existe, à quel point votre douleur a-t-elle modifié votre capacité à travailler ? 0 1 2 3 4 5 6 *Aucun changement* — *Changement extrême* ☐ Cochez ici, si vous ne travaillez plus pour des raisons autres que votre douleur.	
4. A quel point votre douleur a-t-elle changé la satisfaction ou le plaisir que vous procure la participation à des activités sociales et récréatives ? 0 1 2 3 4 5 6 *Aucun changement* — *Changement extrême*	
5. A quel point votre personne de confiance vous soutient-elle par rapport à votre douleur? 0 1 2 3 4 5 6 *Aucun soutien* — *Très bon soutien*	
6. Evaluer votre humeur générale au cours de <u>la dernière semaine</u>. 0 1 2 3 4 5 6 *Moral extrêmement bas* — *Très bon moral*	

7. En moyenne, quelle a été l'intensité de votre douleur au cours de <u>la dernière semaine</u> ? 0 1 2 3 4 5 6 *Pas intense du tout* *Extrêmement intense*	
8. A quel point votre douleur a-t-elle changé votre capacité à participer à des activités récréatives ou à d'autres activités sociales? 0 1 2 3 4 5 6 *Aucun changement* *Changement extrême*	
9. A quel point votre douleur a-t-elle changé la satisfaction ou le plaisir que vous procurent vos activités familiales ? 0 1 2 3 4 5 6 *Aucun changement* *Changement extrême*	
10. A quel point votre personne de confiance s'inquiète-t-elle pour vous en raison de vos douleurs? 0 1 2 3 4 5 6 *Pas inquiète du tout* *Extrêmement inquiète*	
11. A quel point avez-vous l'impression d'avoir eu le contrôle sur votre vie, au cours de <u>la dernière semaine</u> ? 0 1 2 3 4 5 6 *Aucun contrôle* *Très bon contrôle*	
12. A quel point souffrez-vous à cause de votre douleur? 0 1 2 3 4 5 6 *Aucune souffrance* *Souffrance extrême*	
13. A quel point votre douleur a-t-elle changé vos relations avec votre conjoint ou votre famille? 0 1 2 3 4 5 6 *Aucun changement* *Changement extrême*	
14. A quel point votre douleur a-t-elle changé la satisfaction ou le plaisir que vous procure votre travail ? 0 1 2 3 4 5 6 *Aucun changement* *Changement extrême* ☐ Cochez ici, si vous ne travaillez pas en ce moment.	
15. A quel point votre personne de confiance est-il attentif à votre problème de douleur? 0 1 2 3 4 5 6 *Pas du tout attentive* *Extrêmement attentive*	
16. A quel point avez-vous l'impression d'avoir été en mesure de faire face à vos problèmes au cours de <u>la dernière semaine</u> ? 0 1 2 3 4 5 6 *Pas du tout* *Extrêmement bien*	
17. A quel point votre douleur a-t-elle changé votre capacité à effectuer les tâches ménagères ? 0 1 2 3 4 5 6 *Aucun changement* *Changement extrême*	

18. A quel point avez-vous été irritable au cours <u>de la dernière semaine</u>? 0 1 2 3 4 5 6 *Pas du tout irritable* *Extrêmement irritable*	
19. A quel point votre douleur a-t-elle changé vos relations d'amitié avec des personnes autres que votre famille ? 0 1 2 3 4 5 6 *Aucun changement* *Changement extrême*	
20. A quel point avez-vous été tendue ou anxieux/se au cours de <u>la dernière semaine</u>? 0 1 2 3 4 5 6 *Pas du tout tendu ou anxieux* *Extrêmement tendu ou anxieux*	
Score total	

Développé par Kerns, R. Turk D.C., Rudy T.E. (1985)

Traduit par Van Damme et al. (2014)

Multidimensionele Pijnvragenlijst

(MPI deel 1)

Vooraleer u start met het invullen van de vragenlijst, gelieve de 2 volgende vragen te beantwoorden:

1. Sommige vragen verwijzen naar een vertrouwenspersoon. Een vertrouwenspersoon is een persoon met wie u zich nauw betrokken voelt. Dit kan een persoon zijn die u regelmatig of sporadisch tegenkomt. Het is zeer belangrijk iemand te identificeren als vertrouwenspersoon. Kruis aan wie u beschouwt als vertrouwenspersoon.

☐ *Echtgenoot/partner*

☐ *Huisgenoot*

☐ *Vriend, buur*

☐ *Kind of ander familielid*

☐ *Andere : ……*

2. Woont u tegenwoordig met deze persoon? Ja / Neen

Wanneer er in de onderstaande vragen verwezen wordt naar uw vertrouwenspersoon, gelieve steeds uw antwoorden te kiezen met betrekking tot deze persoon.

We willen graag iets meer weten over uw pijn en hoe de pijn uw leven beïnvloedt. In deze lijst krijgt u 20 vragen voorgelegd. Onder elke vraag is een schaal aangebracht waarop u uw antwoord kunt aangeven. Lees elke vraag zorgvuldig. Omcirkel het nummer dat het beste bij uw situatie past.

1. Geef aan hoeveel pijn u op dit moment heeft. 0 1 2 3 4 5 6 *Geen pijn* — *Heel veel pijn*	
2. In welke mate belemmert uw pijn uw dagelijkse bezigheden? 0 1 2 3 4 5 6 *Geen belemmering* — *Heel veel belemmering*	
3. In welke mate heeft de pijn uw vermogen te werken veranderd, sinds de pijn begon? 0 1 2 3 4 5 6 *Geen verandering* — *Heel veel verandering* ☐ Kruis dit vakje aan, indien u niet meer werkt om een andere reden dan de pijn.	
4. In hoeverre heeft uw pijn de mate van tevredenheid of plezier dat u ondervindt door deelname aan sociale en ontspannende activiteiten veranderd?	

0 1 2 3 4 5 6 *Geen verandering* *Heel veel verandering*	
5. Hoe ondersteunend of behulpzaam is uw vertrouwenspersoon voor u met betrekking tot uw pijn? 0 1 2 3 4 5 6 *Helemaal niet ondersteunend* *Heel erg ondersteunend*	
6. Geef aan hoe uw stemming was <u>de afgelopen week</u>. 0 1 2 3 4 5 6 *Heel slechte stemming* *Heel goede stemming*	
7. Gemiddeld genomen, hoe erg was uw pijn <u>de afgelopen week</u>? 0 1 2 3 4 5 6 *Helemaal niet erg* *Heel erg*	
8. In hoeverre wordt u door de pijn belemmerd bij deelname aan ontspanning en sociale contacten? 0 1 2 3 4 5 6 *Helemal niet* *Heel erg*	
9. In hoeverre heeft uw pijn de mate van tevredenheid of plezier dat u ondervindt door deelname aan gezinsbezigheden veranderd? 0 1 2 3 4 5 6 *Geen verandering* *Heel veel verandering*	
10. Hoe bezorgd is uw vertrouwenspersoon vanwege uw pijn? 0 1 2 3 4 5 6 *Helemaal niet bezorgd* *Heel erg bezorgd*	
11. Heeft u het gevoel dat u <u>de afgelopen week</u> uw leven onder controle had? 0 1 2 3 4 5 6 *Helemaal geen controle* *Volledig onder controle*	
12. In hoeverre lijdt u onder uw pijn? 0 1 2 3 4 5 6 *Geen lijden* *Heel veel lijden*	
13. In welke mate heeft uw pijn uw relatie met uw echtgeno(o)t(e)/partner of familie veranderd? 0 1 2 3 4 5 6	

Geen verandering *Heel veel verandering*	
14. Hoeveel heeft uw pijn de mate van bevrediging of plezier in uw werk veranderd? 0 1 2 3 4 5 6 *Geen verandering* *Heel veel verandering* ☐ Zet hier een kruisje als u momenteel niet werkt.	
15. Hoeveel aandacht schenkt uw vertrouwenspersoon aan uw pijn? 0 1 2 3 4 5 6 *Helemaal geen aandacht* *Heel veel aandacht*	
16. In welke mate was u <u>de afgelopen week</u>, naar uw idee, in staat uw problemen het hoofd te bieden? 0 1 2 3 4 5 6 *Helemaal niet in staat* *Heel goed in staat*	
17. In welke mate heeft uw pijn de mogelijkheid tot het uitvoeren van huishoudelijke werkzaamheden veranderd? 0 1 2 3 4 5 6 *Geen verandering* *Heel veel verandering*	
18. Hoe prikkelbaar bent u <u>de afgelopen week</u> geweest? 0 1 2 3 4 5 6 *Helemaal niet prikkelbaar* *Erg prikkelbaar*	
19. In hoeverre zijn vriendschappelijke contacten, buiten uw gezin, veranderd of beïnvloed door de pijn? 0 1 2 3 4 5 6 *Geen verandering* *Zeer grote verandering*	
20. Hoe gespannen of angstig was u gedurende de afgelopen week? 0 1 2 3 4 5 6 *Helemaal niet gespannen* *Heel erg gespannen*	
Totale score	

Ontiwkkeld door Kerns, R. Turk D.C., Rudy T.E. (1985)

Vertaald door Van Damme B. et al. (2014)

QUESTIONNAIRE ÖREBRO

(ÖMPQ)

Date:

Nom:

Date de naissance:

Sexe: ☐ homme
☐ femme

Situation professionnelle actuelle:

☐ travail rémunéré (employé ou indépendant)
☐ travail à domicile sans revenus
☐ retraité
☐ étudiant
☐ sans emploi
☐ autre:…….

Date début du congé de maladie (si d'application) : …….

Ces questions vous concernent si vous avez des douleurs au niveau du dos, des épaules ou de la nuque. Lisez-les questions attentivement et répondez-y avec précision. Ne prenez pas trop longtemps pour répondre aux questions. Il importe toutefois que vous répondiez à chacune des questions. Quelque soit votre situation, il y a toujours une réponse à donner.

	(nombre de cases x 2)
1. Où avez-vous mal? Cochez les cases appropriées. ☐ Nuque ☐ Haut du dos ☐ Jambe ☐ Epaules ☐ Bas du dos	
2. Au cours des 12 derniers mois, combien de jours n'avez-vous pas pu travailler à cause de vos douleurs? Cochez une case. ☐ 0 jours (1) ☐ 1-2 jours (2) ☐ 3-7 jours (3) ☐ 8-14 jours (4) ☐ 15-30 jours (5) ☐ 1 mois (6) ☐ 2 mois (7) ☐ 3-6 mois (8) ☐ 6-12 mois (9) ☐ plus d'un an (10)	
3. Depuis combien de temps avez-vous vos douleurs actuelles ? Cochez une case. ☐ 0-1 semaine (1) ☐ 2-3 semaines (2) ☐ 4-5 semaines (3) ☐ 6-7 semaines (4) ☐ 8-9 semaines (5) ☐ 10-11 semaines (6) ☐ 3-6 mois (7) ☐ 6-9 mois (8) ☐ 9-12 mois (9) ☐ > 1 an (10)	

4. Votre travail est-il physiquement lourd ou monotone ? Entourez un chiffre. **0 1 2 3 4 5 6 7 8 9 10** *Absolument pas* *Très lourd ou très monotone* ☐ *Sans emploi*	
5. Quelle était l'intensité de votre douleur pendant la semaine qui vient de s'écouler ? Entourez un chiffre. **0 1 2 3 4 5 6 7 8 9 10** *Pas de douleur* *Douleur maximale imaginable*	
6. En moyenne, de quelle intensité a été votre douleur au cours des trois derniers mois? Entourez un chiffre. **0 1 2 3 4 5 6 7 8 9 10** *Pas de douleur* *Douleur maximale imaginable*	
7. En moyenne, évaluez la fréquence des périodes douloureuses <u>au cours des trois derniers mois</u> ? Entourez un chiffre. **0 1 2 3 4 5 6 7 8 9 10** *Jamais* *Tout le temps*	
8. Considérant tout ce que vous pouvez faire pour lutter contre la douleur, au cours d'une journée normale, dans quelle mesure êtes-vous capable de la réduire ? Entourez un chiffre. **0 1 2 3 4 5 6 7 8 9 10** *Incapable de la diminuer* *Capable de la diminuer complètement*	**10-x**
9. Dans quelle mesure vous êtes-vous senti tendu ou anxieux au cours de la semaine qui vient de s'écouler? Entourez un chiffre. **0 1 2 3 4 5 6 7 8 9 10** *Complètement calme et relâché* *Aussi tendu et anxieux que je ne l'ai jamais été*	
10. Au cours de la semaine qui vient de s'écouler, à quel point avez-vous été gêné par un sentiment de dépression ? Entourez un chiffre. **0 1 2 3 4 5 6 7 8 9 10** *Pas du tout* *Extrêmement*	
11. A votre avis, quelle est l'ampleur du risque que votre douleur actuelle devienne persistante ? Entourez un chiffre. **0 1 2 3 4 5 6 7 8 9 10** *Aucun risque* *Risque très élevé*	
12. A votre avis, quelles sont vos chances que vous soyez capable de travailler dans six mois ? Entourez un chiffre. **0 1 2 3 4 5 6 7 8 9 10** *Aucune chance* *Très grande chance*	**10-x**

13. Si vous considérez vos activités professionnelles, votre hiérarchie (votre administration, votre direction…), votre salaire, vos perspectives de promotions, et vos collègues, à quel point êtes-vous satisfait de votre travail ? Entourez un chiffre. **0 1 2 3 4 5 6 7 8 9 10** *Pas satisfait du tout* *Totalement satisfait* ☐ *Sans emploi*	**10-x**
Les phrases ci-dessous ont été formulées par des personnes souffrant de douleurs dorsales. Pour chacune de ces déclarations, entourez un chiffre de 0 à 10 pour indiquer à quel point les efforts physiques (comme se pencher, porter, se promener ou conduire la voiture) peuvent affecter votre douleur.	
14. Des efforts physiques aggravent ma douleur. **0 1 2 3 4 5 6 7 8 9 10** *Absolument pas d'accord* *Tout à fait d'accord*	
15. Une augmentation de la douleur est un signe que je devrais arrêter ce que je suis en train de faire jusqu'à ce que la douleur diminue. **0 1 2 3 4 5 6 7 8 9 10** *Absolument pas d'accord* *Tout à fait d'accord*	
16. Je ne devrais pas faire mes activités normales, y compris mon travail, avec ma douleur actuelle. **0 1 2 3 4 5 6 7 8 9 10** *Absolument pas d'accord* *Tout à fait d'accord*	
Voici une liste de cinq activités. Veuillez entourer le chiffre qui décrit le mieux votre capacité actuelle à participer à chacune de ces activités.	
17. Je peux faire un travail léger pendant une heure. **0 1 2 3 4 5 6 7 8 9 10** *Pas possible à cause de la douleur* *Tout à fait possible sans que la douleur ne m'en empêche*	**10-x**
18. Je peux me promener pendant une heure. **0 1 2 3 4 5 6 7 8 9 10** *Pas possible à cause de la douleur* *Tout à fait possible sans que la douleur ne m'en empêche*	**10-x**
19. Je peux faire les tâches ménagères habituelles. **0 1 2 3 4 5 6 7 8 9 10** *Pas possible à cause de la douleur* *Tout à fait possible sans que la douleur ne m'en empêche*	**10-x**
20. Je peux faire les courses de la semaine. **0 1 2 3 4 5 6 7 8 9 10** *Pas possible à cause de la douleur* *Tout à fait possible sans que la douleur ne m'en empêche*	**10-x**

21. Je peux dormir la nuit. **0 1 2 3 4 5 6 7 8 9 10** *Pas possible à cause de la douleur* *Tout à fait possible sans que la douleur ne m'en empêche*	**10-x**
Score total	

Développé par Linton & Hallden (1996)
Traduit et validé par Nonclerq & Berquin
Adapté par Van Damme et al. (2014)

ÖREBRO VRAGENLIJST: SCREENING MUSCULOSKELETALE PIJN

(ÖMPQ)

Datum:

Naam:

Geboortedatum:

Geslacht: ☐ man
☐ vrouw

Huidige werksituatie*:

☐ betaald werk ☐ studeren
☐ onbetaald werk thuis ☐ werkloos
☐ gepensioneerd ☐ anders:……..

Datum begin ziektemelding (indien werkongeschikt):

Deze vragen en uitspraken zijn op u van toepassing als u pijn hebt zoals rug-, schouder- of nekpijn. Lees de vragen aandachtig door en beantwoord elke vraag zorgvuldig. Denk niet te lang na over de vragen. Het is wel belangrijk dat u elke vraag beantwoordt. Er is altijd een antwoord voor mogelijk uw situatie.

1. Waar hebt u pijn? Duid de betreffende zone(s) aan. ☐ Nek ☐ Bovenrug ☐ Been ☐ Schouder ☐ Lage rug	**X2**
2. Hoeveel dagen bent u de afgelopen 12 maanden afwezig geweest op uw werk als gevolg van uw pijnklachten? Duid één antwoord aan. ☐ 0 dagen(1) ☐ 1-2 dagen (2) ☐ 3-7 dagen (3) ☐ 8-14 dagen (4) ☐ 15-30 dagen (5) ☐ 1 maand (6) ☐ 2 maanden (7) ☐ 3-6 maanden (8) ☐ 6-12 maanden (9) ☐ > 1 jaar (10)	
3. Hoe lang hebt u de huidige pijnklachten? Duid één antwoord aan. ☐ 0-1 week (1) ☐ 2-3 weken (2) ☐ 4-5 weken (3) ☐ 6-7 weken (4) ☐ 8-9 weken (5) ☐ 10-11 weken (6) ☐ 3-6 maanden (7) ☐ 6-9 maanden (8) ☐ 9-12 maanden (9) ☐ > 1 jaar (10)	

