KATHOLIEKE UNIVERSITEIT LEUVEN

GROUP BIOMEDICAL SCIENCES

FACULTY KINESIOLOGY AND REHABILITATION SCIENCES

REVIEW OF LITERATURE AND DEVELOPMENT OF A COGNITIVE FUNCTIONAL EXERCISE PROGRAM FOR THE REHABILITATION OF SITTING RELATED LBP USING A NOVEL TRAINING DEVICE (FLEXCHAIR®)

TRIAL PROTOCOL DEMONSTRATED BY CASE REPORT

by Tinne Van Acker

master thesis submitted in partial fulfillment of the requirements for the degree of master of rehabilitation sciences and physiotherapy

supervision by
Prof. Dr. W. Dankaerts, promotor

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Following guidelines of *Manual Therapy*

WOORD VOORAF

Deze masterproef is de laatste stap in mijn opleiding revalidatiewetenschappen en kinesitherapie. Ik heb over een onderwerp geschreven wat mij erg interesseert waardoor het echt een leerrijke ervaring is geworden. Het resultaat zou niet mogelijk geweest zijn zonder de tijd en bijdrage van vele anderen. Via deze weg wil ik hen graag bedanken.

Allereerst wil ik mijn promotor Prof. Dr. W. Dankaerts bedanken voor zijn begeleiding en vertrouwen de afgelopen 2 academiejaren. Hij stond van bij de start altijd klaar om raad te geven en stelde zijn zelfstandige praktijk te Tienen ter beschikking van het onderzoek.

Ook een woord van dank aan de mensen van Flexchair®movement voor het mogen volgen van de tweedaagse opleiding Flexchair®RBT. Eveneens mocht er gebruik gemaakt worden van hun apparatuur en database.

Tenslotte bedank ik mijn ouders die mij de kans gaven om deze opleiding te volgen. Wanneer ik het moeilijk had zijn zij in mij blijven geloven. Ook partner, vrienden en familie waren onmisbaar in deze intensieve periode.

Bedankt allemaal!

Koersel, 25 mei 2010 T. V. A.

SITUERING

Lage rugpijn is een van de meest voorkomende medische problemen bij volwassenen. In de literatuur blijkt dat ongeveer zeventig tot tachtig procent van de bevolking minstens een maal in zijn leven geconfronteerd wordt met een episode van lage rugpijn (Katz, 2002; van Tulder et al., 2002; Ehrlich, 2003; Woolf and Pfleger, 2003). Lage rugpijn evolueert vaak naar een steeds terugkerend probleem. Volledig en blijvend herstel van pijn en functionaliteit komt zelden voor (Andersson et al., 1998). De kosten van lage rugpijn voor de maatschappij zijn hoog en bovendien is lage rugpijn een belangrijke oorzaak van ziekteverzuim (Dagenais et al., 2008).

Langdurig zitten wordt vaak geassocieerd met een toename van lage rugpijn (Kelsey et al., 1980), daarom is aandacht voor een correct en actief zitgedrag van groot belang. Flexchair®movement is een organisatie die zich hiervoor wil inzetten. Zij ontwikkelden de Flexchair®, een nieuw dynamisch zittoestel met een driedimensionaal kantelmechanisme en visueel feedbacksysteem. Door de zadelzit wordt een goede houding van de rug tijdens zitten en bewegen gestimuleerd. Volgens de makers worden de stabiliserende, intrinsieke structuren rond de lage rug en het bekken geactiveerd. In het verleden zijn er weinig studies gedaan over specifieke training in zit om zitgerelateerde lage rugpijn te verbeteren. Daarom is het doel van deze masterproef het geven van een overzicht van de literatuur over zitgerelateerde lage rugpijn en de ontwikkeling van een specifiek cognitief functioneel oefenprogramma, waarbij gebruik gemaakt wordt van de Flexchair® om zitgerelateerde lage rugklachten te verbeteren bij patiënten met een Flexiepatroon. Het Flexiepatroon vormt een specifieke subgroep van chronische lage rugpijn patiënten en is het meest voorkomend. Patiënten met een Flexiepatroon hebben een functioneel verlies van motorische controle in flexie, resulterend in een verlies van segmentale lordose ter hoogte van de symtomatische segmenten. Alle flexiegerelateerde houdingen en bewegingen lokken de pijn uit (Dankaerts et al., 2006). De toepassing van het ontwikkelde oefenprogramma wordt gedemonstreerd aan de hand van een case report.

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ABSTRACT

In modern society a sedentary lifestyle is frequently demanded, which often results in prolonged sitting. In clinical practice it appears that sitting is a major aggravating factor for low back pain (LBP). The Flexchair® is a novel dynamic training device. A wireless sensor registrates the movement of the chair and this is displayed on a screen, so the seated subject receives direct feedback on his sitting performance. No research exists on specific training in sitting, to improve sitting related LBP. Therefore, the aim of this study was to review the literature on sitting related LBP (part 1) and to develop a specific cognitive functional exercise program using the Flexchair® to improve sitting related LBP in patients with a Flexion Pattern (FP). This was demonstrated by a case report (part 2). This case report is the first attempt to improve sitting related LBP by specific training in sitting and subclassification of LBP patients. The results showed that the new developed exercise program improved the sitting related LBP in this patient. The Flexchair® seems very promising for training patients with specific sitting related LBP. RCT based studies with an intervention targeting the underlying mechanism of FP motor control impairment (MCI) are needed.

Keywords: low back pain, posture, sitting, rehabilitation

PART 1: REVIEW OF LITERATURE ON SITTING RELATED LBP

Low back pain (LBP) is a condition which limits patients in their daily activities. It affects up to 80% of people at some point during their lifetime (Katz, 2002; van Tulder et al., 2002; Ehrlich, 2003; Woolf and Pfleger, 2003). Estimates of the economic costs of LBP in different countries vary greatly, but must be considered a substantial burden on society (Dagenais et al., 2008). When LBP disorders do not resolve beyond normal expected tissue healing time, they become chronic. Up to 85% of chronic low back pain (CLBP) disorders have no known diagnosis, leading to a classification of 'non-specific CLBP'. The underlying cause of CLBP disorders is often multi-factorial. The presence and dominance of the patho-anatomical, physical, neuro-physiological, psychological and social factors can influence the disorder. This influence is different for each individual (O'Sullivan et al., 2005).

1.1 Prolonged sitting and LBP

In modern society a sedentary lifestyle is frequently demanded, which often results in prolonged sitting. Occupations that involve prolonged sitting have a high incidence of LBP (Kelsey et al., 1980; Wilder et al., 1988; Williams et al., 1991). Despite a preponderance of literature on the *risk factors* for LBP for example in heavy physical work and manual handling techniques (Rubin, 2007) the effect of sedentary occupations that involve sitting for prolonged periods of time appear to have received less attention.

Several systematic reviews of the epidemiological literature have failed to find that sitting at work is associated with LBP and some studies suggest that sitting may even have a neutral or protective effect in relation to LBP (Hartvigsen et al., 2000; Lis et al., 2007).