4. Is uw werk zwaar of eentonig? Omcirkel één cijfer. **0 1 2 3 4 5 6 7 8 9 10** *Helemaal niet* *Zeer zwaar of eentonig* ☐ *Niet aan het werk*	
5. Hoe zou u de pijn beoordelen die u de afgelopen week hebt gehad? Omcirkel één cijfer. **0 1 2 3 4 5 6 7 8 9 10** *Geen pijn* *Ergst denkbare pijn*	
6. Hoe erg was uw pijn gedurende de afgelopen 3 maanden gemiddeld? Omcirkel één cijfer. **0 1 2 3 4 5 6 7 8 9 10** *Geen pijn* *Ergst denkbare pijn*	
7. Hoe vaak hebt u gemiddeld de laatste 3 maanden periodes van pijn gehad? Omcirkel één cijfer. **0 1 2 3 4 5 6 7 8 9 10** *Nooit* *Altijd*	
8. Als u rekening houdt met alles wat u doet om met de pijn om te gaan, in welke mate bent u op een gemiddelde dag in staat om pijn te verminderen? Omcirkel één cijfer. **0 1 2 3 4 5 6 7 8 9 10** *Kan de pijn helemaal niet verminderen* *Kan de pijn totaal verminderen*	**10-x**
9. Hoe gespannen of angstig hebt u zich in de afgelopen week gevoeld? Omcirkel één cijfer. **0 1 2 3 4 5 6 7 8 9 10** *Helemaal niet gespannen of angstig* *Zeer gespannen of angstig*	
10. Hoeveel last hebt u de afgelopen week gehad van sombere gevoelens? Omcirkel één cijfer. **0 1 2 3 4 5 6 7 8 9 10** *Helemaal niet* *Zeer vaak*	
11. Hoe groot is volgens u het risico dat uw huidige pijn blijft bestaan? Omcirkel één cijfer. **0 1 2 3 4 5 6 7 8 9 10** *Geen risico* *Zeer hoog risico*	
12. Hoe groot is volgens u de kans dat u binnen 6 maanden in staat bent te werken? Omcirkel een cijfer. **0 1 2 3 4 5 6 7 8 9 10** *Geen kans* *Zeer grote kans*	**10-x**
13. Als u rekening houdt met uw werkzaamheden, de leiding, salaris, promotiekansen en	**10-x**

collega's: hoe tevreden bent u dan met uw werk? Omcirkel één cijfer. **0 1 2 3 4 5 6 7 8 9 10** *Helemaal niet tevreden* *Volledig tevreden* ☐ *Niet aan het werk*	
De hierna volgende uitspraken hebben andere mensen over hun rugpijn gegeven. Omcirkel bij elke verklaring een cijfer van 0 tot 10 om aan te geven in hoeverre lichamelijke inspanning zoals buigen, tillen, wandelen of autorijden uw rug zou beïnvloeden.	
14. Lichamelijke inspanning verergert mijn pijnklachten. Omcirkel één cijfer. **0 1 2 3 4 5 6 7 8 9 10** *Volledig oneens* *Volledig eens*	
15. Een toename van de pijnklachten is een teken dat ik moet stoppen met wat ik aan het doen ben tot de pijn is verminderd. Omcirkel één cijfer. **0 1 2 3 4 5 6 7 8 9 10** *Volledig oneens* *Volledig eens*	
16. Met mijn huidige pijn zou ik mijn gewone dagelijkse activiteiten, inclusief mijn werk, niet moeten doen. Omcirkel één cijfer. **0 1 2 3 4 5 6 7 8 9 10** *Volledig oneens* *Volledig eens*	
Hieronder volgt een lijst van 5 activiteiten. Omcirkel het cijfer dat het beste omschrijft in hoeverre u op dit moment in staat bent om aan elk van deze activiteiten deel te nemen.	
17. Ik kan gedurende een uur lichte werkzaamheden uitvoeren. **0 1 2 3 4 5 6 7 8 9 10** *Kan ik niet vanwege pijn* *Kan ik doen zonder dat pijn mij hindert*	**10-x**
18. Ik kan een uur wandelen. **0 1 2 3 4 5 6 7 8 9 10** *Kan ik niet vanwege pijn* *Kan ik doen zonder dat pijn mij hindert*	**10-x**
19. Ik kan gewone huishoudelijke taken verrichten. **0 1 2 3 4 5 6 7 8 9 10** *Kan ik niet vanwege pijn* *Kan ik doen zonder dat pijn mij hindert*	**10-x**
20. Ik kan de wekelijkse boodschappen doen. **0 1 2 3 4 5 6 7 8 9 10** *Kan ik niet vanwege pijn* *Kan ik doen zonder dat pijn mij hindert*	**10-x**

21. Ik kan 's nachts slapen. **0 1 2 3 4 5 6 7 8 9 10** *Kan ik niet vanwege pijn* *Kan ik doen zonder dat pijn mij hindert*	**10-x**
Totale Score	

Ontwikkeld door Linton & Hallden (1996)

Vertaald door Van Damme et al. (2014)

Questionnaire sur la santé du patient - Symptômes physiques

(PHQ-15)

Au cours des <u>4 dernières semaines</u>, à quel point avez-vous été gêné par les problèmes suivants ?

		Valeur Colonne:	**Absolument pas gêné** ***(0)***	**Un peu gêné** ***(1)***	**Fort gêné** ***(2)***
a.	Maux d'estomac		☐	☐	☐
b.	Maux de dos		☐	☐	☐
c.	Douleurs aux bras, aux jambes ou aux articulations (genoux, hanches, etc.)		☐	☐	☐
d.	Crampes menstruelles ou autres problèmes liés à votre cycle menstruel **(uniquement pour les femmes)**		☐	☐	☐
e.	Maux de tête		☐	☐	☐
f.	Douleurs à la poitrine		☐	☐	☐
g.	Vertiges		☐	☐	☐
h.	Evanouissements		☐	☐	☐
i.	Sensation que votre cœur bat plus fort ou qu'il s'emballe		☐	☐	☐
j.	Essoufflements		☐	☐	☐
k.	Douleurs ou problèmes pendant les rapports sexuels		☐	☐	☐
l.	Constipation, selles molles ou diarrhée		☐	☐	☐
m.	Nausées, flatulences ou indigestion		☐	☐	☐
n.	Impression de fatigue ou de manque d'énergie		☐	☐	☐
o.	Troubles du sommeil		☐	☐	☐

Sous-total colonne (nombre de x * valeur colonne)	0		
Score total (Colonne1+Colonne2+Colonne3)			

Développé par les Drs. Robert Spitzer, Janet B.W. Williams, Kurt Kroenke et leurs collègues, avec une bourse de formation de Pfizer Inc.

Traduit par Van Damme et al. (2014)

Patiënten Gezondheidsvragenlijst - Lichamelijke symptomen

(PHQ-15)

Hoeveel last heeft u de afgelopen 4 weken gehad van één of meer van de volgende problemen?

		Kolomwaarde:	**Helemaal geen last** ***(0)***	**Een beetje last** ***(1)***	**Veel last** ***(2)***
a.	Buikpijn		☐	☐	☐
b.	Rugpijn		☐	☐	☐
c.	Pijn in uw armen, benen, of gewrichten (knieën, heupen, enz.)		☐	☐	☐
d.	Menstruele krampen of andere problemen tijdens uw menstruatie ***ALLEEN VROUWEN***		☐	☐	☐
e.	Hoofdpijn		☐	☐	☐
f.	Pijn in de borststreek		☐	☐	☐
g.	Duizeligheid		☐	☐	☐
h.	Flauwvallen, episodes van flauwte		☐	☐	☐
i.	Bonzend hart of hartkloppingen		☐	☐	☐
j.	Kortademigheid		☐	☐	☐
k.	Pijn of problemen bij geslachtsgemeenschap		☐	☐	☐
l.	Constipatie, dunne ontlasting of diarree		☐	☐	☐
m.	Misselijkheid, winderigheid of spijsverteringsproblemen		☐	☐	☐
n.	Gevoel van vermoeidheid of weinig energie		☐	☐	☐
o.	Slaapstoornissen		☐	☐	☐

Subtotaal kolom (aantal x * kolomwaarde)	0		
Totale Score (Kolom1+Kolom2+Kolom3)			

Ontwikkeld door Drs. Robert Spitzer, Janet B.W. Williams, Kurt Kroenke en collegae, met onderwijstoelage van Pfizer Inc.

Vertaald door Van Damme et al. (2014)

Quebec schaal voor functionele dysfunctie

(QBPDI)

Ce questionnaire porte sur la façon dont vos maux de dos affectent votre vie quotidienne. Les personnes souffrant de maux de dos trouvent parfois difficile d'entreprendre certaines activités quotidiennes. Nous aimerions savoir si vous éprouvez des difficultés à réaliser les activités énumérées ci-dessous en raison de votre douleur au dos. Il y a une échelle de 0 à 5 pour chaque activité. Veuillez faire un seul choix pour chaque activité (ne passez aucune activité) en entourant le chiffre vous correspondant le mieux.
Aujourd'hui, éprouvez-vous des difficultés à accomplir les activités suivantes en raison de votre douleur au dos ?

		Aucune difficulté	Difficulté minime	Un peu difficile	Difficile	Très difficile	Impossible à faire
1.	Sortir du lit	**0**	**1**	**2**	**3**	**4**	**5**
2.	Dormir toute la nuit	**0**	**1**	**2**	**3**	**4**	**5**
3.	Vous retourner dans le lit	**0**	**1**	**2**	**3**	**4**	**5**
4.	Circuler en voiture	**0**	**1**	**2**	**3**	**4**	**5**
5.	Rester debout pendant 20-30 minutes	**0**	**1**	**2**	**3**	**4**	**5**
6.	Rester assis sur une chaise pendant plusieurs heures	**0**	**1**	**2**	**3**	**4**	**5**
7.	Monter un seul étage à pied	**0**	**1**	**2**	**3**	**4**	**5**
8.	Marcher un peu (300-400m)	**0**	**1**	**2**	**3**	**4**	**5**
9.	Marcher quelques kilomètres	**0**	**1**	**2**	**3**	**4**	**5**
10.	Atteindre des étagères en hauteur	**0**	**1**	**2**	**3**	**4**	**5**
11.	Lancer une balle	**0**	**1**	**2**	**3**	**4**	**5**
12.	Courir une centaine de mètres	**0**	**1**	**2**	**3**	**4**	**5**
13.	Sortir des aliments du réfrigérateur	**0**	**1**	**2**	**3**	**4**	**5**
14.	Faire votre lit	**0**	**1**	**2**	**3**	**4**	**5**
15.	Enfiler vos chaussettes/collants	**0**	**1**	**2**	**3**	**4**	**5**
16.	Vous pencher pour nettoyer la baignoire p.e.	**0**	**1**	**2**	**3**	**4**	**5**
17.	Déplacer une chaise	**0**	**1**	**2**	**3**	**4**	**5**

		Aucune difficulté	Difficulté minime	Un peu difficile	Difficile	Très difficile	Impossible à faire
18.	Tirer ou pousser des portes lourdes	**0**	**1**	**2**	**3**	**4**	**5**
19.	Porter deux sacs de courses	**0**	**1**	**2**	**3**	**4**	**5**
20.	Soulever et transporter une grosse valise	**0**	**1**	**2**	**3**	**4**	**5**
	Sout-total Colonne						
	Score Total						

Développé par Kopec JA et al.

Vertaald door Van Damme et al. (2014)

Quebec-vragenlijst voor ADL-beperkingen

(QBPDI)

Onderstaande vragenlijst gaat over de manier waarop uw rugklachten uw dagelijks leven beïnvloeden. Mensen met rugklachten kunnen moeite hebben met het uitvoeren van sommige dagelijkse activiteiten. Wij willen graag weten of u moeite heeft met het uitvoeren van onderstaande activiteiten **vanwege uw rugklachten**. Voor elke activiteit is er een schaal van 0 tot 5. Wilt u bij iedere activiteit één antwoord kiezen (**geen activiteit overslaan**), en het daarbij behorende cijfer omcirkelen.

Heeft u vandaag moeite om de volgende activiteiten uit te voeren vanwege uw rugklachten?

		Totaal geen moeite	Nauwelijks moeite	Enige moeite	Veel moeite	Zeer veel moeite	Niet in staat
1.	Opstaan uit bed	**0**	**1**	**2**	**3**	**4**	**5**
2.	Een volledige nacht doorslapen	**0**	**1**	**2**	**3**	**4**	**5**
3.	Omdraaien in bed	**0**	**1**	**2**	**3**	**4**	**5**
4.	Zich verplaatsen met de auto	**0**	**1**	**2**	**3**	**4**	**5**
5.	Langdurig staan (20 tot 30 minuten)	**0**	**1**	**2**	**3**	**4**	**5**
6.	Enkele uren op een stoel zitten	**0**	**1**	**2**	**3**	**4**	**5**
7.	Eén verdiep trappen oplopen	**0**	**1**	**2**	**3**	**4**	**5**
8.	Een klein eindje wandelen (300-400 m)	**0**	**1**	**2**	**3**	**4**	**5**
9.	Enkele kilometers wandelen	**0**	**1**	**2**	**3**	**4**	**5**
10.	Naar een hoge plank reiken	**0**	**1**	**2**	**3**	**4**	**5**
11.	Een bal werpen	**0**	**1**	**2**	**3**	**4**	**5**
12.	Een eindje hardlopen (+/-100m)	**0**	**1**	**2**	**3**	**4**	**5**
13.	Iets uit de koelkast nemen	**0**	**1**	**2**	**3**	**4**	**5**
14.	Het bed opmaken	**0**	**1**	**2**	**3**	**4**	**5**
15.	Sokken of panty aantrekken	**0**	**1**	**2**	**3**	**4**	**5**
16.	Vooroverbuigen om bv de badkuip te reinigen	**0**	**1**	**2**	**3**	**4**	**5**
17.	Een stoel verplaatsen	**0**	**1**	**2**	**3**	**4**	**5**
		Totaal geen moeite	**Nauwelijks moeite**	**Enige moeite**	**Veel moeite**	**Zeer veel moeite**	**Niet in staat**

18.	Een zware deur opentrekken of openduwen	**0**	**1**	**2**	**3**	**4**	**5**
19.	2 tassen met boodschappen dragen	**0**	**1**	**2**	**3**	**4**	**5**
20.	Een zware koffer optillen en dragen	**0**	**1**	**2**	**3**	**4**	**5**
	Totaal Kolom						
	Totale score						

Ontwikkeld door Kopec JA et al.

Vertaald door Van Damme et al. (2014)

Echelle Tampa pour la kinésiophobie (TSK)

Cochez la réponse qui correspond le mieux à vos sentiments (seule une réponse possible).

		Absolument pas d'accord	Pas tout à fait d'accord	Relativement d'accord	Tout à fait d'accord
1.	J'ai peur de me blesser lors d'une activité physique.	**1**	**2**	**3**	**4**
2.	Ma douleur s'intensifierait si je tentais de la surmonter.	**1**	**2**	**3**	**4**
3.	Mon corps me dit que quelque chose ne va vraiment pas.	**1**	**2**	**3**	**4**
4.	Ma douleur serait probablement soulagée si je faisais de l'exercice physique.	**1**	**2**	**3**	**4**
5.	Les autres ne prennent pas mon état de santé suffisamment au sérieux.	**1**	**2**	**3**	**4**
6.	Mon problème de douleur a fragilisé mon corps pour le reste de ma vie.	**1**	**2**	**3**	**4**
7.	La douleur signifie toujours que je me suis blessé(e).	**1**	**2**	**3**	**4**
8.	Même si quelque chose aggrave ma douleur, cela ne veut pas dire que c'est dangereux.	**1**	**2**	**3**	**4**
9.	J'ai peur de me blesser accidentellement.	**1**	**2**	**3**	**4**
10.	La meilleure façon d'empêcher que ma douleur s'aggrave est de m'assurer de ne pas faire des mouvements inutiles.	**1**	**2**	**3**	**4**
11.	Ma douleur ne serait pas si intense s'il ne se passait pas quelque chose de grave dans mon corps.	**1**	**2**	**3**	**4**
12.	Bien que je souffre de douleurs, je me sentirais mieux si j'étais physiquement actif(ve).	**1**	**2**	**3**	**4**
13.	La douleur m'indique quand je dois arrêter toute activité physique afin de ne pas me blesser.	**1**	**2**	**3**	**4**
14.	Il n'est pas prudent qu'une personne dans mon état de santé soit physiquement active.	**1**	**2**	**3**	**4**
15.	Je ne peux pas faire tout ce qu'une personne normale peut faire parce que j'ai plus de risques de me blesser.	**1**	**2**	**3**	**4**
16.	Bien que quelque chose me provoque d'importantes douleurs, je ne pense pas que ce soit vraiment grave.	**1**	**2**	**3**	**4**
17.	Personne ne devrait être obligé de faire des exercices lorsqu'il(elle) ressent de la douleur.	**1**	**2**	**3**	**4**
	Sous-total colonne				
	Score total				

Développé par Miller R.P., Kori S.H. and Todd D.D. (1991)

Traduit par Van Damme et al. (2014)

Tampa Schaal voor Kinesiofobie (TSK)

Geef van onderstaande beweringen aan in welke mate u het eens of oneens bent met deze bewering. Omcirkel het voor u best passend antwoord (slechts 1 antwoord mogelijk).

		in hoge mate mee oneens	Enigszins mee oneens	Enigszins mee eens	in hoge mate mee eens
1.	Ik ben bang dat ik een letsel zal oplopen als ik lichamelijk actief ben.	**1**	**2**	**3**	**4**
2.	Als ik me over mijn pijn zou proberen heen te zetten, zou de pijn erger worden.	**1**	**2**	**3**	**4**
3.	Mijn lichaam zegt me dat er iets gevaarlijk mis mee is.	**1**	**2**	**3**	**4**
4.	Mijn pijn zou waarschijnlijk minder worden als ik lichaamsoefeningen zou doen.	**1**	**2**	**3**	**4**
5.	Mijn gezondheidstoestand wordt door anderen niet serieus genoeg genomen.	**1**	**2**	**3**	**4**
6.	Door mijn pijnprobleem loopt mijn lichaam de rest van mijn leven gevaar.	**1**	**2**	**3**	**4**
7.	Mijn pijn betekent dat er sprake is van een letsel.	**1**	**2**	**3**	**4**
8.	Iets dat mijn pijnklachten verergert, hoeft nog niet gevaarlijk voor me te zijn.	**1**	**2**	**3**	**4**
9.	Ik ben bang om per ongeluk een letsel op te lopen.	**1**	**2**	**3**	**4**
10.	De veiligste manier om te voorkomen dat mijn pijn erger wordt, is gewoon oppassen dat ik geen onnodige bewegingen maak.	**1**	**2**	**3**	**4**
11.	Ik zou niet zoveel pijn hebben als er niet iets gevaarlijks aan de hand zou zijn met mijn lichaam.	**1**	**2**	**3**	**4**
12.	Hoewel ik pijn heb, zou ik er beter aan toe zijn als ik lichamelijk actief zou zijn.	**1**	**2**	**3**	**4**
13.	Mijn pijn zegt me wanneer ik moet stoppen met lichamelijke activiteit om geen letsel op te lopen.	**1**	**2**	**3**	**4**
14.	Voor iemand in mijn toestand is het echt af te raden om lichamelijk actief te zijn.	**1**	**2**	**3**	**4**
15.	Ik kan niet alles doen wat anderen doen, omdat ik te gemakkelijk letsel oploop.	**1**	**2**	**3**	**4**
16.	Zelfs als ik ergens veel pijn door krijg, geloof ik niet dat dat gevaarlijk is.	**1**	**2**	**3**	**4**
17.	Niemand zou lichamelijk actief moeten zijn als hij/zij pijn heeft.	**1**	**2**	**3**	**4**
	Subtotaal kolom				
	Totale Score				

Ontwikkeld door Miller R.P., Kori S.H. and Todd D.D. (1991)

Vertaald door Van Damme et al. (2014)

CHAPTER 4

Cut-off scores and minimal clinical important changes for screening and primary outcome self-report questionnaires in non-specific chronic low back pain

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ABSTRACT

Study Design. Prospective study

Objective. To define cut-off scores for screening questionnaires and minimal clinical important changes for evaluative questionnaires in patients with non-specific chronic low back pain (NS-CLBP).

Summary of Background Data. Although screening and evaluative questionnaires are widely used in the clinical setting and research, there is a lack of information about the cut-off scores and minimal clinical important changes for some of these questionnaires, which are crucial for clinical interpretation.

Methods. Cut-off scores were established on 198 patients with NS-CLBP for 3 screening questionnaires (the Tampa Scale for Kinesiophobia (TSK), the Orebro Musculoskeletal Pain Questionnaire (OMPQ) and the Patient Health Questionnaire 15 (PHQ-15)). External criteria were used and the optimal cut-off point was established by the receiver operating characteristics (ROC) curve. Seventy patients were evaluated before and after therapy to define a range of minimal clinical important changes (MCIC) for 5 evaluative questionnaires: (TSK, OMPQ, Quebec Back Pain Disability Scale (QBPDI), the Multidimensional Pain Inventory subscale pain (MPI_{pain}), the Total Physical Health Scale ($SF\text{-}36_{TPH}$) and the total score of the Short Form 36 ($SF\text{-}36_{TS}$)). This was done using 3 external criteria and 3 methods: the mean change score, the optimal cut-off point (ROC-curve) and the minimal detectable change.

Results. The TSK, the OMPQ and the PHQ-15 were all found to be discriminative tools, with cut-off points of 43.5, 89.5 and 11.5 respectively. A range of MCIC was proposed for each evaluative questionnaire. Moreover all these questionnaires were able to discriminate improved from non-improved patients except the TSK.

Conclusions. The TSK, OMPQ and the PHQ-15 are screening questionnaires able to discriminate between risk and non-risk patients according to the clinician's' opinion. As a consequence cut-off scores could be proposed. The QBPDI, the OMPQ, the $SF\text{-}36_{TPH,}$ $SF\text{-}36_{TS}$ and the MPI_{pain} are good evaluative questionnaires to detect changes in physical function, quality of life and pain experience respectively. Ranges of MCIC are presented which enable the researcher and the clinician to evaluate the clinical relevance of changes.

Key Words: Self-report questionnaires, cut-off scores, minimal clinical important changes, non-specific chronic low back pain, Tampa Scale for Kinesiophobia, Orebro Musculoskeletal Pain Questionnaires, Patient Health Questionnaire 15, Quebec Back Pain Disability Scale, Multidimensional Pain Inventory, Short Form 36

Key Points:

- Cut-off scores were established for the TSK, the OMPQ and the PHQ-15 in a NS-CLBP population.
- A range of MCIC was established for the TSK, the OMPQ, the QBPDI, the $MPI_{pain,}$ the SF-36_{TPH} and the SF-36_{TS}.
- The TSK, OMPQ and PHQ-15 are able to distinguish between risk and non-risk patients
- The QBPDI, the OMPQ, the SF-$36_{TPH,}$ SF-36_{TS} and the MPI_{pain} are able to discriminate between improved and non-improved patients.

Mini Abstract.

The present study examined the cut of scores of TSK, OMPQ and PHQ-15 in 198 patients with non-specific chronic low back pain and determined the range of minimal clinical important changes in TSK, OMPQ, QBPDI, $MPI_{pain,}$ SF-36_{TPH} and SF-36_{TS}.

INTRODUCTION

Self-report questionnaires are widely used for measuring health status or treatment outcomes in patients with non-specific chronic low back pain (NS-CLBP)[1]. However, the clinical interpretation of the questionnaires is complex, because information is missing about cut-off scores and minimal clinical important changes (MCIC).

Screening questionnaires are used to detect patients at risk.[2,3] The Tampa scale for kinesiophobia (TSK), the Orebro Musculoskeletal Pain Questionnaire (OMPQ) and the Patient Health Questionnaire 15 (PHQ-15) are examples of such questionnaires.[4] Cut-off scores (COS) are needed for each screening questionnaire in order to detect patients at risk. They exist for some screening questionnaires, but the interpretation of the results is often restricted to a particular situation or a specific population.[5] Furthermore, COS are mainly established for acute disorders[6] to alert for potential risk for chronicity. However, also in a chronic population the use of screening questionnaires can be useful to guide treatment. Also the applied method to define a COS should be controlled before accepting a score as a discriminating point between risk and non-risk patients. For example, Vlaeyen et al.[7] used a score of 37 to divide a sample of NS-CLBP patients in low and high responders on the TSK, based on the median score of this sample. Altough the goal of that study[7] was not to establish a clinical useful COS, clinicians tend to accept this score of 37 as a COS to detect patients with a clinical important kinesiophobia.

Evaluative questionnaires[8] need to be responsive enough to capture clinically important changes.[9] From a clinical perspective it is crucial to evaluate whether a change due to a therapeutic intervention is relevant. For research purposes, the size of the change in score that are clinically important needs to be determined. A MCIC is the smallest change in score in the domain of interest which patients perceive as beneficial and which would mandate a change in patient management.[10,11,12] MCIC are also population dependent and may vary in function of the duration of the complaints and the method used.[13,14] Therefore it is important that these values are established for the target population and comparison should be made between different methods.

The first aim of the present study is to establish cut-off scores for 3 screening questionnaires (TSK, PHQ-15 and OMPQ) in subjects with NS-CLBP. The second aim of the study is to evaluate the responsiveness and MCIC for 5 evaluative questionnaires (TSK, the OMPQ, the Quebec Back Pain

Disability Index (QBPDI), the multidimensional pain inventory part 1 subscale pain (MPI_{pain}), the Short Form Health Survey subscales total physical health ($SF\text{-}36_{PCS}$) and total score ($SF\text{-}36_{TS}$).

MATERIALS AND METHODS

Patient population and data collection

Patients with NS-CLBP were recruited from different locations: the Center of Musculoskeletal Medicine and Rehabilitation of the national Military Hospital, the physiotherapy department of the University Hospital Centre in Liège and different physiotherapy practices in Belgium. Inclusion criteria were: a minimum age of 18 years, having French or Dutch as native language, suffering from NS-CLBP with a history of more than three pain episodes during the past year or pain persisting for at least three months and never having completed these self-report questionnaires before. Patients with specific LBP or psychiatric disease were excluded from this study. After their visit to the medical doctor, they completed an electronic version of a series of questionnaires.[15] One hundred ninety eight patients accepted to participate to this study. Data of these patients were used to establish COS for the screening questionnaires. Among the 198 patients, 70 patients were asked to fill the questionnaires again after completing a non-standardized physiotherapy treatment to estimate the MCIC ranges for the evaluative questionnaires. The second set of questionnaires included the Patient Global Impression of Changes (PGIC).

Part 1: Screening questionnaires and COS (a cross sectional study)

Outcome measures

For this part of the study, data of 3 questionnaires were used: (1) the TSK[16]; (2) The PHQ-15[4,17]; (3) the OMPQ[6].

External criteria

During the first session between the patient and the clinician, the physician as well as the physiotherapist gave their opinion about the possible negative impact of yellow flags and kinesiophobia upon the prognosis of the patient, as external criteria for the TSK and the OMPQ,

respectively. They were blinded to the patient's questionnaires and were asked to answer the following questions.

(1) This patient (a) has serious yellow flags* and needs a psychological therapy to enhance the chance for a good prognosis; (b) has no serious yellow flags* and should have a good prognosis, without psychological therapy; (c) No opinion;

(2) This patient (a) is afraid of moving. Giving him/her exercises could be difficult. He/she needs psychological therapy before starting physiotherapy; (b) Is not afraid of moving and is ready to do some exercises; (c) No opinion.

The opinions of the physician and the physiotherapist were compared and if different, a consensus was reached. If no consensus was obtained between the physician and the physiotherapist or if the clinicians had no opinion, the patient was excluded from the study (N=1).

For the PHQ-15, a patient's score of the Modified Somatic Perception Questionnaire subscale of the Distress Risk and Assessment method ($DRAM_{MSPQ}$) greater than '12' was identified as an indication for multiple somatic complaining.[18]

** The clinicians received a list with examples of yellow flags:*

Yellow Flags are psychosocial factors that may indicate an increased risk to develop chronicity of LBP. Example given:

- *Attitude and thoughts about pain (catastrofizing, kinesiophobia, passive attitude, …)*
- *Behavior (lack of participation, medical shopping, drinking/ smoking…)*
- *Compensations (little benefit to go back to work, absenteeism, …)*
- *Diagnosis and treatment (contradictory diagnosis, dramatizing therapist, past history, …)*
- *Emotions (anxiety, depression, stress, feeling useless)*
- *Problems at work (motivation, bath work relations, low job satisfaction, high pressure, low levels of education)*
- *Problems at home (relationship, busy household ...)*
- *…*

Population

Data of 197 patients (161 men and 36 women) with NS-CLBP were used for this part of the study. The mean age was 42.43 (range: 18-67) and the mean duration of the NS-CLBP was 59.98 months (range: 3-385 months) (Table 1).

Table 1 Demographic data of the final patient population for estimation of cut-off scores

	Men (n=161)		Women (n=36)	
	Military (n=141)	Civilian (n=20)	Military (n=18)	Civilian (n= 18)
	Mean ± SD (min-max)	Mean ± SD (min-max)	Mean ± SD (min-max)	Mean ± SD (min-max)
Age	41.4 ± 9 (18-55)	50.87 ± 7.83 (37-67)	41.33 ± 11.35 (23-57)	45.82 ± 10.98 (31-65)
Weight	85.55 ± 12.7 (61-120)	80.85 ± 15.87 (52-127)	67.72 ± 8.512 (52-82)	70.88 ± 13.66 (52-102)
Length	179.94 ± 6.26 (160-194)	176.6 ± 7.37 (163-190)	166.61 ± 5.381 (158-177)	168.53 ± 8.22 (158-189)
Pain Intensity (VAS)	4.43 ± 2.39 (0-10)	5.95 ± 2.28 (1-10)	5.44 ± 2.40 (2-10)	5.44 ± 1.95 (1-8)
Pain Duration (months)	57.9 ± 79.15 (3-385)	69.05 ± 78.04 (3-256)	72 ± 76.47 (3-252)	54.17 ± 11.35 (23-57)

Table 2 Demographic data of the final patient population for estimation of MCIC ranges

	Men (n=50)		Women (n=16)	
	Military (n=41)	Civilian (n=9)	Military (n=6)	Civilian (n= 10)
	Mean ± SD (min-max)	Mean ± SD (min-max)	Mean ± SD (min-max)	Mean ± SD (min-max)
Age	43.02 ± 8.64 (22-55)	56 ± 8.63 (45-67)	40 ± 14.91 (23-57)	45.29 ± 10.03 (31-62)
Weight	88.95 ± 13.95 (61-117)	85.25 ± 20.73 (52-127)	68.33 ± 9.73 (60-82)	74.9 ± 12.7 (60-102)
Length	179.85 ± 6.31 (160-193)	179 ± 7.54 (170-190)	167.5 ± 6.59 (158-177)	172.2 ± 8.15 (158-189)
Pain Intensity (VAS)	4.29 ± (2.11 (0-8)	5.89 ± 2.93 (1-10)	4.33 ± 1.96 (2-7)	4.7 ± 2.11 (1-8)
Pain Duration (months)	77.71 ± 94.35 (3-364)	105.67 ± 95.56 (15-252)	74.83 ± 122.86 (11-324)	64.4 ± 65.44 (3-192)

MCIC= minimal clinical important changes

Statistical analysis

Bootstrap analysis[19] was performed in MATLAB to estimate the 95%CI of the cut-off score (10000 bootstrap samples). No significant differences were found between the French and Dutch population concerning the COS (95% confidence interval) for any of the three questionnaires. Therefore, data of both populations were analyzed together.

Further statistical analyses were performed with SPSS version 22 ($p<0.05$). To determine the optimal COS of the three questionnaires a receiver operating characteristics (ROC) curve was created for each questionnaire. The score at the point with the shortest distance from the top left corner was advocated as the optimal COS.[20] The discriminating power (risk or non-risk patients) of the screening tool was evaluated positively if the area under the ROC curve (AUC) was >0.5 with a significance level of $p<0.05$.

Part 2: Evaluative questionnaires, responsiveness and MCIC (a longitudinal study)

Outcome measures

For the longitudinal part of the study, data of five evaluative questionnaires were used: (1) the QBPDI to assess the functional disability post-treatment[21]; (2) MPI_{pain}[22]; (3) the TSK[16]; (4) the OMPQ[6],(5) the $SF\text{-}36_{TS}$ and the $SF\text{-}36_{PCS}$.[23]

External criteria

Deyo and Centor[24] proposed to use multiple external criteria if a golden standard is missing. Therefore three different external criteria were used in this study as measures of improvement: (1) the Clinical Global Impression of Change[25] (CGIC) as a clinician based criterion;[26-27] (2) 2 forms of the Patient Global Impression of Change (PGIC) as a patient based criterion.[28-29]

At the end of the therapy the physiotherapist completed a modified version of the CGIC[25], a seven point rating scale ranging from 1 (very much improved) through to 7 (very much worse), regarding to 3 different domains of patient's improvement:[27] pain, activity limitations and fear of movement.

The patient indicated post-treatment changes using a modified version of the PGIC. Patients were asked to score their improvement, regarding 5 different domains (pain, activity limitations, fear of

movement, emotions and quality of life), [27] using two different scales: (1) a 7-point rating scale ranging from 1 (no change) to 7 (a great deal better) ($PGIC_A$), (2) a 11-point numerical rating scale from 0 (much better) to 10 (much worse) ($PGIC_B$).

The external criteria were matched to the outcome measures as follows: (1) the QBPDI with the CGIC and the PGIC for activity limitations; (2) MPI_{pain} with the CGIC and the PGIC for pain; (3) the TSK with the CGIC and the PGIC for fear of movement; (4) the OMPQ with the PGIC for emotions; (5) the SF-36_{TS} with the PGIC for quality of life and the SF-36_{TPH} with the CGIC and the PGIC for activity limitations. A CGIC score < 3, a $PGIC_A$ >4 and a $PGIC_B$ <4 were set as a noticeable improvement.

Population

Patients who demonstrated deterioration, either by score on the CGIC or on the PGIC, were excluded from this study, because this group of patients was too small (N=4). Consequently, this study presents only MCIC for improvement. Data of 66 patients (50 men and 16 women) with NS-CLBP were used. The mean age was 44.08 (range 22-67) and the mean duration of the NS-CLBP was of 66 months (range 3-364 months) (Table 2).

Statistical analysis

All statistical analyses were performed with SPSS version 22 ($p<0.05$).

An anchor-based MCIC distribution method[13,14,26] was applied to estimate the MCIC for improvement on the different scales. As proposed by Van der Roer et al.[13] different statistical methods were used to determine a range of MCIC values for a population of NS-CLBP patients:

(1) Mean change scores: The change score was calculated by subtracting the follow-up score from the baseline score, except for the SF-36 where the change score was calculated by subtracting the baseline score from the follow-up score. This was done to ensure that improvement corresponded to a positive value. The mean change score was calculated three times, using the 3 different external criteria for noticeable improvement discussed previously: (1) the mean change score of all patients

who scored “2” on the CGIC, (2) the mean change score of all patients who scored “5” on the $PGIC_A$, (3) the mean change score of all patients who scored “3” on the $PGIC_B$.[10]

(2) Optimal cut-off point for improvement (COP_{imp}): Using the evaluative measure as a diagnostic test and an external criteria to dichotomize patients in ‘improved’ or ‘unchanged’, a ROC curve could be established for each evaluative measure.[23] Using alternatively the 3 different external criteria previously discussed (CGIC, $PGIC_A$ and $PGIC_B$), 3 ROC-curves were performed for each evaluative measure. The AUC was used to evaluate if the instrument could discriminate between improved and unchanged patients. If the AUC exceeded 0.5 ($p<0.05$) the discriminative power of the questionnaire was evaluated positively. To determine COP_{imp}, the point with the smallest distance to the upper left corner of the graph was chosen. This is the COP_{imp} that yields the lowest overall misclassification.

(3) The minimal detectable change, also used to determine the range of the MCIC, was established in a previous study.[15] Results are added to Table 4.

RESULTS

Part 1: Screening questionnaires and cut-off scores

Results for the 3 screening questionnaires (OMPQ, TSK and PHQ-15) are represented in Table 1. This table demonstrates that all screening questionnaires were able to discriminate (AUC>0.700 and $p<0.05$) between patients at risk and patients without a risk, according to the external criteria used. The proposed COS for each screening questionnaire and the corresponding sensitivity and specificity are also summarized in Table 3.

Table 3 ROC AUC, cut-off scores, sensitivity and specificity for the three outcome variables

Outcome variable	AUC ROC curve (SD)	Sign. Level ROC curve	COS	Sensitivity	Specificity
OMPQ	0.933 (0.019)	<0.001	89.5	0.816	0.885
TSK	0.770 (0.036)	<0.001	43.5	0.659	0.767
PHQ-15	0.915 (0.031)	<0.001	11.5	0.764	0.939

AUC ROC curve = Area under the Receiver Operating Characteristics curve;

OMPQS= Orebro Musculoskeletal Pain Screening Questionnaire; COS= cut-off score

TSK = Tampa Scale for Kinesiophobia; PHQ-15= Patient Health Questionnaire (15 items); SD=standard deviation

Significance level: $p<0.05$

The first part of the study confirms that in patients with NS-CLBP the OMPQ (COS=89.5), the TSK (COS=43.5) and the PHQ-15 (COS=11.5) were able to detect patients with important yellow flags, kinesiophobia and multiple somatic complaints, respectively.

Part 2: Evaluative questionnaires, responsiveness and MCIC

Table 4 represents the results for the mean change score of each evaluative questionnaire (QBPDI, MPIpain, TSK, OMPQ, SF-36_{TS}, SF-36_{TPH}), based on three different external criteria for improvement: (1) CGI=2; (2) $PGIC_A$=5; (3) $PGIC_B$=3. The corresponding patient numbers (N_{imp}) indicate the number of patients that meets that specific criterion, for each questionnaire separately.

Table 4 Mean change score based on three different external criteria

		Mean Change Score (SD)		Mean Change Score (SD)		Mean Change Score (SD)
Scale	Nimp	CGIC = 2	Nimp	$PGIC_A$ = 5	Nimp	$PGIC_B$ = 3
QBPDI	26	9.38 (1.95)	12	8.5 (2.986)	14	7.36 (2.453)
MPI_{pain}	33	3.73 (0.60)	18	0.78 (0.47)	15	1.13 (0.56)
TSK	13	4.23 (1.46)	13	4.23 (1.46)	10	4.50 (0.703)
OMPQ			15	21.60 (6.050)	13	21.15 (6.362)
SF-36_{TS}			15	11.69 (2.68)	9	12.80 (2.58)
SF-36_{TPH}	26	21.18 (3.07)	12	22.61 (5.54)	14	21.66 (4.29)

QBPDI = Quebec Back Pain Disability Index; MPI_{pain}= Multidimensional Pain Inventory subscale pain;
TSK= Tampa Sale for Kinesiophobia; OMPQ=Orebro Musculoskeletal Pain Questionnaire;
SF-36TS=total score of the Short Form 36; SF-36TPH= total physical health subscale of the Short Form 36
N_{imp}=number of subjects that meets the criterion
CGIC=clinical global impression of change
PGIC=patient global impression of change

Results for the discriminating power of the evaluative questionnaires (improved or non-improved patients) and the COP_{imp}, both established by a ROC curve, are shown in Table 5. As indicated in the table, the analyses were performed using three different external criteria: (1) CGIC; (2) $PGIC_A$; (3) $PGIC_B$. As indicated in this table, all evaluative questionnaires were able to discriminate between improved and non-improved patients, according to as well the patients' ($PGIC_{A\ and\ B}$) as the clinicians' opinion (CGIC), with an AUC between 0.612 and 0.814 ($p<0.05$), except for the TSK whose ROC curve did not reach the significance level ($p>0.05$).