A recent study demonstrated that the intradiscal pressure in standing is similar compared to upright sitting, it was concluded by the authors that there is no evidence that sitting has a more negative effect than standing for incidence of LBP (Claus et al., 2008). The question that rises: is everybody sitting upright at any time during the day? In clinical practice it appears that sitting is a major aggravating factor for LBP.

However, there is an abundance of biomechanical evidence (Hedman and Fernie, 1997) suggesting plausible mechanisms by which prolonged sitting could result in LBP. This prolonged sitting is often associated with many negative effects such as an altered nutrition of the intervertebral disc (Lis et al., 2007). A fatigue injury mechanism could appear because of prolonged static loads either due to low but prolonged muscle contraction and/or prolonged

flexed postures of the spine. This may lead to accumulated damage to the intervertebral disc (Callaghan et al., 2001).

In general, the muscle system of the trunk has been divided into a *local* stabilizing system (e.g. lumbar mm. multifidi, lower m. internal oblique) and a *global* mobilizing system (e.g. m. iliocostalis lumborum pars thoracis). Recent research shows that the manner in which the spine is postured in sitting highly influences how this trunk muscle system is activated.
The effect of three different postures on trunk muscle activation was investigated (O'Sullivan et al., 2006). To achieve thoracic upright sitting, subjects retract their shoulder blades and extend the thoracolumbar spine. Relaxing the thoracolumbar spine and rotating the pelvis posteriorly, subjects accomplish a slumped posture. Lumbo-pelvic upright sitting is achieved by relaxing the thorax and rotating the pelvis anteriorly to obtain a neutral lordosis of the lumbar spine. Compared to thoracic upright sitting, slump sitting is associated with significantly smaller muscle activity of internal and external oblique and iliocostalis lumborum pars thoracis. Slump sitting, compared to lumbo-pelvic upright sitting, is associated with significantly smaller muscle activity of superficial lumbar multifidus, internal oblique, and iliocostalis lumborum pars thoracis.
In summary, there is an over activity of the global muscle system in thoracic upright sitting. In slump sitting the local stabilizing system fails to control the lumbar spine. Lumbopelvic upright sitting seems to be the posture in which the local muscle system can provide the most adequate stability (O'Sullivan et al., 2006).

1.2 Flexion Pattern LBP disorder: a common LBP pattern

In LBP patients, there are subgroups with different motor control impairments (MCI), namely: Lateral Shifting Pattern (tendency to flex and laterally shift at the symptomatic segment), Active Extension Pattern (tendency to hold the lumbar spine actively into extension), Passive Extension Pattern (tendency to passively over-extend at the symptomatic segment), Multi-directional Pattern (multidirectional MCI) and Flexion Pattern (FP) (Dankaerts et al., 2006).
The FP is the most common seen in LBP patients. Patients with a FP present with functional loss of motor control into flexion, resulting in an excessive abnormal flexion strain (loss of segmental lordosis) at the symptomatic segment(s). All flexion related postures (e.g. slump sitting) and functional activities provoke pain (Dankaerts et al., 2006). A recent study

demonstrated that the differences in motor control between no-LBP, Active Extension Pattern and FP are real phenomena (Dankaerts et al., 2009).

Researchers found a decrease in the superficial lumbar multifidus and transverse fibers of the internal oblique starting at mid-range of spinal movement from upright to slump sitting. The presence of a full electromyographic silence (Flexion Relaxation Phenomenon) at mid-range highlights the importance of posture on trunk muscle activation (O'Sullivan et al., 2006).

1.3 Muscle endurance and LBP

A study by O'Sullivan et al. (2006), investigating LBP in a population of industrial workers, found evidence that in workers with flexion-related LBP disorders, there is a relationship between reduced lumbar muscle endurance, habitually posturing of the lumbar spine close to end range flexion in sitting, reduced levels of physical activity and time spent sitting.

1.4 Treatment of LBP

Despite the high prevalence of CLBP there is limited evidence that *specific* treatments are effective. Lumbar extensor strengthening exercises and lumbar stabilization exercises have no clear benefit compared with other exercise programs (Mayer et al., 2008; Standaert et al., 2008). There is conflicting evidence that management of CLBP with backschooling is effective (Brox et al., 2008). From a biopsychosocial perspective, cognitive behavioral therapy alone is not enough to threat CLBP patients, but the addition of a brief schedule of cognitive behavioral therapy has shown to reduce pain and anxiety, though such effects may not last in time (Gatchel et al., 2008). These treatments are just some examples, there are many other studies using different methods, all with moderate to limited evidence (Gay et al., 2008; Poitras et al., 2008; Pradhan et al., 2008; Wai et al., 2008; Bronfort et al., 2008).
This can be explained by the importance to divide patients into subgroups when the evidence of a treatment is being investigated. It has been suggested by several researchers that this is caused by the heterogeneity of the CLBP population. In clinical reality different subgroups in LBP patients do exist, therefore a wash-out effect will be created (O'Sullivan et al., 2005). Despite this growing evidence, there is a lack of studies documenting outcome on these specific subgroups following a targeted intervention.

1.5 Dynamic sitting device (Flexchair®)

The Flexchair® is a novel dynamic training device with a three-dimensional mechanism (Figure 1). It has a saddle shaped seat to promote neutral spine sitting and movement. The device is fixed on a wooden plate. The manufacturers state that the Flexchair® allows full range of motion of the lumbo-pelvic region and gives feedback about the lumbar spine posture during sitting, this is by use of an accelerometer (sensor) which is placed under the seat. This wireless sensor registrates the movement of the chair and this movement is displayed on a screen. This allows the seated person to receive direct feedback on his sitting performance.

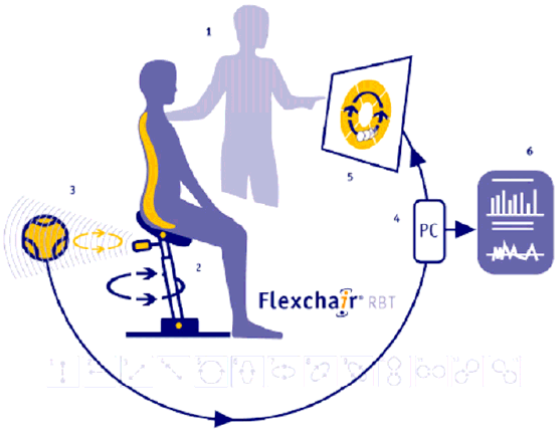

Figure 1: Flexchair®. 1: therapist gives instructions; 2: three-dimensional mechanism of Flexchair®, 3: sensor registrating low back alignment and movement; 4: computer processing data; 5: visual feedback system; 6: outcome on quantity and quality of movement.

A recent study (academic thesis Esther Groenen and Pieter-Jan Flamaing, 2008) showed, for sagittal plane movement, a strong correlation between the registration of the Flexchair® and the actual low back alignment when subjects performed a dynamic sitting task. If the position or movement of the chair matches the position or movement of the lumbo-pelvic region, users would indeed have direct feedback regarding the position they adapt, which could be used during training.