Table 5 Areas under the ROC-curves for each scale using 4 different external criteria's and the optimal cut-off point (minimal distance to the upper left corner) suggested by each ROC-curve

	Using the corresponding clinician judgement (CGI<3)					Using the corresponding PGIC_A (>4)					Using the corresponding PGIC_B (<4)				
Scale	N_{imp}	ROC area	SE	Sign.	COP_{imp}	N_{imp}	ROC area	SE	Sign.	COP_{imp}	N_{imp}	ROC area	SE	Sign.	COP_{imp}
QBPDI	30	0.612	0.07	0.118	7.5	34	0.647	0.069	0.040	6.5	35	0.682	0.07	0.011	6.5
MPI_{pain}	42	0.851	0.049	<0.001	1.5	47	0.746	0.064	0.002	0.5	45	0.794	0.058	<0.001	0.5
TSK	16	0.613	0.083	0.176	4.5	37	0.504	0.072	0.959	4.5	37	0.496	0.074	0.959	4.5
OMPQ						29	0.714	0.066	0.003	18.5	31	0.649	0.068	0.037	18.5
$SF\text{-}36_{TS}$						38	0.741	0.061	0.001	12.37	39	0.697	0.066	0.007	12.56
$SF\text{-}36_{TPH}$	30	0.706	0.065	0.004	15.19	34	0.64	0.068	0.051	14.95	35	0.672	0.067	0.017	12.68

QBPDI = Quebec Back Pain Disability Index; MPI_{pain}= Multidimensional Pain Inventory subscale pain; TSK= Tampa Sale for Kinesiophobia;
OMPQ=Orebro Musculoskeletal Pain Questionnaire; SF-36TS=total score of the Short Form 36; SF-36TPH= total physical health subscale of the Short Form 36;
ROC=Receiver Operating Characteristics; COP_{imp}=optimal cut-off point for improvement; PGIC=patient global impression of change; CGIC: clinical global impression of change
SE=standard error

Table 6 The MIC assessed for different outcome measures with three different methods: Mean Change (3 different external criteria), MDC and optimal cutoff point (4 different external criteria)

Scale	Range Mean Change (SD)	Range optimal cut-off point	Range MDC (95%CI)	Total Range
QBPDI	7.36 (2.453) - 9.38 (1.953)	6.5-7.5	13.23 - 15.65	6.5-15.65
MPI_{pain}	0.78 (0.47) - 3.73 (0.60)	0.5 -1.5	4.61 - 5.66	0.5 - 5.66
TSK	4.23 (1.46) - 4.50 (0.703)	4.5	9.69 - 10.83	4.23 - 10.83
OMPQ	21.15 (6.362) - 21.60 (6.050)	18.5	23.38 - 28.13	18.5 - 28.13
$SF\text{-}36_{TS}$	11.69 (2.68) - 12.80 (2.58)	12.37-12.56	17.29 - 20.41	12.37 - 20.41
$SF\text{-}36_{PCS}$	21.18 (3.07) - 22.66 (4.29)	12.68 - 15.19	19.98 - 22.87	12.68 - 22.87

QBPDI = Quebec Back Pain Disability Index; MPI_{pain}= Multidimensional Pain Inventory subscale pain;
TSK= Tampa Sale for Kinesiophobia; OMPQ=Orebro Musculoskeletal Pain Questionnaire;
$SF\text{-}36_{TS}$=total score of the Short Form 36; $SF\text{-}36_{TPH}$= total physical health subscale of the Short Form 36
MDC=minimal detectable change

Table 6 gives a summary of the range of MCIC for each evaluative questionnaire established by the different methods: (1) the range of mean change scores using 3 different external criteria (cfr. Table 4); (2) the range of COP_{imp} using 3 different external criteria (cfr. Table 5); (3) the range of MDC[15] (4) the total range of the three methods confounded.

DISCUSSION

The first part of the study confirms that the OMPQ (COS=89.5), the TSK (COS=43.5) and the PHQ-15 (COS=11.5) were able to detect patients with NS-CLBP demonstrating yellow flags, kinesiophobia and multiple somatic complaints, respectively. The second part of the study concludes that the QBPDI (MCIC range: 6.5 - 15.56), the $SF\text{-}36_{TS}$ (MCIC range: 12.4 - 20.4) and the MPI_{pain} (MCIC range: 0.5 - 5.66) were able to discriminate between improved and non-improved patients. Current results cannot confirm that TSK is able to detect changes in kinesiophobia after a non-standardized exercise therapy treatment.

COS and MCIC ranges are very population dependent and also depend on the method used to define them. This explains why many differences are found between the scores established in this study and those who are described in the literature. For example, the COS of the OMPQ described by Linton[6] to screen an acute LBP population, namely 105, was much higher. For the PHQ15, scores of 5, 10, and 15 were proposed to demarcating low, medium, and high levels of multiple somatic complaining, but these levels were established in general internal medicine and family practice clinics and obstetrics-gynecology clinics.[17] For the TSK, previous research proposed a COS of 37 for NS-CLBP patients[7], but this was calculated by taking the median score of a group of 33 subjects with NS-CLBP. Concerning the MCIC of the QBPDI higher values (between 15 and 17.5) were found in acute LBP populations,[13,31] but the current results are close to the NS-CLBP population studied by van der Roer et al.[13] In the general US population the reliable change index (RCI) for the eight subscales of the SF-36 ranged between 17.07 and 38.47 points.[32] The range of MCIC of the total score of the SF-36 is somewhat lower in the present study; the differences regarding the characteristics of the population included and the method used probably explains that. Previous research based on the distributional characteristics of the scale on patients with diverse chronic pain symptoms proposed a benchmark of

at least 0.6 (which range from 0.4 to 0.8) as clinical significant change in score for the interference subscale of the MPI.[33]

COS and MCIC ranges also greatly depends on the type of external criteria.[14] This study tried to answer to some issues concerning these criteria, although in most cases objective external criteria are lacking. For the screening questionnaires, the literature describes a validated external criterion for the PHQ-15, but none was available for the OMPQ and the TSK. The COS determined in this study for these two questionnaires are depending on subjective external criteria. Considering that the choice of external criteria has a huge influence on results, different expert opinions were compared in this study for the TSK and OMPQ, to minimize errors due to the external criteria. For the MCIC, the external criteria inter alia determine whether the MCIC is considered from the perspective of the patients or the clinician.[14] Demoulin et al.[34] reported an optimal cut-off point of 5 points for the QBPDI, but only a patients' related criterion was used. As clinicians and patients do not always agree which changes are considered important, it is important to take the two perspectives in account to determine the ranges of MCIC, as done in the current study. The use of global rating scales, as used in this study, is also controversial[14], inter alia because they could be very general and not focus on the specific outcome measure. Therefore the PGIC and the CGIC, used in this study, were divided in different subcategories, to focus on specific outcome measures. Finally, the MCIC value also depends on the external criteria definition of minimal importance. The authors agree with De Vet et al.[14] who defend the use of important improvement against the use of slightly improved. The argument that some patients easily say that they have slightly improved to please their physiotherapist, is certainly true.

Current results cannot confirm that TSK is able to detect changes in kinesiophobia. This is in contrast with a study of Woby et al.[35] which demonstrated clearly that the TSK was responsive to change (AUC >0.700). The use of both the subjective clinician and patient based external criteria, to analyze the discriminative power of the TSK in this study can be questioned. For patients it could be difficult to understand the aspect of fear of movement and to evaluate improvement of this aspect. Also for the clinician it can be difficult to evaluate if the kinesiophobia has changed over time, certainly for patients who did not really demonstrate any kinesiophobia at the start of the therapy. Woby et al.[35] used a global rating scale asking for changes in beliefs/views concerning their back condition. Although this

is less specific to fear of movement, it may be better understood by the patients/clinicians. In addition, patients were treated by a non-standardized physiotherapy treatment. It could be that the use of more specific treatment, for example aiming to diminish fear and avoidance patterns, could more accentuate changes observed by the TSK.

Although presenting the MCIC as a range, including all reasonable values, is a part of the solution to the obstacles described above.[13,14] But using the MCIC as a range could induce some problems when interpreting questionnaire results in clinical practice. For practical use it will be easier to use a specific value. Change score smaller than the MCIC range should be regarded as irrelevant for the patient, while change scores beyond the range indicate that the patient has benefited from the therapy.[13] If the change score falls within the range of the MCIC, other factors should also be considered, such as patient's satisfaction with the therapy, return to work, etc.[13] Applying the lowest MCIC value reported here to all situations would be tempting but false, inter alia because the smallest value probably lies within the measurement error.

Concerning the interpretation of the AUC, discussion can arise. Both for screening and evaluative questionnaires, in this study, an AUC exceeding 0.5 ($p<0.05$) was adopted to evaluate positively the discriminative power of the questionnaire. An area of 1 indicates that the instrument classifies perfectly, whereas an area of 0.5 indicates that it performs no better than a random classification.[36] However, determination of a meaningful good AUC is difficult. It is clear that an AUC near to 1 indicated a very good discriminative power, but the closer the AUC is to 0.5, the more careful one should be in drawing conclusions. An AUC of 0.6 is not very convincing, but all depends on the domain of investigation and the size of the sample measured. Concerning the latter, the bigger the sample size, the faster little differences are considered significant. Although the samples in this study are not really huge, significance levels are achieved for almost all the questionnaires. In addition, the domain of interest plays an important role in the interpretation of the results. In exact siences (e.g. mathematics) a higher AUC is probably required than in physchological investigations. Making the criterion harder (eg. require an AUC of 0.8) will lead to a more severe COS and COP_{impr}. Consequently, in screening tools more patients will be categorized as non-risk patients and in

evaluative tools more change in the questionnaire score will be required to conclude that the patients' status improved.

In conclusion, the TSK, OMPQ and the PHQ-15 are able to discriminate between risk and non-risk patients. COS were proposed for a NS-CLBP patient population. The QBPDI, the OMPQ, the SF-36 and the MPI_{pain} are able to detect changes in respectively physical function, quality of life and pain experience. MCIC are presented in this study.

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RESEARCH PART 3:

THE LINK BETWEEN PHYSICAL AND PSYCHOSOCIAL ASSESSMENT

CHAPTER 5

Psychosocial components as predictors of performance: Differences between back and abdominal endurance tests.

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ABSTRACT

The influence of psychosocial components on the duration of back and abdominal static endurance tests in patients with persistent non-specific low back pain should be investigated to ensure the correct interpretation of this kind of measures. Three-hundred and thirty-two patients (291 men and 41 women) from 19 to 63 years performed an abdominal and back muscle endurance test after completing a battery of psychosocial questionnaires. During the endurance tests, surface electromyography signals of the inferior fibres of the internal obliques, the external obliques, the lumbar multifidus and the thoracic part of the iliocostalis were recorded. Patients were dichotomized as underperformers and good performers, by comparing their real endurance time, to the expected time of endurance derived from the normalized median frequency slope. Independent *t*-tests were performed to examine the differences between these two groups on the outcome of the questionnaires. In the back muscle endurance test, the underperformers had significantly lower (p<0.05) scores on some of the physical subscales of the SF-36. The underperformers group of the abdominal endurance test scored significantly higher on the DRAM MZDI (p=0.018) and on the PCS scale (p=0.020). This group showed also significantly lower scores on the SF-36 (p<0.05). Back muscle endurance tests are influenced by physical components, while performance on abdominal endurance tests seems influenced by psychosocial components.

Keywords: persistent non-specific low back pain, psychosocial components, physical performance, Biering-Sorensen Test, Abdominal Endurance Test

INTRODUCTION

Physical and psychosocial deconditioning is common in patients with chronic LBP (Brox et al., 2005; Frost et al., 1998). Research showed that the clinical evolution and prognosis of LBP is influenced by psychosocial factors such as pain related fear (Crombez et al., 1999; Sullivan et al., 2009), pain catastrophizing (Burton et al., 1995; Meyer et al., 2009), pain and functional self-perceived disability (Vlaeyen and Linton, 2000; Thomas and France, 2008), self-reported health (Ahrens et al., 2010) and depression (Ryan et al., 2010). All these psychosocial influences make it hard to ensure that physical measurements in patients with persistent non-specific LBP provide an accurate representation of the real physical condition.

Biering Sorenson (Biering Sorenson, 1984) developed a test to measure back muscle fatigability and demonstrated that a shorter position-holding time during this test predicted LBP within the next years (Demoulin et al., 2006). However, a clear influence of psychosocial factors on the endurance time of the Biering-Sorenson test (B-S test) was demonstrated, in healthy subjects as well as in patients with chronic LBP (Larivière et al., 2010; Coorevits et al., 2008). In order to obtain a more objective measurement of the intrinsic muscle fatigue, a measure for the decrease of the median frequency during static submaximal testing, recorded by surface electromyography (sEMG), can be used (Coorevits et al., 2008). A regression coefficient of the median frequency slope towards lower frequencies can be used as a fatigue index for the investigated muscle. This regression coefficient is often normalized by the intercept, which is the crossing point of the slope and the Y-axis (Konrad, 2005)**.** A combination of the use of the regression coefficient of the median frequency, time to exhausting and self-reporting questionnaires, could be useful to understand the different influencing factors on physical performance.

In contrast to the almost systematic use of the B-S test and its modified versions to analyze back muscle endurance, much more variation in position and procedure is observed in abdominal endurance tests. Brox et al. (2005) utilized a dynamic abdominal endurance test to demonstrate that deconditioning (deterioration of impairment and disability) was more related to psychological measures and physical measures of abdominal and back muscle endurance than to general cardiovascular fitness (estimated by a submaximal bicycle ergometer test). However, static endurance tests are preferred since variation in muscle length throughout the test can alter the frequency content of the EMG signal (Mannion et al., 1996; Sparto et al., 1999).

In conclusion, research on the relation between psychosocial factors and physical performance is scarce and often lacks standardized and specialized physical testing or sufficient patients. Therefore, the aim of the present study was to investigate the influence of psychosocial components on the duration of standardized back and abdominal static endurance tests in patients with persistent non-specific LBP. Determining good performance may lead to a better understanding of factors that make patients perform less than they physically can during these tests. The hypothesis was that underperformance during back and abdominal endurance tests in patients with persistent non-specific LBP is influenced and may be predicted by psychosocial components.

MATERIALS AND METHODS

Patients

Three-hundred and thirty-two patients (291 men and 41 women; military and civilian employees) from 19 to 63 years old with persistent non-specific LBP, with or without leg pain, were included in this study after screening by a medical doctor specialized in physical medicine at the Military Hospital Queen Astrid in Brussels. When needed additional investigations were performed to assure that no identifiable specific anatomical or neurophysiological causative factors were present. Pregnant women, patients with previous spinal surgery, nerve root entrapment with neurological deficit, patients with specific LBP diseases and patients with a BMI ≥ 33 were excluded from this study. Study population characteristics are shown in Table 1. The study was approved by the Ethical Committee of the Ghent University.

Table 1 Descriptive statistics on the study population

	Males (n=291)		Females (n=41)		Total (n=332)	
Characteristics	**Mean**	**± *SD (min-max)***	**Mean**	**± *SD (min-max)***	**Mean**	**± *SD (min-max)***
Age	42	± 8.1 (19-63)	43.8	± 7.9 (22-55)	42	± 8 (19-63)
BMI[1]	26.1	± 3.9 (18.2-39.4)	25.2	± 3.4 (18.4-34.4)	25.9	± 3.6 (18.2-39.4)
Sports hrs / week	3.7	± 4.6 (0-24)	4.4	± 4.8 (0-16)	3.8	± 4.6 (0-24)
Pain duration (days)	1913.4	± 3354.3 (100-38676)	1920	± 2112.7 (87-9984)	1914.2	± 3224.5 (100-38676)
Pain intensity (0-10)[2]	4	± 2.1 (0-10)	5.7	±1.9 (2-9)	4.6	± 2.2 (0-10)

[1]Body Mass Index; [2]Pain intensity over the last week

Psychosocial assessment questionnaires

All subjects received self-report questionnaires before performing physical tests. General questions related to the sociodemographic status and characteristics of their LBP were registered. Several validated questionnaires were used as a measure of physical and/or psychological influence of the LBP on daily life. A numerical scale was used to indicate the average pain over the last week. Pain Catastrophizing was measured by the Pain Catastrophizing Scale (PCS) (Sullivan et al., 1995). The Hospital Anxiety or Depression Scale (HADS) (Zigmond and Snaith, 1983) determined the levels of anxiety and depression that a patient was experiencing. The Distress Risk Assessment Method (DRAM) consisting of the Modified Somatic Perceptions Questionnaire (MSPQ) (Mannion et al., 2011; Main, 1983) and the Modified Zung Depression Index (MZDI) (Mannion et al., 2011; Zung et al., 1965) were used as screening tools for depression and somatic pain respectively. The Short Form Health **Survey** (SF-36) (Ware and Gandek, 1998) and its different subscales gave a general measure of health, both mental and physical components. Depending on the mother tongue, the participants filled in the questionnaires in Dutch or French (validated versions).

Physical Assessment – endurance tests

An isometric endurance test for the abdominal muscles (AE test) (Stevens et al., 2008) was performed (Fig. 1). The patient was seated on a bench in a straight-knee position, with the trunk unsupported at a 45-degree angle. The hands were placed on the shoulders with the arms flexed alongside the trunk. Neutral position of the head and lumbar spine was respected.

Figure 1 The abdominal endurance test

For the evaluation of the isometric endurance of the trunk extensor muscles patients performed a modified version of the B-S test (Fig. 2) (Demoulin et al., 2006; Coorevits et al., 2008; Demoulin et al., 2013; Stevens et al., 2006). The patient was lying on a bench in a prone position with the anterior-superior iliac spines at the rotation point of the bench. The lower body was fixed to the table by two straps, one around the pelvis and one on the ankles. The patients had to hold their hands touching their foreheads, with their elbows out to the side and leveled with the trunk. Patients were also instructed to hold their head in a neutral position, and to look downward. The test was started with the upper body in an about 70° downward position so that a concentric contraction of the trunk extensor muscles was needed initially to reach the horizontal position.

Figure 2 A modified version of the Biering-Sorenson test

The patient was asked to isometrically maintain these positions. This was checked by visual evaluation. The time the patient held these positions was recorded. Verbal encouragement was given by the tester during both endurance tests to ensure that the maximal effort was produced by the patient.

EMG recording

sEMG was used to quantify the rate of development of muscle fatigue. After appropriate skin preparation in order to get a good electrode-skin contact and to reduce skin impedance, 8 pairs of circular Ag/AgCl sensor surface electrodes (Ambu® Blue Sensor M, Ambu A/S, Ballerup, DK) were placed parallel to the muscle fibres (Ng et al., 1998), bilaterally, of 2 deep stabilizing and 2 superficial

torque producing abdominal and back muscle groups as follows: The inferior fibres of the internal obliques (IO) (midway between the anterior iliac spine and the symphysis pubis, above the inguinal ligament) (Stevens et al., 2008; Van Damme et al., 2012), the external obliques (EO) (15 cm lateral to the umbilicus) (Cholewicki et al., 1997; Hubley-Kozey and Vezina, 2002), the lumbar multifidus (LMF) (above and below the L5 spinous process, parallel to the line between the posterosuperior iliac spine and the L1–L2 interspinous space) (Danneels et al., 2001; Ng et al., 1997), the thoracic part of the iliocostalis (ICLT) (above and below the L1 level, midway between the midline and the lateral aspect of the body) (Stevens et al., 2008; Van Damme et al., 2012; Danneels et al., 2002). A reference electrode was placed on the thoracic cage.

Electromyographic signals were recorded using an 8-channel sEMG system (Myosystem 2000, Noraxon U.S.A. Inc., Scottsdale, AZ) connected to a computer. The raw sEMG signals were recorded at a sampling rate of 1000Hz, amplified (overall gain 1000, common mode rate rejection ratio 115 dB), filtered to produce a bandwidth of 10-500 Hz and analog digital conversion (12-bit resolution) was at 1000 Hz. Each recorded sEMG signal that was stored on the computer was divided in intervals of 5 s. The median frequency (MF) of the sEMG power spectrum was calculated at each 5-s interval with Fast-Fourier Transform algorithms using the Noraxon MyoResearch software v2.11. During a sustained isometric contraction of the muscles, the MF spectral shifts indicate local muscle fatigue and decrease over time (Sung et al., 2009). The MF was defined as the frequency that divided the spectrum into two equal areas. Finally, linear regression analyses were performed on the calculated MF's as a function of time. The initial MF (MF_{init}) was defined as the intercept of the regression line and the MF slope (MF_{slope}) was determined as the slope of the regression line. MF_{slope} was normalized to MF_{init} (Biering Sorenson, 1984), to deal with inter subject and inter location differences in subcutaneous tissue layers. The MF_{slope}, normalized to MF_{init}, gave a measure of fatigability for each recording site for each individual (Mannion et al., 2011; Coorevits et al., 2008).

Data analysis

The outcome of each questionnaire was calculated following the instructions of the original designers. SPSS 21.0 was used for statistical analyses. Statistical significance was accepted at the 5% level.

Patients were dichotomized as underperformers and performers, by comparing their real endurance time, to the expected time of endurance derived from the normalized MF_{slope} (NMF_{slope}). This was

done for the B-S test and the AE test separately. The NMF_{slope} (Coorevits et al., 2008) provided a measure of fatigability for each muscle on both sides, for each subject. The endurance time was regressed on the NMF_{slope} for the most fatigable region of the LMF during the B-S test and for the most fatigable region of the IO during the AE test. The deep stabilizing muscles were selected because, in this group, they showed generally a steeper slope than the superficial torque-producing muscles. Endurance appears to be limited by the most fatigable region of a muscle group (Mannion and Dolan, 1994). Stepwise multiple regression analyses (Probability of F-to-enter ≤0.05; Probability of F-to-remove ≥0.10) were used to determine a linear model for the endurance time of the two endurance tests. The influence of gender on the slope and the intercept of the regression line were analyzed. For this reason, the dummy variable gender and gender*NMF_{slope} were introduced as two extra independent variables into the model. Using the regression equation derived from the group data, the "expected" endurance time for a given subject was determined for both exercises. Depending on whether their real endurance time fell short (a) or was equal to or exceeded (b) the expected time, they were classified as underperformers (a) or as performers (b) for that specific exercise. A similar method was used by Mannion et al. (2011), but in the present model gender was also added in the regression model.

For the AE test and the B-S test separately, independent *t*-tests were performed to examine the differences between underperformers and performers on the different variables and self-reporting questionnaires. Stepwise multiple regression analysis (Probability of F-to-enter ≤0.05; Probability of F-to-remove ≥ 0.10) was performed using the variables that were found significantly different between the two groups in a bivariate analysis as predictor variables. For the regression analyses, the normality of the errors, independency of the errors and the homoscedasticity assumption were verified.

RESULTS

The linear regression analysis for the B-S test (Fig. 3) provided two different parallel regression lines, one for each gender. The regression line for the female patients was situated below the model of the male patients. In the AE test no significant differences were found between the regression line of male and female patients. This means that the prediction line (Fig. 4) was the same for male and female subjects.

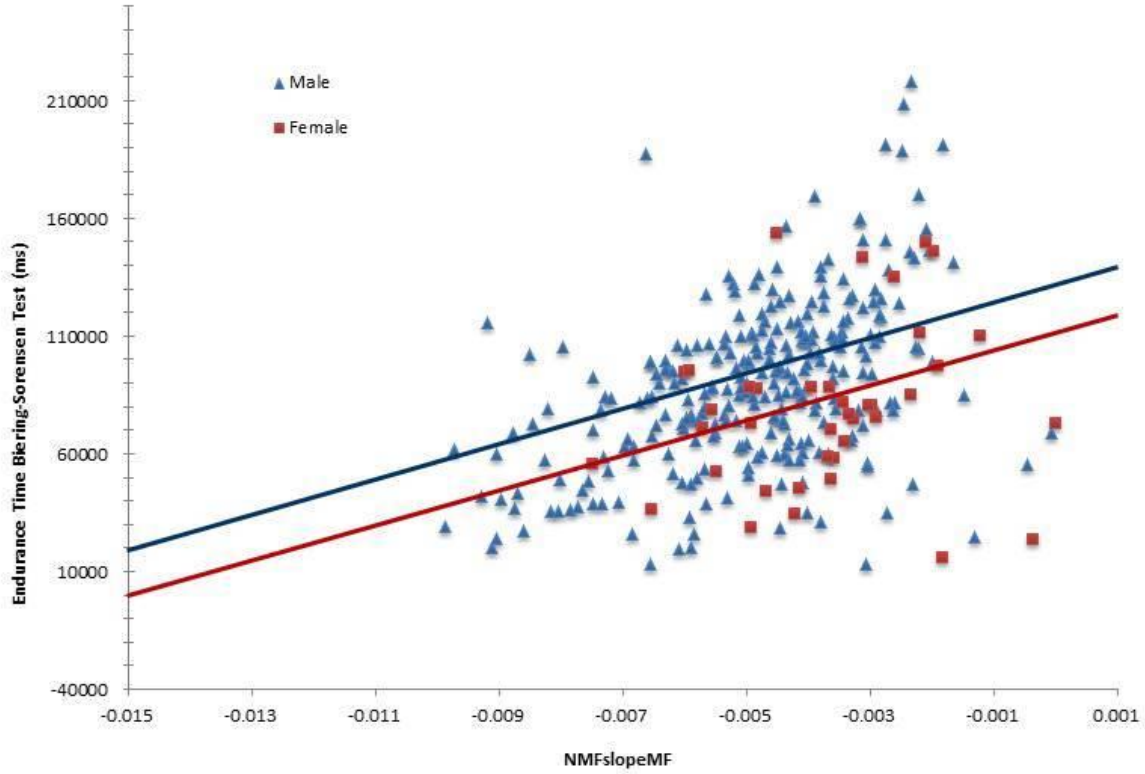

Figure 3 Plot of the real endurance time (ms) versus the normalized slope of the multifidus, for male and female patients, during a modified version of the Biering-Sorensen Test. The predicted endurance time is given by the regression equation for each gender separately. The regression line for the male was: Y= 122244 + (6638904*x). For female subjects the regression line was Y= (122244-18289) + (6638904*x).

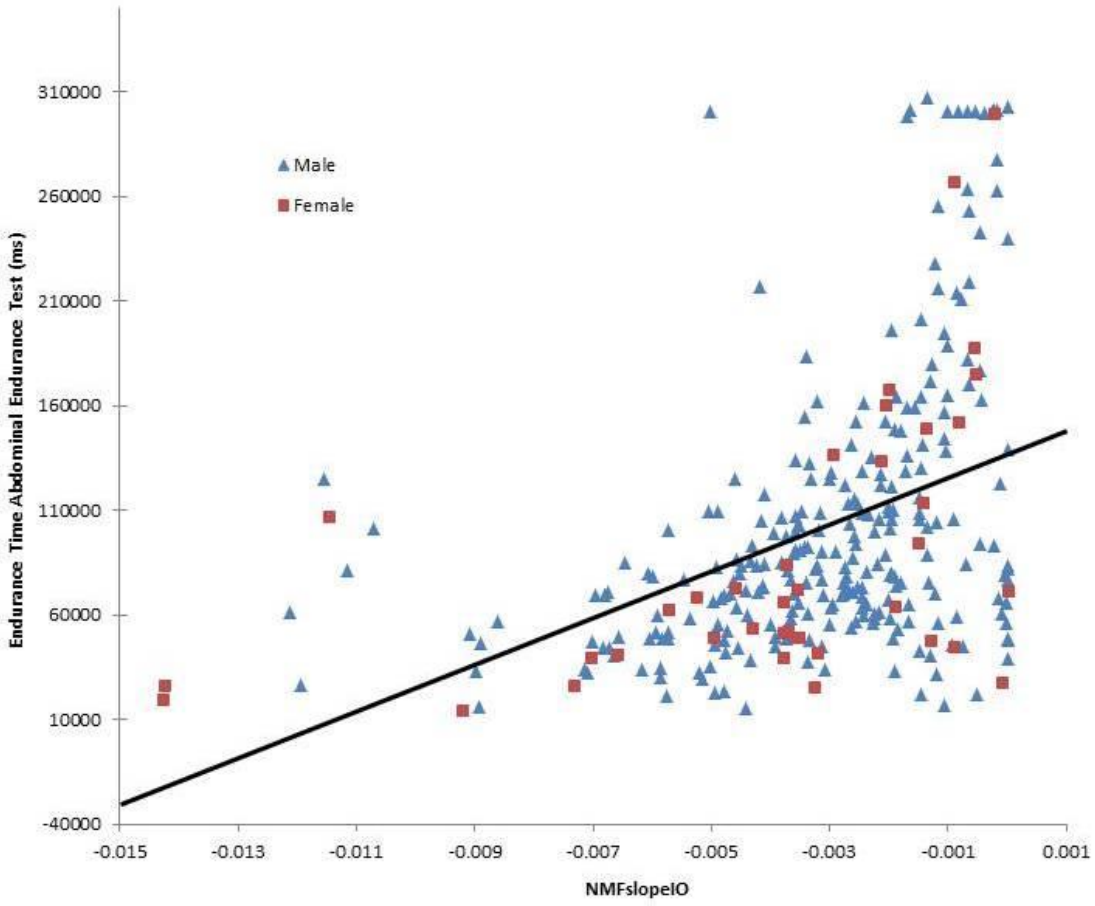

Figure 4 Plot of the real endurance time (ms) versus the normalized slope of the internal obliques, for male and female patients, during an abdominal endurance test. The predicted endurance time is given by the regression equation(Y= 135858,264 + (11104256,44*x), which was found identical between the two genders.

Biering-Sorenson Test

Independent *t-test*s between the underperformers and performers on the B-S test (Table 2) showed that the mean age (p=0.007) and mean BMI (p<0.001) of the underperformers were higher than these of the performers. No significant difference was found in hours of sport per week (sport hrs/week) between the two groups (p=0.988). The two groups had a similar NMF_{slope} of the LMF (NMF_{slope}LMF), but the performers group demonstrated a significantly longer endurance time on the B-S test (p<0.001).

Table 2 Differences in psychosocial characteristics and other potential confounding factors for the B-S Test between underperformers and good performers.

	Mean Group Values ± *SD*		Unpaired T-test Equality of Means	95% *CI* of the Difference	
Variable	**Underperformers (*N*=175)**	**Good performers (*N*=157)**	***p* Value***	***CI* low**	***CI* high**
Age (years)	43.13 ± 7.25	40.71 ± 8.71	0.007	0.682	4.167
BMI[1]	26.91 ± 3.79	24.96 ± 2.99	<0.001	1.201	2.688
Sports hrs / week	3.89 ± 4.4	3.79 ± 4.9	0.988	-1.017	1.002
B-S test[2] (s)	60.89 ± 22.58	113.72 ± 27.68	<0.001	-58.268	-47.403
$NMF_{slope}MF$[3]	-0.0049 ± 0.00	-0.0047 ± 0.002	0.443	-0.00064	0.00028
SF-36_PhysicalFunction[4]	64.8 ± 16.35	71.21 ± 16.77	<0.001	-9.989	-2.831
SF-36_GeneralHealth[5]	61.14 ± 17.27	68.76 ± 17.71	<0.001	-11.394	-3836
SF-36_total_PhysicalHealth[6]	55.91 ± 14.85	59.26 ± 15.60	0.046	-6.635	-0.058

Only the psychosocial characteristics which appeared statistically significant (*p<0.05) are shown.

[1]Body Mass Index; [2]Duration of the Biering-Sorensen test in seconds; [3]Normalized median frequency slope of the lumbar multifidus muscle;

[4-6]Subscales of the Short Form (36) Health Survey

The scores on some of the subscales of the SF-36 were significantly higher for the performers: Physical Function (p<0.001), General Health (p<0.001) and total Physical Health (p=0.046).

Stepwise multiple regression analysis (Table 3) of all the variables that were found significant in bivariate analysis revealed that a greater BMI (β=-221.748; p<0.001) and lower scores on the Physical Function subscale of the SF-36 (β=355.209; p=0.001) were significant predictors of underperformance on the B-S test. These components explained more than 10% (R^2=0.113) of the variance.

Abdominal Endurance Test

Independent *t*-tests between the underperformers and performers on the AE test (Table 4) showed that the underperformers group of the AE test had a significantly higher BMI (p=0.014). No significant difference was found in sport hrs/week between the two groups (p=0.482). The two groups had a similar NMF_{slope} of the IO ($NMF_{slope}IO$), but the performers group demonstrated a significantly longer endurance time on the AE test (p<0.001). The underperformers group scored significantly higher on the DRAM MZDI (p=0.018) and on the PCS scale (p=0.020). This group showed also significantly lower scores on the SF-36 and some of its subscales: General Health (p=0.009), Social Functioning (p=0.048), Role Emotional (p=0.008), total Physical Health (p=0.025) and total Mental Health (p=0.006).

Stepwise multiple regression analysis (Table 5) of all the variables that were found significant in bivariate analysis revealed that a higher BMI (β=-2748.282; p=0.005) and a lower score on the total mental health subscale of the SF-36 (β=547.415; p=0.011) were predictive for underperformance on the AE test. These components explained more than 4% of the variance (R^2=0.049).

Table 3 Results of the final step of the stepwise multiple regression analysis of the B-S test

Independent variables	Unstandardized Coefficients *B*	Standardized Coefficients *Beta (β)*	Significance *p* Value	R^2
(Constant)	33638.460		0.045	
BMI[1]	-2221.748	-0.244	<0.001	
$SF\text{-}36_{PF}$[2]	355.209	0.178	0.001	
				0.113

Criteria: Probability-of-F-to-enter ≤0.050; Probability-of-F-to-remove ≥0.100).

[1]Body Mass Index; [2]Physical Function subscale of the Short Form (36) Health Survey

Table 4 Differences in psychosocial characteristics and other potential confounding factors for the AE Test between underperformers and good performers.

	Mean Group Values ± *SD*						
	Underperformers		**Good performers**		**Unpaired T-test Equality of Means**	**95% *CI* of the Difference**	
Variable	**(*N*=212)**		**(*N*=120)**		***p* Value***	***CI* low**	***CI* high**
Age	42.14	± 8.06	41.72	± 8.08	0.649	-1.392	2.232
BMI[1]	26.32	± 3.85	25.40	± 2.93	0.014	0.130	1.724
Sports hrs / week	3.85	± 4.93	3.65	± 4.38	0.449	-0.839	1.258
AE Time[2] (s)	67.42	± 34.70	158.87	± 73.20	<0.001	-103.135	-79.771
$NMF_{slope}IO$[3]	-0.0031	± 0.002	-0.0031	± 0.003	0.998	-0.00058	0.00058
PCS_total[6]	18.45	± 9.81	15.88	± 9.30	0.020	0.408	4.738
DRAM_MZDI[7]	22.32	± 11.87	19.11	± 11.74	0.018	0.555	5.870
SF-36_GeneralHealth[8]	62.83	± 18.30	68.12	± 16.60	0.009	-5.295	2.023
SF-36_SocialFunctioing[9]	73.58	± 22.36	78.54	± 20.82	0.048	4.957	2.493
SF-36_RoleEmotional[10]	74.84	± 37.51	85.00	± 30.51	0.008	-10.157	4.015
SF-36_total_PhysicalHealth[11]	56.08	± 15.33	59.98	± 14.92	0.025	-3.896	1.735
SF-36_total_MentalHealth[12]	67.99	± 16.10	72.92	± 14.74	0.006	-4.933	1.785
SF-36_total[13]	62.39	± 15.40	66.92	± 14.38	0.009	-4.529	1.718

Only the psychosocial characteristics which appeared statistically significant (*p<0.05) are shown.

[1]Body Mass Index; [2]Duration of the abdominal endurance test in seconds; [3]Normalized median frequency slope of the internal obliques; [4-5]Subscales of the pain catastrophizing scale;

[6]Total score of the pain catastrophizing scale; [7]Modified Zung depression index of the distress risk assessment method; [8-12]Subscales of the Short Form (36) Health survey;

[13]Total score of the Short Form (36) Health survey

Table 5 Results of the final step of the stepwise multiple regression analysis of the AE-test

	Unstandardized Coefficients	Standardized Coefficients	Significance	
Independent variables	***B***	***Beta (β)***	***p* Value**	R^2
(Constant)	33258.758		0.275	
BMI[1]	-2748.282	-0.158	0.005	
SF-36_total_MentalHealth[2]	547.415	0.143	0.011	
				0.049

Criteria: Probability-of-F-to-enter ≤0.050; Probability-of-F-to-remove ≥0.100

[1]Body Mass Index; [2]Total Mental Health subscale of the SF-36

DISCUSSION

The present study examined the relationship between psychosocial components and underperformance -performance less than expected- on abdominal and back muscle endurance tests in patients with persistent non-specific LBP. The main findings were that underperformance on back muscle endurance tests was more likely to be influenced by physical components (self-reporting on physical health), whereas abdominal muscle endurance tests seemed more affected by psychosocial components (self-reporting of mental health). Performing less than expected as in underperformance, does not necessarily involve low performance, but may even present high performance in well-trained subjects.

Back muscle endurance

For the B-S test underperformers had statistical significant lower scores on different subscales of the SF-36: Physical Function, General Health and total Physical Health. All these scales reflect a physical component. So, we could suggest that more negative perceptions of physical health could induce underperformance on the B-S test.

The results described above are in line with observations in elderly patients with chronic LBP (Ledoux et al., 2012). Functional capacity, measured by endurance and peak torque during prone and side bridge positions, was very much dependent on physical components (physical activity and disability levels), and not on psychosocial components as depression scores or pain catastrophizing. In the current study baseline physical activity, reported in sport hrs/week was not different between the group underperformers and good performers, but a more detailed questioning about physical activity could have given more information. Disability levels in se were not reported in the current study, but reporting on physical health was significantly different between the two groups in the B-S test.

Demoulin et al. (2013) did not find any association between endurance time on the B-S test and pain-related fear measures, but no subdivision was made between performance groups. Mannion et al. (2011) found that underperformers on the B-S test had more negative back beliefs, greater psychological disturbance, greater catastrophizing and lower exercise self-efficacy compared with the performers. In contrast to the results of the present study, the underperformers showed significant greater catastrophizing and psychological disturbance. Larivière et al. (2010) suggested that pain catastrophizing is related to outcome on the B-S test. These different results might be explained by

the population characteristics. In contrast to all active working patients in the present study, Larivière et al. (2010) observed a population in which 10 of the 27 patients were not at work (7 due to back problems). In the study of Mannion et al. (2011) the group symptoms were similar to the present group, but there were a lot more female subjects (57%). In contrast to the present study, Mannion et al. (2011) did not take gender into account while making the subdivisions in underperformers and performers group. However, several studies demonstrated a clear gender difference in muscle fatigability during the B-S test. Kankaanpää et al. (1998), for example, demonstrated sex differences in paraspinal muscle fatigability during the B-S test and explained this by gender differences in muscle anatomy and physiology. Therefore, gender cannot be thought away in determining the performance group. In addition, gender differences have been found consistently in catastrophizing, with women reporting significantly higher scores than men on the PCS (D'Eon et al., 2004; Thorn et al., 2004). In several studies, performance was evaluated by a Functional Capacity Evaluation (FCE) or other physical tests and no strong relationship was found between the FCE-physical outcome and psychological factors (Schiphorst et al., 2008; Reneman et al., 2007; Smeets et al., 2007). This is in line with the results found in the present study, although the physical tests were very different.

Abdominal muscle endurance

Underperformers on the AE test had significantly higher scores on the DRAM MZDI and on the PCS. The SF-36 and some of its subscales (general health, social functioning, role emotional, total physical health and mental health) of this group showed lower scores, indicating more problems with these health components. Patients who were more emotionally distressed and patients with high levels of catastrophizing tended to underperform on the AE test. No studies were found which specifically investigated the relation between underperformance on abdominal muscle tests and psychological distress. Brox et al. (2005) investigated healthy controls and patients with sub-acute and chronic LBP and found that patients with chronic LBP demonstrated significantly higher pain, self-reported functional disability and fear-avoidance and lower abdominal and back muscle endurance times than sub-acute patients. A study of Sullivan et al. (2002) revealed that pain catastrophizing was significantly predictive for low performance on a repeated lifting task in patients with chronic LBP.

However, performing less than expected as in underperformance, does not necessarily involve low performance, but may even present high performance in e.g. well-trained subjects.