No research exists on specific training in sitting, to improve sitting related LBP. Therefore, the aim of the second part of this study was to develop a specific cognitive functional exercise program using a novel dynamic training device (Flexchair®) to improve sitting related LBP in patients with a FP. It's application was demonstrated by a case report. The variables 'pain' [Visual Analogue Scale (Williamson and Hoggart, 2005)], 'disability' [Revised-Oswestry Disability Index (Hudson-Cook et al., 1989)], 'quality of life' [36-Item Short Form

(McHorney et al., 1994)], 'fear avoidance' [Tampa Scale of Kinesiophobia (Kori et al., 1990)] and 'back muscle endurance' [Modified Biering-Sorensen test (Demoulin et al., 2006)] were measured pre-intervention, post-intervention and at 3-week follow-up. Approval from the ethical committee of the University of Hasselt was obtained prior to the case study. This exercise program could be used for a large trial, with long term follow-up and a number of different physiotherapists delivering the intervention.

PART 2: DEVELOPMENT OF COGNITIVE FUNCTIONAL EXERCISE PROGRAM DEMONSTRATED BY CASE REPORT

Based on the review of the literature, it was found to be important to divide LBP patients into subgroups when a rehabilitation program is being developed (O'Sullivan et al., 2005). The targeted group for this intervention were patients with a FP, most commonly seen pattern in LBP patients (Dankaerts et al., 2006). Specific exercises on the Flexchair® were chosen to develop a functional exercise program in sitting to improve sitting related LBP. Exercises in the software of the Flexchair® were adjusted especially for the FP LBP disorder. It was found essential to add a cognitive component to the exercise program, with the aim to give the patient understanding of the mechanism of the ongoing pain sensitization and the relation between prolonged sitting and LBP. After it's development, this specific cognitive functional exercise program was applied in a case study.

2.1 Subjective and physical examination

A comprehensive subjective (Table 1) and physical examination (Table 2) was first performed on the patient in order to classify her disorder. The pain presentation of the patient is illustrated by Figure 2.

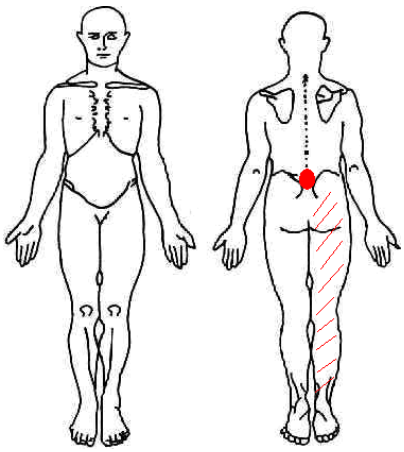

Figure 2: Body chart illustrating pain presentation of patient. LBP (right buttock region, occasionally over the entire right leg posterior).

49-year-old female; divorced since 10 years; 2 children (adolescents)

Work: part-time (4/5) administrative; involves mainly sitting and visiting building sites (walking around)
Home: household activities
Hobbies: cycling; walking; handcrafting
History: this episode started 2 years ago (lifting injury)
Past history: first onset of LBP during pregnancy (-20 y); recurrent LBP afterwards (e.g. when renovating house)
Pain: LBP (right buttock region, occasionally over the entire right leg posterior)
Aggravating postures: sitting (sometimes incapacity to sit); she has an incapacity to sit in the car (never drives car because of LBP, takes public transport: train/bus); standing; lying flat
Aggravating activities: walking; bending; lifting
Easing postures/activities: sitting with an open hip angle; standing up and walking around after 20' of sitting
Previous treatment: fit-ball (stabilizing) exercises; specific mobilizing exercises (lying flat moving leg)
Pain intensity [Visual Analogue Scale (Williamson and Hoggart., 2004)]: 3.3/10 (last 3 months in general); 5.4/10 (last 3 months in sitting); 5.3/10 (last week in general); 5.7/10 (last week in sitting); 7.1/10 (at present in general); 8.4/10 (at present in sitting)
Disability-score [Revised-Oswestry Disability Index (Hudson-Cook et al., 1989)]: 38%
Quality of life [36-Item Short Form (McHorney et al., 1994)]: 45/100
Fear avoidance [Tampa Scale of Kinesiophobia (Kori et al., 1990)]: 30/68
Medical imaging (X-ray and CT): L3-L4: disc bulge, slight narrowing of neuroforamina (R>L), minimal foraminal annular tear on the right; L4-L5: mild disc degeneration, mild disc protrusion, no neuro-discal conflict, mild facet degeneration on the left side, slight narrowing of the left neuroforamen
Psycho-social risk factors ('yellow' flags): absent
Serious pathology ('red' flags): absent

Key features:

- Localised LBP (minimal buttock and right leg pain)
- Minimal signs of neural tissue involvement
- No reported impairment of movement
- Flexion-directional pain pattern mechanical in nature
- Absence of dominant radiological abnormality
- Absence of dominant non-organic features
- Absence of any signs suggesting serious underlying pathology

Table 1: Subjective examination findings

Posture and movement analysis

- Standing: slightly hyper-lordotic thoraco-lumbar posture; reduction in tone in the transverse abdominal wall and gluteal muscles
- Forward bending: sudden drop into lumbar flexion (curve reversal) at end range; full range of motion (fingers to floor) with associated pain
- Return from forward bending: initiated from the thoraco-lumbar spine by hyper-extending
- Backwards bending: provoked pain at L3-L4 and L4-L5; slight decrease in range of motion
- Side bending (R/L): provoked pain at L3-L4 and L4-L5; slight decrease in range of motion
- Sitting posture: flexed at the lower lumbar spine; extended at the thoraco-lumbar spine

Specific movement tests (O'Sullivan, 2004):

- Inability to maintain neutral lordosis during trunk flexion and load transfer in sitting
- Repositioning sense in sitting (O'Sullivan et al., 2003): inability to reposition the lumbar spine within a neutral lordosis; 'over-shoot' into flexion (kyphosis)

Specific muscle testing (O'Sullivan, 2004): Inability to activate the lower transverse abdominal wall (transverse fibres of internal oblique and lower transversus abdominis) in side lying without breath holding

Modified Biering-Sorensen test (Demoulin et al., 2006): 11 seconds

Screening neurological examination (Hall and Elvey, 1999): Absence of clear neurological findings (provocation testing, reflexes, sensation and manual muscle testing)

Passive physiological motion segment testing (Maitland, 1986): Absence of segmental movement restriction into flexion; increased segmental motion into flexion; substantial restriction of movement into extension at L3-L4 and L4-L5 lumbar segments

Passive accessory testing (Maitland, 1986): Posterior/Anterior pressure (PA) at L3-L4 and L4-L5; stiffness detected and both levels highly symptomatic; reproductive of the patient's symptoms

Key features :

- Full range of motion with aberrant quality of motion into flexion; slight decrease in range of motion into extension and lateral bending
- Through range painful arc with hesitation and lateral movement at midrange of spinal motion into flexion
- No control of mid-position ['neutral zone' (Panjabi, 1992)] in sitting and during forward bending
- Loss of neutral zone control of symptomatic spinal segments during loaded postures and spinal movements
- Increased passive segmental motion into flexion at the 3 lower lumbar segments
- Absence of clear neurological findings
- Absence of segmental movement impairment into flexion; segmental movement impairment into extension at L3-L4 and L4-L5
- Provocation of pain linked to specific impairments of control of posture into flexion
- Absence of dominant psycho-social findings (e.g. catastrophizing); although patient presents clearly with 'fear for sitting'

Table 2: Physical examination findings

2.2 Classification based on history and physical examination

Classification of a disorder should be based on information of the history taking examination and a 'cluster of tests' in combination with a reasoning process (Elvey and O'Sullivan, 2004). In this way, several key features of the physical examination findings consistent with the history, helped to formulate the hypothesis of a classification of FP MCI disorder (O'Sullivan, 2004). The critical factors of the classification were that this patient had mechanically induced, localized pain, provoked by all flexion-related postures.

2.3 Intervention

The patient's management consisted of a three week cognitive behavioral motor learning intervention with a total of 6 sessions (2 sessions of 30 minutes a week, session 1 took 60 minutes). "Motor learning is a set of internal processes associated with practice or experience leading to relatively permanent changes in the capability for responding" (Schmidt et al., 1991). The intervention was divided into stages, based on the model proposed by Fitts and Posner (1995). This approach to exercise training focused on the quality of control of segmental spinal posture and movement. Important was that the patient had to achieve each stage of the intervention before it was progressed. A flow chart of the intervention is illustrated by Figure 3.

2.3.1 Cognitive stage

In the cognitive stage the patient is concerned with understanding the nature of the task, developing strategies that could be used to carry out the task and determining how the task should be evaluated. A high degree of cognitive activity such as attention is required. This stage represents the beginner level of ability when the patient is first introduced to basic concepts and ideas (Fitts and Posner, 1995).

During the cognitive stage (session 1) the patient was given information on sitting related LBP with the use of a PowerPoint presentation (Appendix 1 p. A.1). She was made aware that her adopted movement patterns and postures resulted in maintaining her pain and that she had no control of her neutral spine positions. The patient was instructed to change her sitting posture to relax the thoracolumbar region with co-contraction of the transverse abdominal wall and to maintain a neutral lordosis.

Flexchair® evaluation of Motor Control in Sitting at the start (MCiS@start) exists of 6 exercises (exercise 1, 2, 3, 4, 5 and 6) on the Flexchair® with rising level of difficulty and was used as an intake test for the evaluation of motor control of the lumbar spine in sitting. These specific exercises were chosen because they require the basic lumbo-pelvic movements. Exercise 1, 3 and 4 were adjusted in the software of the Flexchair® to limit kyphosis of the lumbar spine (specific for FP). This test was the patient's first contact with the Flexchair® and was executed with minimal standardized instructions of the therapist. The height of the Flexchair® was adjusted to ensure that the angle between upper and lower legs of the patient was 120°. The lower legs of the patient were vertical (line through femoral lateral epicondyle and lateral malleolus). The feet of the patient were positioned shoulder white apart with the arms in supination on the upper legs. Every exercise was performed during 2 minutes with a short break of 30 seconds between each exercise. The sensor correction factor is a measure for the sensitivity of movement on the Flexchair® and the reproduction on the screen (visual feedback system). The sensor correction factor for the performance of exercise 1, 2, 3 and 4 was 4.5. The sensor correction factor for the performance of exercise 5 and 6 was 3, because of precaution for end-range movements in flexion (specific for FP). These values were chosen in consultation with Flexchair®movement. The patient received a score on quantity (number of executions in 2 minutes) and quality (percentage of correct movement) of movement. This MCiS@start-score (Appendix 2 p. A.5) was discussed with the patient and helped to form a specific training program.

2.3.2 Associative stage

In the associative stage the patient has selected the best strategy for the task and now begins to refine the skill. There is less variability in performance and improvement occurs more slowly. The cognitive aspects of learning are less important at this stage because the patient focuses more on refining a particular pattern rather than on selecting among alternative strategies (Fitts and Posner, 1995).

During *session 1* the patient performed exercise 1 and 2 on the Flexchair®. The therapist gave instructions for exercise 1 and the patient practiced the exercise during 2 minutes. After 2 minutes of practice, the patient received feedback about her performance and exercise 1 was executed a second time during 2 minutes (Figure 4). The practice of exercise 2 and the practice of exercises in later sessions all followed the same protocol. General points of interest during the practice of all exercises are summarized in Figure 5. After session 1 the patient

received 2 home exercises (home exercise 1 and 2) with clear instructions. Home exercise 1 exists of the lumbo-pelvic movements of exercise 1 on the Flexchair® executed on a sit cushion (Figure 6). Home exercise 2 exists of the lumbo-pelvic movements of exercise 2 on the Flexchair® executed on a sit cushion. Home exercise 1 and 2 were performed 2 times a day during 2 minutes. Home exercise enlarged after every session with the addition of the new practiced exercises that session. New home exercises were performed 2 times a day during 2 minutes and the others were performed 2 times a day during 1 minute. The patient recorded during 3 weeks daily the time and amount of home practice on a register. The sessions following session 1 started with a Motor Control in Sitting test (MCiS) of the exercises learned in the previous session performed during 1 minute with a short break of 30 seconds between each exercise. After every MCiS the patient received feedback about performance. *Session 2* started with MCiS 1 (exercise 1 and 2). Afterwards the patient practiced exercise 3 and 4 on the Flexchair®. After session 2 the patient received 4 home exercises (exercise 1, 2, 3 and 4). The patient started with MCiS 2 (exercise 3 and 4) during *session 3*. Further exercise 5 and 6 on the Flexchair® were practiced. Exercise 5 and 6 were added to the home exercises after session 3. *Session 4* started with MCiS 3 (exercise 5 and 6). After the test, the patient received 2 new exercises on the Flexchair® (exercise 7 and 8), practiced with sensor correction factor 3 because of precaution for end-range movements in flexion (specific for FP). Exercise 7 and 8 were added to the home exercises after session 4 and exercise 1 and 2 were leaved out. MCiS 4 (exercise 7 and 8) was executed at the start of *session 5*. Further the patient practiced exercise 9 and 10 on the Flexchair® with sensor correction factor 3, because of precaution for end-range movements in flexion (specific for FP). After session 5 the patient received 6 home exercises (exercise 9 and 10 were added, exercise 3 and 4 were leaved out).