Multiple regression analysis demonstrated that a greater BMI and lower scores on the Physical Function subscale of the SF-36 were significant predictors of underperformance on the B-S test and that a higher BMI and lower scores on the total mental health subscale of the SF-36 were predictive for underperformance on the AE test. It is striking that performance on back muscle endurance tests was more likely influenced by physical components, while the abdominal muscle endurance test seemed more affected by psychological components. Different subjective observations were made, which could explain this discrepancy. Some aspects, typically observed during the AE test, could influence the patient's motivation to perform. In general, subjects reported more pain discomfort during the AE test. The sitting position is for many patients a pain provocative position. Although the neutral position of the back was respected during the AE test, patients did not like to sit in this position and needed a lot more motivation to hold it. Previous research demonstrated that pain catastrophizing is in strong relation with pain (Sullivan et al., 2001). Pain catastrophizing measured by the PCS, in the absence of pain, is not associated with impaired physical function or with reduced motivation to perform physical maneuvers. However, under conditions where movement is associated with pain, pain catastrophizing appears to contribute to a reduction in physical outcome (Sullivan et al., 2002) and this could explain underperformance. In contrast to the lumbar extension control position during the B-S test, the abdominal endurance demanded more control to avoid lumbar flexion. Higher catastrophizing and emotionally distressed patients may fear flexion positions more than extension postures. Flexion-related pain disorders are the most common disorders observed in clinical practice (O'Sullivan, 2000). In the sitting flexion endurance test, patients also experienced vibrations in the abdominal muscles; these vibrations were generally not observed during the B-S test. Due to the uncomfortable sensation of these vibrations, the patient's performance could have been disturbed. In addition, the visual focus was also very different between the two endurance tests. During the B-S test, the patients' vision was orientated to the ground, which created less visual disturbance in comparison to the view of the test environment, equipment and testers during the AE test. Highly test-anxious persons often divide their attention between task-irrelevant and task-relevant variables and become more distractible, whereas low-test anxious persons focus their attention more fully on the task (Pijpers et al., 2005; Eubank et al., 2000). This could explain why patients who were more

psychologically distressed tend to underperform on the AE-test compared to subjects who were not psychologically distressed, and could also clarify why we did not find such a difference in the B-S test. However, the relative shift in attention away from environmental cues, and towards internal monitoring of feelings, thoughts and movements – which is more likely to happen in the B-S-test - has also been demonstrated to have a detrimental effect on motor performance especially in anxious people (Maxwell et al., 2000; Janelle, 2002).

Patients who are more psychologically distressed could be more influenced by all these different factors. Further exploration of the causes of this statistical difference between the AE test and the B-S test is needed.

Although the results of the multiple regression analyses were in accordance to the clear statistical significant differences between the group of the underperformers and the good performers, the effect sizes of the regression analyses were small. Only about 10% in the B-S test and 4% in the AE test of the variance could be explained by the defined variables. In sociological and biological measurements high percentages are almost never achieved, however it is often possible to identify about 25% of the variance of a relationship (Botz and Doering, 2002). This was not achieved in the present study. However, interpretation of linear regression analysis is not straightforward (Schneider et al., 2010) and results should be placed in the context of the relevant research (field, research question). Clinicians should decide if explaining 4% of variance is clinically useful in this research.

In previous research, BMI was observed as a significant predictor of endurance time in the B-S test (Mbada et al., 2009). This could be explained by the association between BMI and the rate of MF decrease during this test. A higher BMI was shown to create a greater fatigability and a lower endurance time of the paraspinal muscles (Kankaanpää et al., 1998). The present study examined this more thoroughly, and found in addition a direct association between BMI and underperformance, both on the abdominal as well as on the back muscle endurance test. A high BMI was even a predictor of underperformance on these two endurance tests. In the literature, BMI is often associated with lower physical performance but also with a higher occurrence of psychosocial problems (Vaidya, 2006; Fabricatore and Wadden, 2004).

The method used in this study to determine the group of underperformers and performers could be questioned, because controversy exists concerning the use of MF_{slope} to determine the time to exhaustion (Bouillard et al., 2012). Because parameters derived from the EMG power spectrum are

less dependent on the force level of the muscle compared to amplitude parameters and appear to be more sensitive to the myoelectric manifestations of muscle fatigue (Ng et al., 1996; Potvin and Bent, 1997), the use of spectral EMG variables as fatigue index was preferred over the EMG amplitude parameters (Roy and Oddsson, 1998). MF has been suggested to be the most suitable parameters for describing localized muscle fatigue (Kankaanpää et al., 1998; Larivière et al., 2002) and may provide an objective measure of muscle fatigue (Arnall et al., 2002; Mannion et al., 1998; Ng et al., 1996; Nicolaisen and Jorgensen, 1985; Roy et al., 1989). In contrast, Bouillard et al. (2012) demonstrated that other physiological (e.g. motor unit synchronization) and non-physiological (e.g., change in fiber pennation angle, change in the muscular temperature) factors may affect the sEMG signal and thus its changes over time. Other parameters have also been proposed, such as the Dimitrov spectral index, which was shown to be higher correlated with endurance time than the initial slope of the MF in a small healthy population performing isotonic biceps brachii contractions (Lee et al., 2011). In addition, the MF was demonstrated to be not a suitable indicator for dynamic contractions (Van Dieën et al., 1996) and contractions at approximately 9-10% of maximal voluntary isometric contraction (MVIC) (Gonzalez-Izal et al., 2010). However, since most of the studies analyzing back muscle fatigue have used MF (Allison and Henry, 2001; Biedermann et al., 1990; Champagne et al., 2008; Dedering et al., 2000; Elving et al., 1999; Kankaanpää et al., 1998; Larivière et al., 2002; Mannion et al., 2011; Müller et al., 2010; Ng et al., 2002; Peach and McGill, 1998; Süüden et al., 2008), and the endurance tests were not dynamically performed and achieved higher levels than 9 to 10% of MVIC, the method applied in the present study was choosen. However, the accuracy of the method using MF_{slope} to estimate the endurance time is not known and thus some participants may not have been well classified. In addition, the low R^2 values could induce some doubt about the usefulness of the linear regression models. However, the quality of a statistical model can not be defined by R^2; prudence is warranted in interpreting R^2 values (Achen, 1977; Kennedy, 2008; Goldberger, 1991; King, 1986).

Finally, the aim of this study was not to make a model to predict underperformance on endurance test, but to demonstrate, in addition to previous research, that endurance time on the B-S test and the AE test is not a clear measure of intrinsic muscle fatigue. Psychosocial components and reporting on physical health are interacting with performance on these tests and should be taken into account while making conclusions based on these tests. In addition, differences found between the AE test

and B-S test in this study indicate that these interactions could be test-specific. So these results cannot be generalized to all performance measures. There is a clear need for the use of sEMG in measuring intrinsic muscle fatigue in research and/or clinical settings. Using sEMG in the clinical practice is not feasible, but clinical practitioners, who want to measure endurance, should be aware that psychosocial components could influence performance.

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GENERAL DISCUSSION

1. Summary of the findings

General agreement exists on the need to standardize the assessment and rehabilitation of patients with NS-CLBP in a biopsychosocial model. The planetary model offers a framework to therapists to consider most of the relevant aspects of this approach.[1] However, instruments to objectify physical and psychological components of NS-CLBP need to be improved.

The main purpose of this dissertation was to optimize some aspects of the assessment of patients with NS-CLBP. Part I of the research focused on dysfunctions of the sensorimotor control system, more specifically on trunk muscle recruitment patterns during both isokinetic strength and motor control exercises. Part II of this dissertation concentrated on the clinical use of questionnaires, aiming to improve the assessment of functional disability, pain-related factors and relevant psychosocial aspects. A cross-cultural adaptation of some instruments was performed and reproducibility was investigated. In addition, COS and MCIC were established. The third part emphasized the link between assessment of the myofascial system (muscle endurance) and the use of self-report questionnaires in the assessment of functional disability, pain-related and psychosocial factors in patients with NS-CLBP.

1.1. Trunk muscle recruitment patterns

Based on the literature an adequate coordination between recruitment of deep stabilizing muscles and superficial torque producing muscles seems essential for an optimal sensorimotor control.[2-4] Altered trunk muscle patterns are often seen as a key problem in the NS-CLBP population.[5] Therefore, trunk muscle recruitment patterns are often investigated in healthy subjects[6-10] as well as in patients with NS-CLBP[7,8,11] In order to find an explanation for the recurrent and/or persistent character of LBP. Until now, no consensus exists about (1) the representation of an optimal recruitment pattern; (2) and the most optimal way to differentiate between healthy subjects and LBP patients based upon the recruitment patterns of trunk muscles.

Trunk muscle recruitment is often analyzed in terms of muscle activity, studying the activity of different muscle groups separately. However, to emphasize the relationship between different muscle groups, trunk muscle recruitment patterns in terms of ratios appear more appropriate.[9,12-14] Depending on the research question different relationships can be analyzed. The proportion of agonist and antagonist muscle activity can be calculated, to indicate the dominant muscle group in a specific exercise.[15,16]

Another option is to analyze the proportion of deep stabilizing muscles relative to global torque producing muscles[9-10,12,13,17], as applied in the present dissertation. Both kinds of ratios are found to be altered in patients with NS-CLBP and provide complementary information.[15,17]

1.1.1. Trunk muscle recruitment patterns during high load isokinetic testing

One of the pitfalls in analyzing trunk muscle recruitment patterns is that these patterns seem to depend on the specific posture, movement or exercise investigated[16,18-20], and the demands to dynamically stabilize the spine.[17,21]

In *chapter 1* of this dissertation it is demonstrated that, in healthy subjects, the velocity parameters of the exercise influence the trunk muscle recruitment patterns. Results showed that for controlled flexion-extension exercises in standing position on the Cybex TEF modular component, the velocity of isokinetic extension exercises influences the recruitment of the back muscles in healthy subjects. With increasing velocity the deep stabilizing muscle groups (i.e. the LMF) seem to be higher activated relatively to the global torque producing muscle groups (i.e. the ICLT). No impact has been demonstrated for the abdominal muscles, but further exploration is needed.

There is little information concerning trunk muscle recruitment patterns in terms of ratios of deep stabilizing to superficial torque producing muscles in high load exercises, but an effect of increasing resistance of instrumented exercises on the relative trunk muscle activity during instrumented seated axial rotation as well as flexion and extension exercises (Tergumed) was described earlier.[9,10] Increasing resistance was found to create significantly higher relative muscle activity for both stabilizing and global torque producing muscles. This is in line with the results of our current study in which the relative muscle activity of both the LMF and the ICLT increased with decreasing velocity. On isokinetic devices, a lower speed of movement is obtained by increasing the resistance. Therefore, also in the current study it can be stated that increasing resistance (isokinetic exercises with low velocity) induces higher relative muscle activity of both stabilizing and global torque producing back muscles. However, no effect was found on the abdominal muscle activity.

In the context of this study (*chapter 1*) no investigations were done on a patient population. However, previous research demonstrated that differences are present between healthy subjects and patients with NS-CLBP concerning trunk muscle recruitment during high load exercises. Danneels et al.[8]

found for example that patients with NS-CLBP had significantly lower activity of the LMF and mainly the ICLT in strength exercises compared to healthy subjects.

1.1.2. Trunk muscle recruitment patterns during low load sensorimotor control exercises

Trunk muscle recruitment patterns investigated during exercises on isokinetic dynamometers or other high load exercises are not representative for most of the daily living activities which are mostly low load activities. Nevertheless muscle recruitment patterns during low load actvitities are relevant since accumulating evidence suggests that the high incidence of occupational low back injuries, that occur while performing less demanding tasks, may be related to altered neuromuscular strategies.[21-23] Sustained postures and repetitive movements can induce changes in muscles and movement patterns.[24] However, the neuromuscular adaptations associated with tasks requiring lighter physical efforts are poorly understood[23] and the differences in the trunk muscle activation patterns between healthy subjects and LBP patients remain unclear for several reasons.

The first difficulty in analyzing trunk muscle recruitment patterns in this kind of exercises, is that in low load activities the trunk muscle recruitment patterns are very task specific.[16,18-19,25] For example, Stevens et al.[26] compared three different bridging exercises and concluded that both the relative muscle activity and the ratio of the abdominal obliques (IO and EO) were depended on the task and the presumable need for stability.

Secondly, there are regional differences in the recruitment of for example the transversus abdominis (TrA), the IO[27-30] and the LMF[31]. This means that the place of muscle activity recording can influence the conclusions about trunk muscle recruitment patterns.

Third, the large variability observed in trunk muscle activity in patients and healthy subjects can make the comparison between these two groups difficult. This is not surprising, since there is evidence that pain leads to variable changes in muscle activity.[25] Induced pain, for example, can increase[32-36], decrease[32-35] or not change[36-38] muscle activity. In this context, Hodges and Tucker[25] provided a new theory to explain motor changes in pain, since the pain-spasm model (vicious circle theory),[39] neither the pain adaptation model[40] can explain changes observed in pain patients adequately.[25] The model proposes that the nervous system has a range of options to achieve protection of the painful or injured part, and that this may involve increased, decreased or redistributed muscle activity. This theory tries to answer the variability observed between individuals and tasks in a patient population

and is composed of 5 key elements: (1) Adaptation to pain involves redistribution of activity within and between muscles in an individual- and task-specific manner to protect the painful part from further pain or injury. For example, in the trunk muscle system reduced activity of the TrA is accompanied by an individual-specific increase in activation of other abdominal and back muscles as a part of postural adjustment before arm movement.[41] Furthermore, experiments inducing pain during simple trunk movements demonstrated different patterns of increasing and decreasing activity in each individual participant, although the net activity of the trunk muscles increases.[42] (2) The redistribution of the activity within and between muscles changes the mechanical outcome. Changes in trunk muscle activity induce altered kinematics (e.g. bloc movement during walking)[43,44] and altered mechanical properties (e.g. increased stiffness) of the spine.[45] (3) These changes in redistribution of the muscle activity and the resultant change in mechanical outcome leads to protection from further pain or injury. For example, increased stiffness of the trunk and decreased counterrotation of the thorax and pelvis during gait may prevent irritation of spine structures. (4) The changes described above are not explained by simple changes in excitability of the motor neurons, but involve changes at multiple levels of the motor system. The relative impact of each level of the motor system may vary between individuals and tasks and lead to different mechanical outputs. This could explain the variability observed in experimental findings. (5) The adaptations achieved have short term benefit (protection of the painful or injured part) but have potential to induce long term consequences due to factors such as increased load, decreased movement and decreased variability.[46] This is why motor control retraining is important in NS-CLBP.

The inter-subject variability in motor control as pointed by Hodges and Tucker[25], exits not only in patients, but also in healthy subjects. Preliminary results of a study concerning trunk muscle recruitment patterns during motor control exercises demonstrated that deep stabilizing muscles as well as superficial torque producing muscles could dominate in motor control exercises and that, depending on the exercises, age and gender could influence the recruitment patterns in healthy subjects.[47] These preliminary outcomes[47] suggest high variability in trunk muscle recruitment patterns also in healthy subjects, as indicated previously.[20,48-49] This variability seems even to depend on the type of exercise: exercises in sitting position demonstrate more variability than exercises in lying position.[20]

Despite the presence of all these obstacles, *chapter 2* however indicates the possibility to develop a statistical model to differentiate patients from healthy subjects, based on trunk muscle recruitment patterns during different motor control exercises. As trunk muscle recruitment patterns seem very task dependent, several exercises were combined and only the most discriminating exercises were retained in the model. As answer to the concern that trunk muscle recruitment patterns are related to the individual problem, the model only focused on male patients with NS-CLBP demonstrating a flexion related MCI.

1.2. Self-report questionnaires

The two main goals of *part 2* of this dissertation were to make a cross-cultural adaptation of a battery of questionnaires and to improve the clinical use of these questionnaires concerning long-term test-retest reliability, cut-off scores and MCIC. The overarching aim of this investigation was to improve the assessment and the monitoring of functional disability, QOL, psychosocial and pain-related factors in patients with NS-CLBP. These goals were accomplished through two studies. In *chapter 3*, questionnaires that needed a cross-cultural adaptation were translated through a specifically described process.[50] Once the questionnaires were adapted, long-term test-retest was investigated on a group of NS-CLBP patients.[51] In *chapter 4*, COS were defined for screening questionnaires and ranges of MCIC were established for outcome measures to facilitate the clinical interpretation of the questionnaires.

1.2.1. Cross-cultural adaptation

Self-report questionnaires have often been investigated in patients with LBP and sufficient guidelines exist to adapt and validate questionnaires. However, for the clinicians, adequate versions of the questionnaires are often lacking. Sometimes questionnaires do not exist in the required language or if they do, they not always respect the cultural differences between countries. In addition, available questionnaires are not always validated on the target population. The first part of *chapter 3* offered an answer to these concerns. Questionnaires lacking valid translation as well as translated questionnaires demonstrating problems related to cultural issues, were translated from the original English version into Dutch and French versions, with respect to previously described guidelines.[50] A

cross-cultural adapted Dutch and French version of the TSK, OMPQ, QBPDI, PHQ-15 and $MPI_{part\ 1}$ was obtained.

To avoid cultural differences related to the language, the translation procedure (including the pilot testing) was not only conducted in the French and Dutch speaking part of Belgium, but also in the Netherlands and France. Consequently, the questionnaires are ready for clinical use in most of the European Dutch and French speaking patients.

1.2.2. Long-term test-retest reliability

For most of the existing questionnaires the test-retest reliability is reported in the literature and mainly positive results are described. However, there are two main problems concerning the information found in the available literature.

First of all, test-retest reliability is mostly investigated over short time intervals (1 to 2 weeks), which is not in line with the real long waiting time interval between assessment and treatment for patients with NS-CLBP generally being the case in most rehabilitation centers, including the MHQA. Therefore, there was a need to test all the selected questionnaires over a longer period of time.

Secondly, guidelines exist to investigate test-retest reliability[52], but they are quite recent and rarely respected. As a consequence, the applied reliability parameters are often inadequate or no information is given about the statistical method used. With respect to these guidelines, the $ICC_{2,1}$, the $SEM_{agreement}$, the 95% confidence intervals and the $MDC_{95\%}$ were defined in the second part of *chapter 3* for the following questionnaires: the QBPDI, the MPI-part 1, the TSK, the OMPQ, the PHQ-15, the PCS, the DRAM, the HADS and the SF-36. Overall, the results of this study confirmed previous positive results about reliability[53-57], except for the SF-36. The latter exhibited poor reproducibility, in contradiction with previous research.[58]

Information on test-retest reliability is essential when investigating clinical important changes (MCIC), as done in *chapter 4*.

1.2.3. COS and MCIC

The aim of *chapter 4* was to improve the clinical use of the investigated questionnaires by establishing COS and ranges of MCIC. This information is essential for therapists to screen for psychosocial risk

factors and to follow-up the patients' improvement or deterioration. The difficulty of these parameters is that they are population dependent. In addition, existing information has often been created arbitrary and is not based on empirical research. In this chapter, COS were described for the TSK, PHQ-15 and OMPQ concerning subjects with NS-CLBP. Responsiveness and ranges of MCIC were established for the TSK**,** the OMPQ, the QBPDI, the MPI-PS**,** the SF-36_{PCS} and the SF-36_{TS}.

1.3. The link between physical and psychosocial assessment

The planetary model emphasizes the link between the different aspects relevant in the assessment and rehabilitation of NS-CLBP. It stresses the interrelation between structure impairments, movement dysfunction, the persons' functioning, psychosocial components and pain-related factors in patients with NS-CLBP.[1]

In part 3 of the current dissertation, performance on back and abdominal endurance tests - in combination with assessment of functioning, psychosocial components and pain-related factors - were used as an example to picture this interaction. Both performance on the B-S test as well as performance on the abdominal endurance test seem influenced by other factors than only physiological aspects (i.e. muscle fatigue). The main findings were that underperformance on back muscle endurance tests was more likely influenced by physical components (self-reporting on physical health), whereas abdominal muscle endurance tests seemed more affected by psychosocial components (self-reporting of mental health).