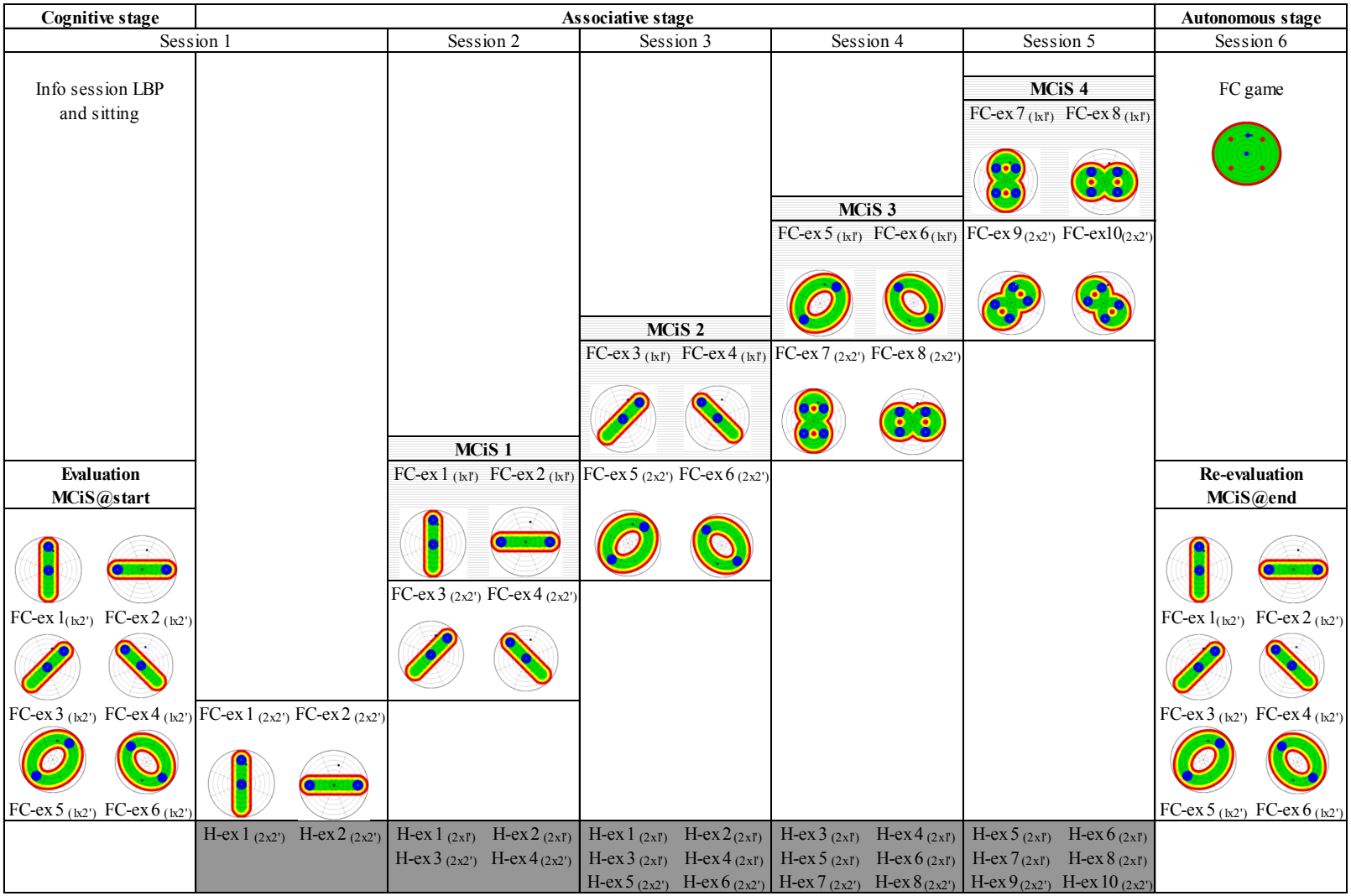

Figure 3: Flow chart of intervention. LBP: low back pain; MCiS: motor control in sitting test; FC-ex: exercises on Flexchair®. Session 1 started with an info session on 'LBP and sitting' followed by an evaluation of MCiS at the start (MCiS@start) and the practice of FC-ex 1 and 2. Session 2 till 5 started with a MCiS (shaded area) of the previous session, followed by the practice of 2 new exercises on the Flexchair®. Finally, a game on the Flexchair® (FC game) was played during session 6, at the end there was a re-evaluation of MCiS (MCiS@end). Home exercises (H-ex) on a sit cushion were given after session 1 till 5.

Instructions exercise 1 ↓ Practice exercise 1 (2') ↓ Feedback from therapist ↓ Practice exercise 1 (2')	1. Bar of Flexchair® vertical at starting point 2. Pelvis and saddle moving synchronously 3. Visible movements of spine 4. Shoulders at right angles to pelvis 5. No compensations	
Figure 4: Practice of exercise 1	**Figure 5:** Points of interest	**Figure 6:** Sit cushion

2.3.3 Autonomous stage

The autonomous stage is defined as the automaticity of the skill and the low degree of attention required for it's performance. The patient can begin to devote her attention to other aspects, like focusing on a secondary task. (Fitts and Posner, 1995).

The *last session* started with a game on the Flexchair®, which required all previously learned lumbo-pelvic movements. The game was played with sensor correction factor 4.5. There was a re-evaluation of Motor Control in Sitting at the end (MCiS@end: Appendix 2 p. A.8).

After completing 6 training sessions, the variables 'pain' [Visual Analogue Scale (Williamson and Hoggart, 2005)], 'disability' [Revised-Oswestry Disability Index (Hudson-Cook et al., 1989)], 'quality of life' [36-Item Short Form (McHorney et al., 1994)], 'fear avoidance' [Tampa Scale of Kinesiophobia (Kori et al., 1990)] and 'back muscle endurance' [Modified Biering-Sorensen test (Demoulin et al., 2006)] were reassessed. The patient was asked to continue performing the home exercises during 3 weeks and to continue recording the time and amount of home practice on a register. There was a re-evaluation of Motor Control in Sitting at 3-week follow-up (MCiS@follow-up: Appendix 2 p. A.11). The 5 variables were once again reassessed.

2.4 Outcome

2.4.1 Clinical outcome

The *Visual Analogue Scale (VAS)* was presented as a 10-cm line, anchored by verbal descriptors 'no pain' (0) and 'worst imaginable pain' (10). The patient was asked to mark a line to indicate the *pain intensity*. This scale has been demonstrated to be valid, reliable and appropriate for use in clinical practice (Williamson and Hoggart, 2005). A 1.5-point change on the VAS has been identified as the minimal clinically important difference needed to be confident an actual change occurred (Ostelo et al., 2008). The patient progressed well during the intervention with a gradual decrease in pain (Figure 7). The pain intensity score of last week in general decreased clinically relevant from 5.3/10 pre-intervention to 2.1/10 post-intervention and remained the same (2.1/10) at 3-week follow-up. The pain intensity score of last week in sitting decreased clinically relevant from 5.7/10 pre-intervention to 0.9/10 post-intervention. There was a slight increase (1.9/10) of pain intensity of last week in sitting at 3-week follow-up. The pain intensity score at present in general decreased clinically relevant from 7.1/10 pre-intervention to 0/10 post-intervention. There was a slight increase (1.4/10) of pain intensity at present in general at 3-week follow-up. The pain intensity score at present in sitting decreased clinically relevant from 8.4/10 pre-intervention to 0.1/10 post-intervention. There was a clinically relevant increase (2/10) of pain intensity at present in sitting at 3-week follow-up.

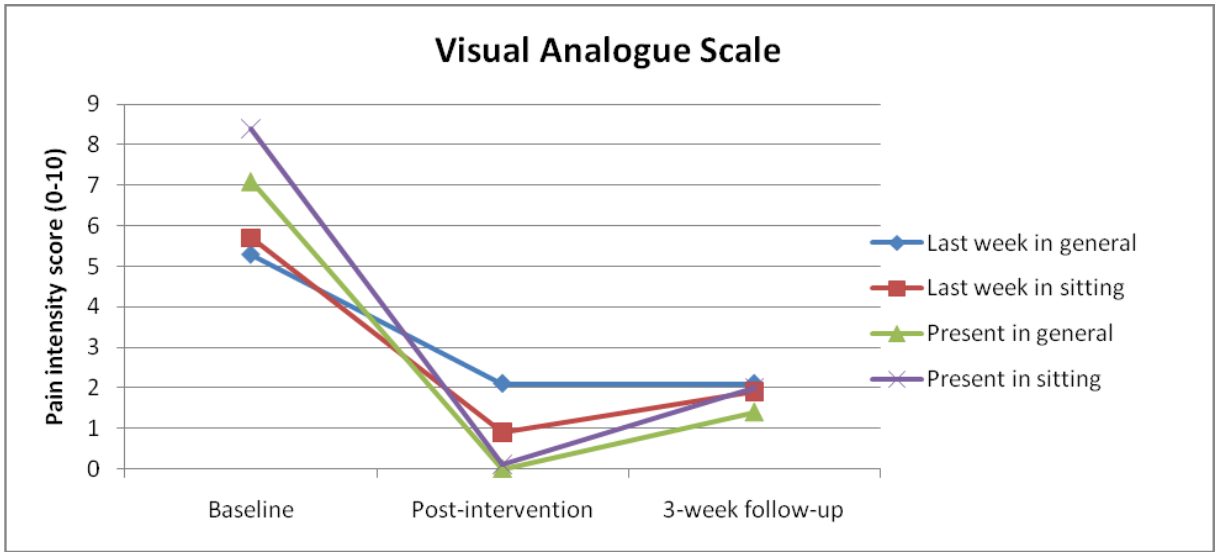

Figure 7: Changes in pain intensity scores (Visual analogue scale, 0-10) at baseline, post-intervention and at 3-week follow-up for pain 'last week in general', 'last week in sitting', 'at present in general' and 'at present in sitting'.

The *Revised-Oswestry Disability Index (R-ODI)* was used to document *functional progress and disability*. This questionnaire contains six statements in each of ten sections. The sections concern impairments (e.g. pain) and abilities (e.g. sitting). Each section is scored from 0 to 5, with higher values representing greater disability. The total score is multiplied by 2 and expressed as a percentage (0-100%). A score of 22% or more is considered a significant disability for activities of daily living. Researchers reported levels of test-retest reliability and internal consistency for this modified version similar to those of the original Oswestry Disability Index (Hudson-Cook et al., 1989). A 6-point change on the R-ODI has been identified as the minimal clinically important difference needed to be confident an actual change occurred (Fritz and Irrgang, 2001). The patient's R-ODI score (Figure 8) decreased across the training period from 38% pre-intervention to 34% post-intervention. The post-intervention R-ODI score still indicated a significant disability for activities of daily living. The patient continued to improve during the 3 weeks following the intervention. At 3-week follow-up the patient's R-ODI score (22%) had improved with 16% from baseline. This is clearly beyond a minimal clinically important difference.

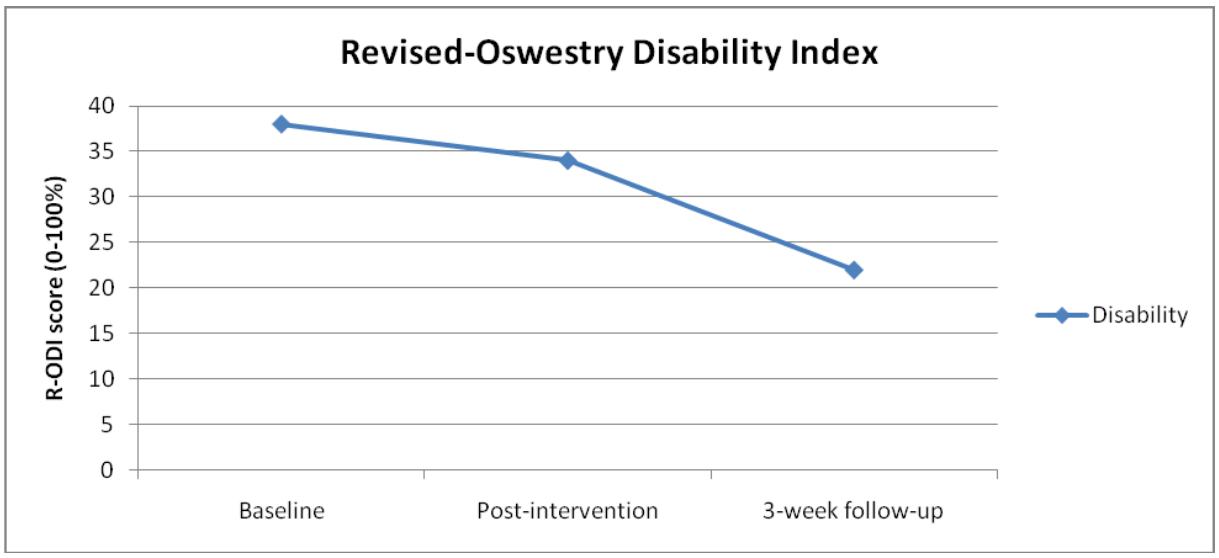

Figure 8: Revised-Oswestry Disability Index (R-ODI). Changes in R-ODI score (0-100%) at baseline, post-intervention and at 3-week follow-up.

Quality of life was measured by the *36-Item Short Form (SF-36)*. This questionnaire measures eight general health concepts: physical functioning, role limitations due to physical health problems, bodily pain, general health perceptions, vitality, social functioning, role limitations due to emotional problems and mental health. Scores are weighted and transformed into a scale from 0 (worst possible health) to 100 (best health). Higher scores always indicate better

health status. Researchers support the use of the SF-36 survey across diverse patient groups (McHorney et al., 1994). The minimal clinically important difference for the 8 subscales of the SF-36 ranges from 3 to 5 points (Samsa et al., 1999). The score on the subscale 'physical functioning' demonstrated a clinically important increase from 40/100 pre-intervention to 60/100 post-intervention (Figure 9). At 3-week follow-up the score on this subscale had further increased to 65/100. The score on the subscale 'role limitations due to physical health problems' increased clinically from 0/100 pre-intervention to 25/100 post-intervention. At 3-week follow-up the score on this subscale decreased clinically to 0/100. The score on the subscale 'bodily pain' increased clinically from 10/100 pre-intervention to 58/100 post-intervention, remaining the same at 3-week follow-up. The score on the subscale 'general health perceptions' increased clinically from 50/100 pre-intervention to 95/100 post-intervention. At 3-week follow-up the score on this subscale increased clinically to the maximum score of 100/100. The score on the subscale 'vitality' increased clinically from 60/100 pre-intervention to 85/100 post-intervention, remaining the same at 3-week follow-up. The score on the subscale 'social functioning' increased clinically from 25/100 pre-intervention to 75/100 post-intervention, remaining the same at 3-week follow-up. The score on the subscale 'role limitations due to emotional problems' decreased clinically from 67/100 pre-intervention to 0/100 post-intervention. At 3-week follow-up the score on this subscale increased clinically to the maximum score of 100/100. And finally, the score on the subscale 'mental health' increased clinically from 80/100 pre-intervention to 88/100 post-intervention. At 3-week follow-up the score on this subscale increased clinically to 96/100. The patient's total score for the SF-36 increased beyond the minimal clinically important difference; from 45/100 pre-intervention to 63/100 post-intervention and 73/100 at 3-week follow-up.