Other examples of these interactions between physical performance and psychosocial components within that specific population have been described in research[59-62] and the overall conclusion is that psychosocial aspects cannot be neglected when assessing physical characteristics and outcome of rehabilitation in patients with NS-CLBP. In people who are disabled by LBP, physical performance seems directly limited by, for example, unhelpful pain cognitions.[59] Cognitive factors may even cause persistent changes in movement patterns, which in turn promote chronicity.[61-62] Watson et al.[62] found that during forward bending, there was a relationship between the pattern of paraspinal muscle activity and fear avoidance and self-efficacy beliefs.

Even more, when assessing changes in physical performance, it is important to note that some of these changes may result from changes in psychosocial aspects (including cognitive factors).[63-64] Moseley[59] demonstrated that changes in pain cognitions are associated with changes in physical

performance in patients with NS-CLBP, mostly explained by a change in the conviction that pain means tissue damage and by pain catastrophizing. Watson et al.[62] found also that when patients participated in a multidisciplinary pain management program, there was a relationship between normalization of the trunk muscle recruitment patterns during forward bending and cognitive factors. Altered cognitions seem to allow increased exposure to activity, which in turn may lead to increased or altered performance.

In addition, our study demonstrated that not all physical performance tests are influenced by the same factors. A clear difference was demonstrated between the influences of psychosocial aspects on the performance on an abdominal endurance test compared to the performance on a back endurance test.

2. Limitations

An overall limitation of this dissertation is that the population investigated was essentially composed of military personnel and civilians working for Belgian Defense. The specific environment of these patients (e.g. long missions abroad), the work-related health monitoring (e.g. annual physical tests) and also the small proportion of women in this population, could have biased the results of the different studies. The military population is a mixture of very active and more sedentary people. As in the civilian population, each military has different environmental influences, as well as family and social concerns. In addition, the Belgian Defense employs about 16 % civilians also included in the participants to the described studies. Although some risk factors for developing LBP are specific to military personnel (concomitant psychological trauma, g-force exposure in pilots and airmen, extreme shock and vibration exposure …), there are many similarities between the military and the general population concerning the predictive factors associated with spinal pain and disability.[65-67] In both populations there is strong evidence that NS-CLBP disorders are associated with a complex combination of physical, behavioral, lifestyle, neuro-physiological (peripheral and central nervous system changes), psychological/cognitive and social factors. The balance and contribution of these different factors will likely vary for each individual. Therefore, also in military settings NS-CLBP should be assessed and treated within a multidimensional bio-psycho-social framework with the goal of breaking the vicious pain circle of NS-CLBP and diminishing its impact.[68-72] In contrast, persons, who want to enter the Belgian army as a military, are refused when a scoliosis > 18°, a hypokyphosis <

10°, a hyperkyphosis > 55°, bilateral spondylolysis with associated spondylolisthesis or a discopathy objectified by Computed Tomography is present. In this way, the military population displays less structural spine deformities than a general civilian population. Even if a lot of similarities are present between a civilian and a military population, some differences should be taken into account: (1) First of all, the misbalance between the proportions of female to male subjects, which is specific in this military population,[73] could hamper the applicability of the current dissertation outcomes for female subjects. For example, the predominantly male population in the Defense setting is important to note regarding *part 1* of this dissertation. In relation to trunk muscle strength[74-76] and trunk muscle recruitment patterns[77] important differences are found between male and female subjects. Smith et al.[76] observed higher values for isokinetic trunk muscle strength (adjusted for body weight) in healthy male subjects, compared to female subjects. Mayer et al.[75] even found that, in a population with NS-CLBP, isokinetic trunk muscle strength was more affected in female subjects compared to male subjects. Also in sEMG analysed trunk muscle recruitment patterns gender differences have been found.[77] In *chapter 1*, male and female subjects were tested, and the effect of gender was taken into consideration. In *chapter 2*, only male subjects were tested and thus caution should be taken when generalizing these results to a female population. (2) Secondly, to answer the physical demands of a military career, an individual has to avoid excess of body weight[78]. The prevalence of overweight and obesity (an important risk factor in NS-CLBP) is lower in the Belgian army (41% of 48 850 male military) compared to the Belgian civilian population (52% of 83 683 civilian male employees).[73] As body weight may have consequences on both physical performances and psychological health, this could have influenced the results. (3) In addition, the military personnel need to perform yearly general physical tests, such as 2400 m running, sit-up and push-up to evaluate their physical readiness to leave for military missions. These differences imply that caution should be taken when generalizing these results to a civilian population.

A second general concern is the test sequence in some of our experiments. Although in research randomization of test sequence is preferred, for practical reasons standard sequences were used in the studies of part 1 and part 3 of this dissertation. Related to fatigue or learning effect, questions can arise regarding the effect of these standard sequences on the results of these studies. However, in *chapter 1,* fatigue effects were expected to be minimal since enough recuperation time (60 seconds rest between different resistance levels) was allowed.[79-81] In *chapter 2*, the different low load exercises

were separated by sufficient rest during which the next exercise was explained. The two exercises investigated in *chapter 5* affected different muscle groups. In our opinion the learning effect should also be negligible in these studies. In *chapter 1* the movement is very straightforward; moreover, a test trial was performed before the start of the testing. In the study described in *chapter 2*, the variation between the exercises is so large, that no learning effect is expected.

2.1. Trunk muscle recruitment patterns

The results of the two studies examining trunk muscle recruitment patterns should also be interpreted in light of some methodological limitations.

Firstly, in both studies, only four muscle groups were analyzed. Butler et al.[23] underlined the need to measure a comprehensive number of muscle sites when investigating trunk muscle recruitment patterns. All trunk muscles are important[21,82] and different segments within a muscle can even respond differently to perturbation.[83-86] However, the majority of the studies reported in the literature used much fewer muscle sites compared to the present dissertation. Investigating more muscle groups would certainly help to better understand trunk muscle recruitment patterns, but in function of the aim of the studies, choices had to be made. Cost-effectiveness should be taken into account with regard to the aim of the study. For example, critics might point the fact that the statistical model developed on the motor control exercises is far from complete, using only 4 muscle groups and only 3 exercises. But the goal of this study was to make a model, easy to use, to assess and re-assess patients with NS-CLBP in an objective way. If measuring more muscle groups, more electrodes are needed. If using more exercises, more time is required. More electrodes and more time imply more costs. Consequently, if the current method seems effective, there is no need to develop a more complicated and time consuming model.

Secondly, the use of a submaximal contraction to normalize the EMG activity in the first two studies of this dissertation may be criticized. Researchers do not agree upon the idea what is the best method to normalize EMG amplitude data[6,12], not on using a submaximal or a maximal contraction, neither on the tests needed to record these values. The choice for normalization on submaximal contraction was made essentially to avoid erroneous results in the patient population. Recording maximal contractions in patients with LBP is often impossible due to pain or kinesiophobia. The present dissertation showed clearly the importance of psychosocial components on physical performance. Normalization to

maximal voluntary isometric contraction therefore carries the risk of overestimating the relative muscle activity (by underestimating the maximal contractions).

Not only the normalization procedures, but also the use of ratios hampers comparisons with other studies. Ratios were used to clarify the proportion of deep stabilizing muscle activity to global torque producing activity, but literature describing this kind of ratios is scarce.[87-88]

In addition, the use of amplitudes to determine muscle activation is not exclusive in analyzing trunk muscle recruitment patterns. Measuring, for example, timing of onset of the different muscle groups[7,89-90] could give additional information, but this implies another methodology. Delayed anticipatory muscle activity response in deep stabilizing abdominal and back muscles has been observed in patients with LBP, indicative of a pathological condition.[7,89-90]

Finally, in *chapter 1* and *2* of this dissertation, surface electrodes were used to measure EMG amplitudes of both deep stabilizing and global torque producing muscle groups during a range of motor control exercises to define trunk muscle recruitment patterns. Although sEMG is often used in studies involving deep lying muscle layers,[91-96] the use of this technique could be questioned. Fine wire electrodes are often preferred for measuring deep located muscle groups,[6,89,97] but in a clinical setting there is a clear need for non-invasive and less cumbersome recording methods. The use of fine wire electrodes is rather invasive and costly and requires a high level of specialization of the therapist,[98] which limits its practical application. In addition, fine wire electrodes offer a detailed view of a specific muscle part, but may be less effective in describing the whole muscle.[99-100] sEMG was used previously to measure the electric activity in terms of amplitudes of deep layered trunk muscles.[9,101-102] Arokoski et al.[103] even found a correlation between normalized intramuscular EMG signals and normalized sEMG. Okubo et al.[104] demonstrated a high correlation between EMG activity of the LMF measured by fine wire electrodes compared to sEMG. This was not true for measures of the TrA. Therefore, in the present studies the IO was measured and not the TrA. Marshall and Murphy[98] demonstrated that medially and inferior to the anterior superior iliac spine the fibers of the TrA and of the IO (inferior fibers) are blended and that it is impossible to distinguish both signals at this location. At this location the fibers have also the same orientation (inferomedial).[6] Because these muscles play a similar role in stabilizing the lumbar spine,[105] we opted to measure the IO.

Other techniques exist to evaluate trunk muscle reruitment patterns. For example, muscle functional MRI is an other non-invasive technique that allows localizing activated muscles leading to a reliable

mapping of the recruited muscles during exercise.[106-107] Although several advantages of MRI over sEMG methods have been described (high spatial resolution leading to better imaging of deeper muscle layers and even to detection of differences in muscle activity between compartments of the same muscle; avoidance of confounding factors such as the thickness of the subcutaneous fat layer, etc.)[108], MRI is very expensive and often not available in research teams. MRI has also several technical limitations (contraindicated in the presence of implanted ferromagnetic objects or certain medical devices, claustrophobia and it has limitations on the number and location of slices that can be acquired for each exercise).[108] Calibration and thus the interpretation of muscle recruitment differences between muscles (either between or even within individuals) are also complicated with MRI.[108] Real-time ultrasound imaging can be reliably used to evaluate and compare the automatic activity of the trunk muscles between participants with and without CLBP[109-111] but is highly dependent on the operator's level of training.[111] Furthermore, the interpretation process is complicated by the fact that the amount of change detected in a muscle's architecture (depth, width, and length) during a contraction does not necessarily represent the intensity or amount of actual muscle activity.[112-113]

2.2. Self-report questionnaires

Quality criteria suggest the need for detailed psychometric testing of newly developed or adapted questionnaires.[52,114-116] The Scientific Advisory Committee (SAC) of the Medical Outcomes Trust[117] defined eight attributes of instrument properties that deserve attention when evaluating the quality of a questionnaire. These include (1) conceptual and measurement model, (2) validity, (3) reliability, (4) responsiveness, (5) interpretability, (6) respondent and administrative burden, (7) alternative forms, and (8) cultural and language adaptations (translations). Within each of these attributes, specific criteria were defined by which instruments should be reviewed. Terwee et al.[52] even proposed explicit criteria for what constitutes good measurement properties for most of these attributes.

In this dissertation, the cross-culturally adapted questionnaires were not fully examined on psychometric properties. Globally, to analyze the quality of a measure two aspects should be investigated: reliability and validity. Reliability, in terms of test-retest reliability, is extensively analyzed in Chapter 3 of this dissertation. This information is required for the further validation process. Validity

is a broad term, which includes different aspects, depending on the aim of the questionnaires (ie. screening or evaluative questionnaire). Examining validity is a process which can involve diverse perspectives. Validation of the original versions of the questionnaires was done extensively in the past and adapting the questionnaires following a strict procedure (as done in *Chapter 3*) ensures that some aspects (e.g. construct validity, content validity) of the validity are maintained over the different versions.[50] In addition, the scope of this project was the clinical use of the questionnaires. Therefore, this dissertation only focuses on a little aspect of the validation procedure, ie the clinical interpretation of the results (cut-off scores and discriminative value of screening questionnaires and responsiveness of evaluative questionnaires).

In addition, the battery of the questionnaires is certainly not a complete psychosocial screening of the patients and even more, some questionnaires might be removed in the future. The selection of the questionnaires was based on previous experience and literature research, but this demands a continuous evaluation and, if necessary, adaptation. Research and new experiences in the clinical practice concerning the domain of NS-CLBP continue to evolve. Both researchers and clinicians should be aware of new evolutions in this domain. The practice and research should be based on the evoluting evidence. For example, instruments measuring pain mechanism are currently not included. Although, the assessment of pain mechanisms seems important in patients with NS-CLBP.

2.3. The link between physical and psychosocial assessment

Although the study linking the endurance tests to the self-report questionnaires (chapter 5) was based on the criticized use of normalized slope as measure for muscle fatigue, it demonstrated well the link between physical assessment and functional disability, psychosocial and pain-related variables. This study was just set as an example of these interactions, but did not enter into detail in the consequences of these interactions. Specific research should continue to focus on this topic more thoroughly.

3. Clinical implications

This research project was conducted in a clinical setting (of the MHQA). The research questions were based on the needs formulated within this clinical setting. This implies that all the results described in this dissertation were immediately translated to the all-day assessment of NS-CLBP.

3.1. Trunk muscle recruitment patterns

Although trunk muscle recruitment patterns are often discussed in NS-CLBP, a lot of controversy exists concerning the differences between patients with NS-CLBP and healthy subjects. However, it remains a fascinating topic and exercises which aim to improve trunk muscle recruitment patterns demonstrate positive results in the rehabilitation of patients with NS-CLBP.[118-122] Therefore, objectifying trunk muscle recruitment patterns during different exercises/activities can be of great value to assess and follow-up patients with NS-CLBP.

However, defining trunk muscle recruitment patterns is complicated. It is clear that these patterns are exercise/posture dependent and that high variability exists between subjects, as underlined in the results of the first part of this dissertation. Physiotherapists should therefore combine different exercises to rehabilitate patients and choose exercises in function of the patients' complaints and the relevance to the patients' leisure and work.

According to Edgerton et al.[14] EMG ratios can be a sensitive discriminator of altered recruitment patterns and muscle dysfunction. Therefore, ratios of relative muscle activity of deep stabilizing muscle groups versus superficial torque producing muscle groups were thought to provide insight into the contribution of both muscle systems in relation to each other. In order to highlight differences in synergistic activity of deep stabilizing versus superficial torque producing muscle groups, ratios of muscle activity levels during various stabilization exercises have been investigated in healthy subjects[101] and in LBP patients.[7,123]

The results of the study described in *chapter 1* show that velocity of isokinetic movement has an impact on trunk muscle ratios in healthy subjects. These results suggest that the choice of the velocity of the isokinetic movement is important in the evaluation and rehabilitation of trunk muscles. However, this study was conducted in a healthy population and caution should be taken when generalizing these results to the evaluation and treatment of patients with NS-CLBP. Replication of this study to a sample of patients with NS-CLBP should be performed to investigate whether the effect of velocity of

isokinetic movements on trunk muscle ratios is similar in a patient population. Further investigations should then focus on the effect of exercise therapy (with or without devices) on these ratios of trunk muscle recruitment during isokinetic tests.

Motor control impairments are present in a large subgroup of patients with NS-CLBP and motor control assessment during low load activities is developed to determine the ability of patients to control their spine. But these tests are subjective and attempts to translate the results of these tests in terms of trunk muscle recruitment are hypothetical. Using sEMG to record trunk muscle patterns during this kind of tests may be a possible solution to objectify the test and to understand the underlying mechanisms. In the European guidelines concerning the management of NS-CLBP[68], sEMG is not indicated as a diagnostic tool. However, the study concerning trunk muscle recruitment patterns during motor control exercises demonstrated some promising results. The developed statistical model (*chapter 2*) enables to differentiate between patients and healthy subjects and possibly to follow-up changes after therapy. This implies that using this approach, an objective dimension can be given to motor control testing and to the evaluation of treatment efficacy. The model is certainly not a complete model and does not explain the whole picture of motor control impairment. This method gives no insights in the patterns used in both populations, but just highlights that a difference is present between these populations. It could be a useful tool to monitor changes after therapy and to draw conclusions about the effectiveness of therapy. However, it remains crucial to interpret these changes in the light of the patients' clinical improvement.

3.2. Self-report questionnaires

Self-report questionnaires are not only increasingly integrated into clinical practice, but also in research settings. The use of these reliable and valid questionnaires in research could help in interpreting possible research results (eg. effects of a specific therapy on NS-CLBP) from a biopsychosocial perspective. The current understanding of psychosocial variables in patients with NS-CLBP indicated that physical assessment and rehabilitation cannot be separated from psychosocial influences.

At the MHQA, the developed battery of questionnaires is used in its entire electronic form, but the questionnaires can be used separately on either electronic or paper versions. Choices should be

made in function of the needs of the research purposes or the clinical implication, and in function of the available time and material.

The findings concerning the clinical interpretation of the questionnaires results, detailed in *chapter 4*, were obtained in an entirely clinical sample of NS-CLBP. The FV and DV of the questionnaires can be used for other populations, but as discussed previously, the reliability, COS and MCIC established in this study are not transposable to populations with other pathologies. For these populations, new cut-off scores and MCIC should be established.

The series of questionnaires allow screening NS-CLBP patients for kinesiophobia, yellow flags, multiple somatic complaints, catastrophizing and depression and to detect improvement in functioning, QOL and psychosocial factors after therapy. However, based on the results of this study, we cannot conclude that the TSK and the subscales of the SF-36 can monitor changes. The results of these studies demonstrated that the SF-36 seems not reliable over a long time interval. Current results suggest that the TSK was not responsive to changes in the patients' kinesiophobia in a NS-CLBP population. However, these results should be interpreted in the light of the external criteria used (patient's and clinician's subjective reporting on kinesiophobia). In addition, the treatment concerned a non-standardized exercise therapy.

3.3. The link between physical and psychosocial assessment

In (re)-assessment of physical performance, psychosocial aspects cannot be thought away and clinicians should be aware of possible influence of these aspects on the outcome of physical tests. Limitations of physical performance that are identified clinically may in part be the consequence of pain cognitions. They therefore may respond to strategies that induce cognitive change. Concerning the rehabilitation of patients with NS-CLBP, implementing a combination of cognitive-educational, psychological and physical strategies[124] might improve the outcome due to cognitive and behavioral changes, in addition to the improvements obtained by physical changes. Choices concerning the treatment pathway should be taken based on the results of the conducted assessment. When interpreting the results of research trials, psychosocial effects of interventions should be considered as active components in physical improvement. Monitoring psychosocial and pain-related factors is essential if the aim of the research is to demonstrate the benefits of physical strategies.

4. Future directions

The research on the assessment of NS-CLBP should continue to improve the understanding of physical, as well as psychosocial components of this condition.

First of all, the objective assessment of sensorimotor control by measuring trunk muscle recruitment patterns using sEMG should be further refined:

The study concerning trunk muscle recruitment patterns during isokinetic exercises can be reproduced in a NS-CLBP population, to investigate differences between healthy subjects and patients. To this date, it is not known if the velocity of the isokinetic movement has the same influence on trunk muscle recruitment patterns in patients as it is the case in healthy subjects. Application of the same test protocols would allow comparison between patients and healthy subjects.

The statistical method developed on low load exercises, presented in this dissertation, should be tested and refined if necessary. The purpose of the study described in *chapter 2*, was to find a way to objectify diagnosis of MCI based on the concept of Kinetic Control. Previous research underlined the need to subclassify patients with NS-CLBP,[125-126] but objective measures to do this are lacking. In the developed statistical model, we focused on patients with a flexion-related MCI, because this group of patients is the most important in the NS-CLBP patients at the MHQA. Including other MCI groups or patients with NS-CLBP who did not demonstrate a clear MCI could provide additional information. Further research should therefore focus on other groups of MCI, but also on the correlation of changes observed in the outcome of the current model and other outcome measures that evaluate improvement after therapy. Patients should be monitored after therapy and the responsiveness of the model should be tested. If the model seems responsive to changes, it could be used to evaluate the effectiveness of different exercise therapies.

The battery of self-report questionnaires discussed in this dissertation is not exhaustive and was even rather extensive. Consequently, clinical experience and further research should refine this series of questionnaires. Some questionnaires might be removed, replaced or added. For example, the DRAM can be replaced by the HADS and the PHQ-15, measuring respectively depression and multiple somatic complaints. As pain mechanisms can be affected in persistent pain and may be responsible for therapy resistance, abnormal pain processing should be detected in patients with NS-CLBP. It could be interesting for clinicians to screen for example for central sensitization. Further investigations in the domain of central sensitization should help us to choose an appropriate instrument to screen for

this kind of problems. In summary, clinicians should be open to new developments and habitual used instruments should be tested in the light of new evolutions. Advantages as well as disadvantages of new measurement instruments should be considered to decide on assessment adaptations in the future. Both in physical as well as in psychosocial assessment, caution should be taken when interpreting results, since these two components of NS-CLBP assessment are interacting with each other.

5. General conclusions

The aim of this dissertation was to improve the physical and psychosocial assessment of patients with NS-CLBP, in order to (1) refine the intake assessment of these patients at the Military Hospital Queen Astrid; (2) to make a valuable contribution to guidelines in the assessment of NS-CLBP in general.

The studies concerning the investigation of trunk muscle recruitment patterns confirm: (1) the task-specificity of trunk muscle recruitment patterns and (2) the difference between patients and healthy subjects. Therefore, exercises should be chosen in function of the individual needs of the patient. In addition, it seems possible to develop a statistical model to differentiate between patients and healthy subjects, although trunk muscle recruitment seems to be characterized by a wide variability in both the patient and healthy population and is influenced by task-specificity. Future research should indicate the capacity of this model to monitor changes after therapy.

This dissertation stresses that psychosocial assessment and physical assessment are inseparable. Psychosocial assessment cannot be ignored in the assessment of NS-CLBP. In this line, the current dissertation was also a step forward in the clinical use of self-report questionnaires. The development of a battery of questionnaires in the Dutch and French languages, and the availability of COS and information about the MCIC's are a valuable contribution to the research and the daily clinical practice.

The current results will hopefully inspire researchers in their quest for optimal assessment techniques and help clinicians to conduct a specific and complete assessment of patients with NS-CLBP.

***Take home message*:**

Research linking physical and psychosocial characteristics emphasized the need to assess and rehabilitate both. The present dissertation provided tools (FV and DV of a series of questionnaires and indications for the interpretation of the patients' scores) to improve psychosocial assessment in NS-CLBP patients, applicable in clinical practice.

In addition, sEMG may be helpful in investigating some relevant aspects of motor control in research and clinical settings.

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ENGLISH SUMMARY

NS-LBP is defined as pain and discomfort, localized below the costal margin and above the inferior gluteal folds, with or without referred leg pain, that is not attributable to a recognizable, known specific pathology. NS-CLBP involves NS-LBP persisting for at least 12 weeks. In the civilian as well as in the military population NS-CLBP is a common problem with an important impact on the patient's functioning and on the society.

Previous research demonstrated that NS-CLBP is not only caused by physical factors, but the psychosocial factors also play an important role in the onset and perpetuation of NS-CLBP. It is commonly accepted that these patients should be assessed biopsychosocialy. The planetary model is therefore an adequate coat rack in the management of NS-CLBP. To ensure a good outcome, it is primordial to tailor the therapy in function of the patient's needs. This is only possible after a detailed physical and psychosocial assessment of the patient. Different tools and concepts were proposed to sustain this assessment, but some pitfalls exist.

The aim of this doctoral dissertation was to optimize some aspects of the assessment of patients with NS-CLBP, to objectify the patient's complaints and the associated influencing factors. The project was subdivided in three parts.

In the first part trunk muscle recruitment patterns were investigated with sEMG. Literature often described altered trunk recruitment patterns in patients with NS-CLBP. Trunk muscle recruitment patterns were analyzed in terms of ratios of deep stabilizing muscle groups to global torque producing muscles. In Chapter 1 de influence of velocity of isokinetic movement on trunk muscle recruitment patterns was investigated. Fifty-three healthy subjects (26 men and 27 women) performed flexion-extension movements on a Cybex isokinetic dynamometer at different velocities (30°/s, 60°/s, 90°/s, 120°/s). The activity of two deep stabilizing muscle groups (m. obliquus internus abdominis (IO) and the lumbar m. multifidus (LMF)) and two superficial torque producing muscles (m. obliquus externus abdominis (EO) and the m. iliocostalis lumborum pars thoracis (ICLT)) were recorded simultaneously. The relative muscle activity as well the ratios LMF/ICLT and IO/EO were analyzed. Results demonstrated that the relative muscle activity of the different back muscles decreased with increasing velocity, but the LMF was less influenced by velocity than the ICLT, resulting in an increased ratio LMF/ICLT at high velocity. This study did not demonstrate an influence of velocity on the abdominal muscle groups. In *Chapter 2* the same ratios were analyzed during 6 sensorimotor control exercises. Sixty-three healthy men and 36 patients with NS-CLBP participated in this study. All patients

demonstrated a flexion-related MCI. Based on the trunk muscle recruitment patterns during the 6 exercises a statistical model was developed to discriminate between patients and healthy subjects.

This part of the project led to the adjustment of several physical tests of the clinical pathway for NS-CLB at the MHQA. Chapter 1 underlined the importance of the use of different velocities in isokinetic evaluation and treatment of these patients. Chapter 2 provided evidence that trunk muscle recruitment patterns can be measured objectively in patients with flexion-related MCI. This is not only relevant in the clinical practice, but also in research as on objective variable in for example studies investigating the influence of therapy.

The second part of the project focused on the improvement of psychosocial evaluation in patients with NS-CLBP. The aim was to optimize the use of self-report questionnaires. Therefore cross-cultural adaptation to Dutch and French was performed for the following questionnaires (Chapter 3): TSK, PHQ-15, QBPDI, OMPQ and the MPI_{part1}. Based on these and other questionnaires (PCS, DRAM, HADS, SF-36) a battery of self-report questionnaires was developed and long-term test-retest reliability was investigated. Test-retest reliability was analyzed on 48 French-speaking and 43 Dutch-speaking patients with NS-CLBP. Results indicated that scores on most of the questionnaires remained stable over time (> 1 month), except for the SF-36. In Chapter 4, the clinical interpretation of the scores on the questionnaires was facilitated by determining cut-off scores for screening questionnaires (TSK, PHQ-15, OMPQ) on198 patients with NS-CLBP, as well as determining MCIC for evaluative questionnaires (TSK, QBPDI, OMPQ, MPI_{part1}, SF-36) on 70 patients with NS-CLBP.

This part of the study allowed the use of these questionnaires in a French and Dutch-speaking population. Although some waiting time exists between the moment the questionnaire is filled in and the start of the therapy, the clinician may be confident that the scores of the questionnaire are stable over a long period of time (> 1 month), if the patient's status remains stable. The cut-off scores and the MCIC led to an easy interpretation of the scores and the change in scores. These results are also important in further research. Results of the questionnaires could for example be used as outcome variable in the evaluation of different therapies.

The third part of this doctoral project underlined the link between psychosocial and physical evaluation, in the line of existing literature. Chapter 5 gave on example of this. Research was done on the influence of psychosocial factors on performance during two endurance tests for the abdominal and back muscles. Three hundred thirty two patients with NS-CLBP filled in a series of

questionnaires. Then they effectuated the Biering-Sorensen back muscle endurance tests (B-S test) and an abdominal endurance test. Simultaneously the muscle activity of the LMF and the ICLT during the B-S test and the IO and the EO during the abdominal endurance test were recorded by sEMG. The time to exhaustion was also recorded. Based on the intrinsic muscle fatigue (normalized slope) the predicted time to exhaustion was calculated for both tests separately. By comparing the real time to exhaustion by the predicted time patients were divided in a performance and an underperformance group. Questionnaire results were compared for both groups. Regression analyses were performed to examine the predictive value of the questionnaires on the time to exhaustion. Results demonstrated that for the B-S test scores on the physical subscales of the SF-36 were lower in the underperformance groups. A higher BMI and low scores on the $SF\text{-}36_{PF}$ were significant predictors of low performance on the B-S test (R^2=0.10). Concerning the abdominal endurance test, the group patients with low performance had significantly higher scores on the $DRAM_{MZDI}$ and the PCS, and lower scores on the SF-36. A higher BMI and lower scores on the $SF\text{-}36_{MCS}$ were significant predictors of lower scores on this test (R^3=0.04). The results demonstrated that both tests were influenced differently. The B-S test seemed more influenced by physical factors and the abdominal endurance test were influenced by mental components. Why this difference exists is not clear, but this demonstrates again that in the interpretations of physical tests, psychosocial influences should be considered. Psychosocial influences are not equal for each physical test; therefore a complete psychosocial evaluation is needed.

The overall aim of this doctoral dissertation was to contribute to the assessment of NS-CLBP, by improving the use of some instruments and tools. The results of these studies are not only interesting for the clinical practice, but are also useful in further research.

NEDERLANDSTALIGE SAMENVATTING

Aspecifieke lage rugpijn (A-LRP) is rugpijn in het gebied tussen de onderste ribben en de bilplooien, met of zonder gerefereerde pijn in de onderste lidmaten, waarbij geen specifieke lichamelijke oorzaak aanwijsbaar is. Chronische A-LRP (A-CLRP) is A-LRP dat meer dan 12 weken duurt. Zowel in de militaire populatie, als binnen de burger populatie, blijft aspecifieke chronische lage rugpijn (A-CLRP) een veel voorkomend probleem die een enorme impact heeft op het functioneren van de patiënt en op de samenleving.

Onderzoek toont aan dat niet enkel fysieke factoren, maar ook psychosociale factoren een belangrijke rol spelen in het ontstaan en het onderhouden van A-CLRP. Het is dan ook algemeen aanvaard dat deze patiënten op biopsychosociaal vlak moeten benaderd worden en het planetair model biedt hier een goed houvast.

Om de slaagkansen van de therapie te verbeteren is het noodzakelijk om deze af te stemmen op de noden van de individuele patiënt. Dit is enkel realiseerbaar indien de patiënt uitgebreid wordt geëvalueerd, op zowel fysiek als psychosociaal vlak. Verschillende instrumenten en concepten werden eerder al voorgesteld om deze evaluaties te ondersteunen, maar er zijn nog een aantal tekortkomingen.

Het hoofddoel van dit doctoraal proefschrift was om een aantal aspecten van de evaluatie van patiënten met A-CLRP te optimaliseren, ten einde zich een objectiever beeld te kunnen vormen van de klachten van de patiënt en de factoren die deze klachten beïnvloeden. Het project werd hiervoor in drie delen onderverdeeld.

In het ***eerste deel*** werd er aan de hand van oppervlakkige elektromyografie onderzoek gedaan naar spierrekruteringspatronen van enkele rompspieren. Deze zijn, volgens de literatuur, vaak verstoord in patiënten met A-CLRP. Spierrekruteringspatronen werden bestudeerd in termen van ratio's van diep stabiliserende musculatuur ten opzichte van oppervlakkige kracht producerende musculatuur. In *hoofdstuk 1* werd de invloed van de snelheid van isokinetische bewegingen op spierrekruteringspatronen (van buik- en lage rugspieren) nagegaan. Drieënvijftig gezonde proefpersonen (26 mannen en 27 vrouwen) voerden flexie-extensie oefeningen uit op een Cybex isokinetische dynamometer aan verschillende snelheden (30°/s, 60°/s, 90°/s, 120°/s). Gelijktijdig werd de activiteit van twee diep stabiliserende spiergroepen (m. obliquus internus abdominis (IO)) en de lumbale m. multifidus (LMF)) en twee oppervlakkige kracht producerende spiergroepen (m. obliquus externus abdominis (EO) en de m. iliocostalis lumborum pars thoracis (ICLT)) opgemeten. De

relatieve spieractiviteit per spier alsook de ratio's LMF/ICLT en IO/EO werden geanalyseerd. De resultaten toonden aan dat de relatieve spieractiviteit van de verschillende rugspieren verminderde met toenemende snelheid, maar dat de snelheid minder invloed had op de LMF dan op de ICLT, met als gevolg dat de ratio LMF/ICLT groter was bij hoge snelheid. De studie kon geen invloed van de snelheid aantonen op de buikspieractiviteit. In *hoofdstuk 2* werden dezelfde ratio's bestudeerd tijdens 6 motorische controle-oefeningen. Aan deze studie namen 63 gezonde mannelijke proefpersonen en 36 mannelijke patiënten met A-CLRP deel. De patiënten vertoonden allemaal een flexie-gerelateerde motorische controle disfunctie (MCI). Op basis van de spierrekruteringspatronen tijdens deze verschillende oefeningen werd een statistisch model opgebouwd dat toelaat om patiënten van gezonde proefpersonen te onderscheiden, op basis van een aantal motorische controle-oefeningen.

Dit deel van het doctoraatsproject heeft geleid tot het aanpassen van enkele fysieke testen binnen het klinisch zorgpad lage rug in het MHKA. *Hoofdstuk 1* heeft aangetoond dat het gebruik van verschillende snelheden op isokinetische toestellen zeker nuttig is in de evaluatie en behandeling van patiënten. *Hoofdstuk 2* heeft bewijs geleverd dat spierrekruteringspatronen objectief gemeten kunnen worden bij patiënten die flexie gerelateerde MCI vertonen. Dit is niet enkel nuttig in de klinische praktijk, maar ook in het onderzoek als objectieve variabelen in bijvoorbeeld het bestuderen van de invloed van een welbepaalde therapie.

In het ***tweede deel*** van de het project werd de focus gericht op het optimaliseren van de psychosociale evaluatie bij patiënten met A-CLRP. Het doel van dit deel was om het klinisch gebruik van vragenlijsten te verbeteren. Hiervoor werden in *hoofdstuk 3* de volgende vragenlijsten vertaald naar het Nederlands en/of Frans volgens een welbepaald protocol: Tampa schaal voor kinesiofobie (TSK), de patiënt gezondheidsvragenlijst (PHQ-15), de Quebec vragenlijst betreffende fysieke beperking ten gevolge van LRP (QBPDI), de Orebro screeningsvragenlijst betreffende musculoskeletale pijn (OMPQ) en de multidimensionele pijn vragenlijst (MPI_{part1}). Op basis van deze en andere vragenlijsten (catastroferen (PCS), risico evaluatie van "lijden" (DRAM), angst en depressie (HADS), algemene gezondheid (SF-36)) werd een volledige testbatterij opgesteld en werd de test - hertest betrouwbaarheid nagegaan op lang termijn. Test – hertest betrouwbaarheid werd geanalyseerd op 48 Franstalige en 43 Nederlandstalige patiënten met A-CLRP. Resultaten toonden aan dat de scores op de vragenlijsten voldoende stabiel bleven over een lang termijn interval (> 1 maand), met uitzondering van de SF-36. In *hoofdstuk 4* werd de klinische interpretatie van de score

van de vragenlijsten vergemakkelijkt door het bepalen van cut-off scores voor screening vragenlijsten (TSK, PHQ-15, OMPQ) op 198 patiënten met A-CLRP, alsook het bepalen van klinisch significante verbeteringen (MCIC) voor evaluerende vragenlijsten (TSK, QBPDI, OMPQ, MPI_{part1}, SF-36) op 70 patiënten met A-CLRP.

Dit deel van de studie heeft ervoor gezorgd dat bovenstaande vragenlijsten klaar zijn voor klinisch gebruik in een Frans- en Nederlandstalige populatie. Ook al is de wachttijd tussen het invullen van de vragenlijst en het starten van de therapie lang (> 1 maand), toch mag de therapeut erop berusten dat de scores stabiel zijn gebleven zolang de status van de patiënt niet veranderd is. De cut-off scores en de MCIC laten een eenvoudige interpretatie toe van de scores en verandering in scores. Deze resultaten betekenen ook een ondersteuning voor verder onderzoek. De vragenlijsten kunnen bijvoorbeeld gebruikt worden als uitkomstvariabelen in het evalueren van een therapie.

In het ***derde deel*** van het doctoraatsproject werd, ter ondersteuning van bestaande literatuur, aangetoond dat psychosociale en fysieke evaluatie elkaar kunnen beïnvloeden. *Hoofdstuk 5* geeft hiervan een voorbeeld. Er werd onderzoek gedaan naar de invloed van psychosociale factoren op de prestatie tijdens twee uithoudingstesten voor enerzijds de buikspieren en anderzijds de rugspieren. Driehonderd tweeëndertig patiënten met A-CLRP vulden een reeks vragenlijsten in. Daarna voerden ze een Biering-Sorensen rugspier uithoudingstest (B-S test) en een uithoudingstest voor de buikspieren uit. Gelijktijdig werd de spieractiviteit opgemeten, aan de hand van sEMG van twee rugspieren (LMF en ICLT) tijdens de B-S test en twee buikspieren (IO en EO) tijdens de buikspier uithoudingstest. De uithoudingstijd werd gemeten voor de twee testen. Aan de hand van de spiervermoeidheid (genormeerde 'slope') werd voor de twee testen afzonderlijk de verwachte uithoudingstijd berekend. Door de reële uithoudingstijd en de verwachte uithoudingstijd met elkaar te vergelijken, werd bepaald of de patiënt goed presteerde of een onvoldoende prestatie vertoonde. Zo werden de patiënten in twee groepen onderverdeeld en werden voor deze twee groepen de scores op de vragenlijsten vergeleken. Ook werd een regressieanalyse uitgevoerd om na te gaan of sommige psychosociale factoren de uithoudingstijd gedeeltelijk kunnen voorspellen. Resultaten toonden aan dat betreffende de B-S test de scores op de fysieke subschalen van de SF-36 lager waren in de groep van patiënten met onvoldoende prestaties. Een hoger BMI en een lage score op de $SF\text{-}36_{PF}$ waren significante voorspellers van lage prestaties op de B-S test (R^2=0.10). Voor de uithouding van de buikspieren had de groep patiënten met lage prestaties significant hogere scores op de $DRAM_{MZDI}$

en de PCS, en lagere scores op de SF-36. Een hoger BMI en een lage score op de $SF\text{-}36_{MCS}$ waren predictieve factoren voor een lage prestatie op deze test (R^3=0.04). Wat opviel in de resultaten was dat beide testen door verschillende factoren worden beïnvloed. De B-S test wordt eerder beïnvloed door fysieke factoren, terwijl de uithoudingstest van de buikspieren beïnvloed wordt door mentale factoren. Waarom deze verschillen bestaan is nog onduidelijk, maar deze studie toont nogmaals aan dat bij de interpretatie van resultaten van fysieke testen, psychosociale factoren niet uit het oog mogen verloren worden. Ook is duidelijk aangetoond dat niet alle fysieke testen door dezelfde factoren worden beïnvloed en dat uitgebreide psychosociale evaluatie noodzakelijk is.

Het doel van dit doctoraal proefschrift was een steentje bij te dragen aan de evaluatie van patiënten met A-CLRP, dit voornamelijk door bepaalde testen en instrumenten beter te objectiveren. De resultaten behaald in dit project kunnen niet enkel gebruikt worden in de klinische praktijk, maar zijn ook nuttig als objectieve variabelen in verder onderzoek naar deze populatie patiënten.

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