Fear avoidance was evaluated by the *Tampa Scale of Kinesiophobia (TSK/68)*. The scale contains 17 statements intended to assess fear of movement and fear of (re)injury. The patient was asked to indicate to what extent the items are a true description of the assumed association between movement and (re)injury on a four-point scale, ranging from 1 (strongly disagree) to 4 (strongly agree). The minimum score that can be recorded is 17/68. A score of 38/68 or more is associated with a significant level of fear avoidance (Kori et al., 1990). The TSK/68 is validated in patients with CLBP (Vlaeyen et al., 1995; Roelofs et al., 2004). A 2-point change on the TSK/68 has been identified as the minimal clinically important difference needed to be confident an actual change occurred (Moffett et al., 2006).

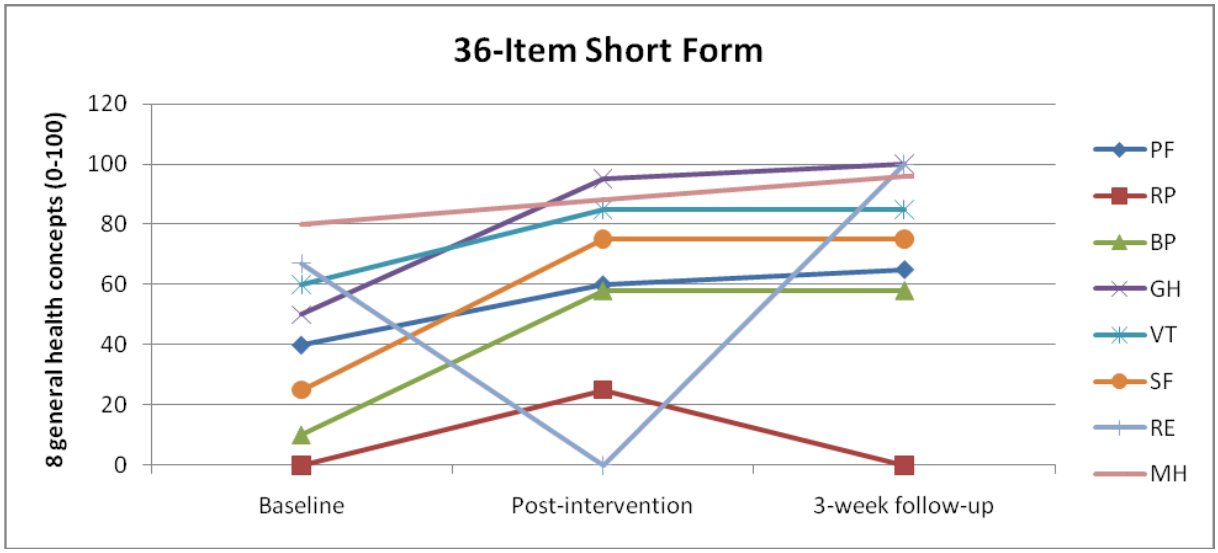

Figure 9: Changes in scores on subscales of 36-Item Short Form (0-100) at baseline, post-intervention and at 3-week follow-up. Higher scores always indicate better health status. PF: physical functioning; RP: role limitations due to physical health problems; BP: bodily pain; GH: general health perceptions; VT: vitality; SF: social functioning; RE: role limitations due to emotional problems; MH: mental health.

The patient's TSK/68 score pre-intervention (30/68) did not indicate significant fear avoidance (Figure 10). This score decreased clinically to 23/68 post-intervention, remaining the same at 3-week follow-up.

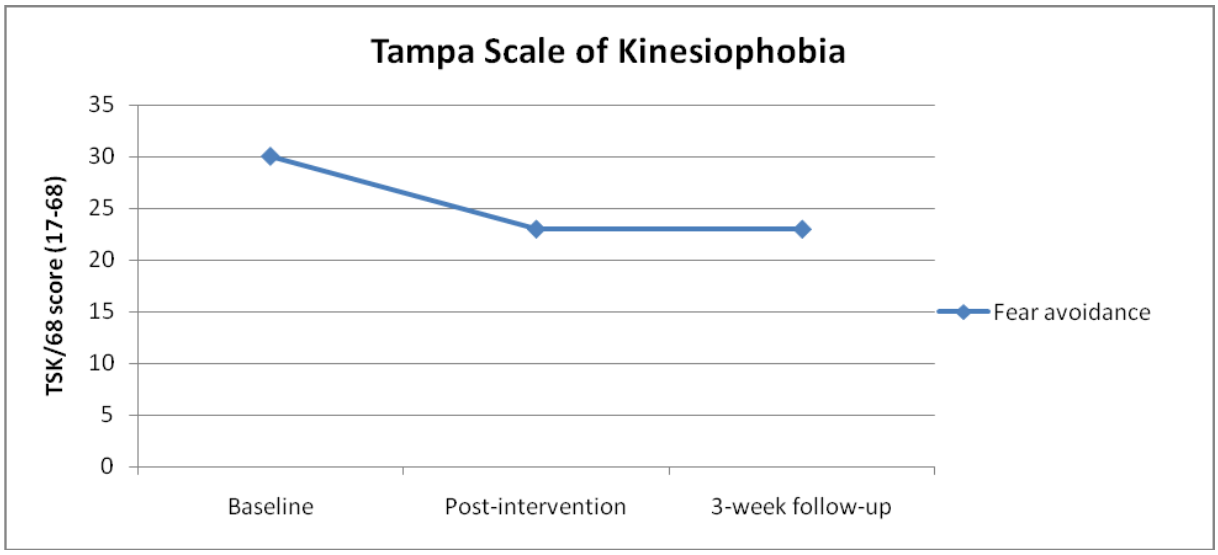

Figure 10: Tampa Scale of Kinesiophobia (TSK/68) scores at baseline, post-intervention and at 3-week follow-up.

Back muscle endurance was measured by the *Modified Biering-Sorensen test*. For this test the patient had to lay prone over the edge of an examining table, with the trunk unsupported. She was instructed to maintain a horizontal position of the trunk for as long as possible. Endurance time was recorded untill the patient deviated more than 10° from the lumbar

neutral position. The Modified Biering-Sorensen test allows for a reproducible, rapid and simple evaluation of the isometric endurance of the trunk extensor muscles. According to Demoulin et al. (2006) this test discriminates between patients with LBP and healthy individuals and may predict the occurrence of LBP in the near future. A 30-second change on the Modified Biering-Sorensen test has been identified as the minimal clinically important difference needed to be confident an actual change occurred (Stewart et al., 2003). Back muscle endurance increased from 11.0 seconds pre-intervention to 35.2 seconds post-intervention (Figure 11). At 3-week follow-up back muscle endurance further increased clinically to 77.0 seconds.

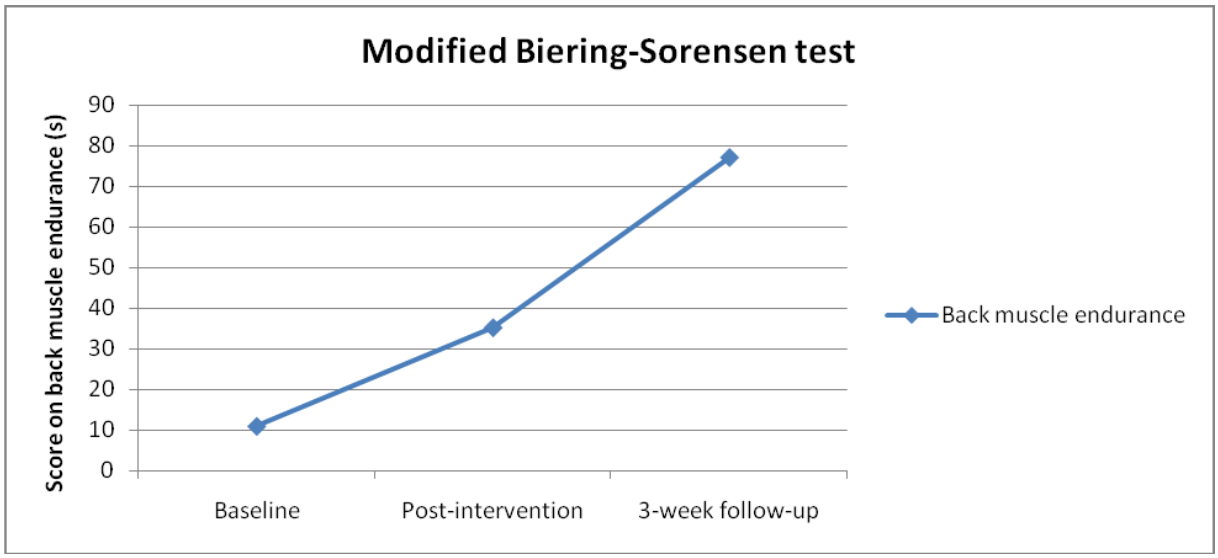

Figure 11: Changes in score on back muscle endurance (Modified Biering-Sorensen test) in seconds (s) at baseline, post-intervention and at 3-week follow-up.

So in summary, these scores reflect a clinically relevant decrease in pain, disability and fear avoidance post-intervention and at 3-week follow-up. For quality of life and back muscle endurance there was a clinically relevant increase post-intervention and at 3 week follow-up.

2.4.2 Evaluation of Motor Control in Sitting (MCiS)

The scores on *quantity of movement* (Figure 12: number of executions in 2 minutes) were improved post-intervention and at 3-week follow-up for all exercises on the Flexchair® with one exception. The patient scored initially 0 on exercise 2 at MCiS@start and progressed to 15 during MCiS@end, but this score decreased post-intervention to a score of 2 at 3-week follow-up. The patient was unable to do a full controlled movement in the frontal plane during

MCiS@start. The movement did not start from the pelvis, but was initiated by compensatory movements of the trunk, legs and shoulders.

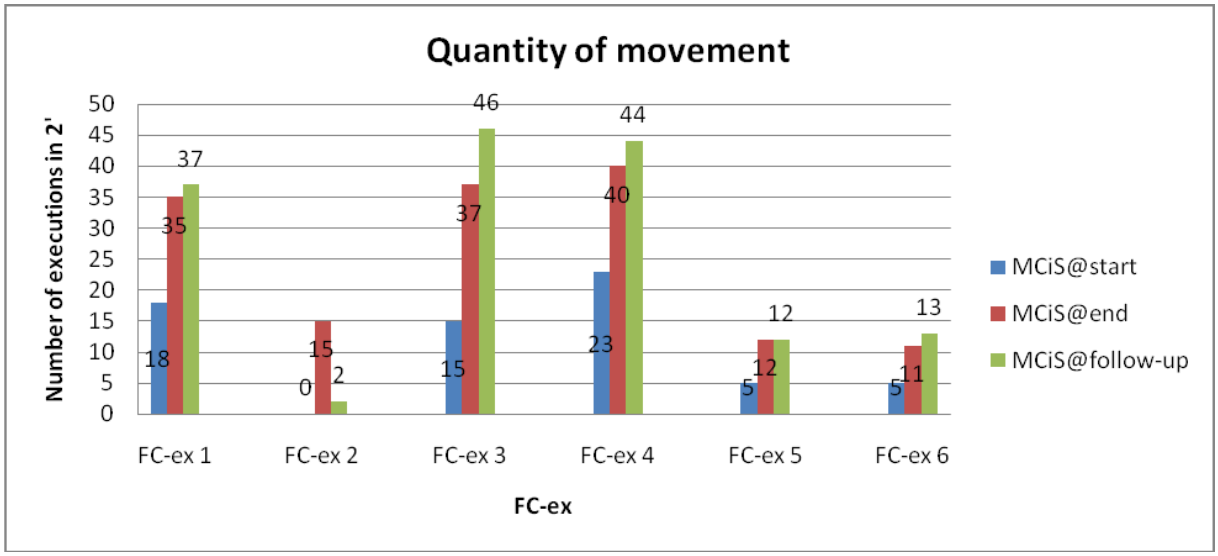

Figure 12: Quantity of movement expressed as the number of executions of exercises on Flexchair® (FC-ex) in 2 minutes (2'). MCiS@start: evaluation of motor control in sitting at the start; MCiS@end: re-evaluation of motor control in sitting at the end; MCiS@follow-up: re-evaluation of motor control in sitting at 3-week follow-up.

The scores on *quality of movement* (Figure 13: percentage of correct movement) improved from pre-intervention to post-intervention for all exercises on the Flexchair®. The quality of movement continued to improve at 3-week follow-up on 2 exercises (3 and 4). While there was a slight decrease in quality of movement on 4 exercises (1, 2, 5 and 6) at this stage.

For exercise 1 at MCiS@start (sagittal plane control), the patient scored 76%. Further analysis of the Flexchair®-data revealed there was a systematic 'overshooting' into the provocative flexion zone (kyphosis of the lumbar spine: see also Appendix 2 p. A.5). The quality-score of exercise 1 improved from 76% to 87% at MCiS@end, because the patient had more control of her neutral spine positions. At this stage there was less overshooting into flexion (Appendix 2 p. A.8). During MCiS@follow-up the quality-score of the patient decreased from 87% to 76%. The patient used a maladaptive movement pattern (Appendix 2 p. A.11).

For exercise 2 (frontal plane control), the patient scored 59% during MCiS@start with a clear difference between the quality of movement to the left versus to the right (Appendix 2 p. A.5). The movement did not start from the pelvis, but was initiated by compensatory movements of the trunk, legs and shoulders. The quality-score of exercise 2 improved from 59% to 82% during MCiS@end with moving to the left and right more balanced. It was noticed that during MCiS@end exercise 2 was executed more in the flexion-zone (compensation mechanism: Appendix 2 p. A.8). At 3-week follow-up (MCiS@follow-up) there was a decrease in quality

of movement (Appendix 2 p. A.11). Exercise 3, 4 and 6 showed the same overshooting pattern into the provocative flexion-zone during MCiS@start as in exercise 1 (Appendix 2 p. A.6-A.7), which improved during MCiS@end (Appendix 2 p. A.9-A.10) and MCiS@follow-up (Appendix 2 p. A.12-A.13).

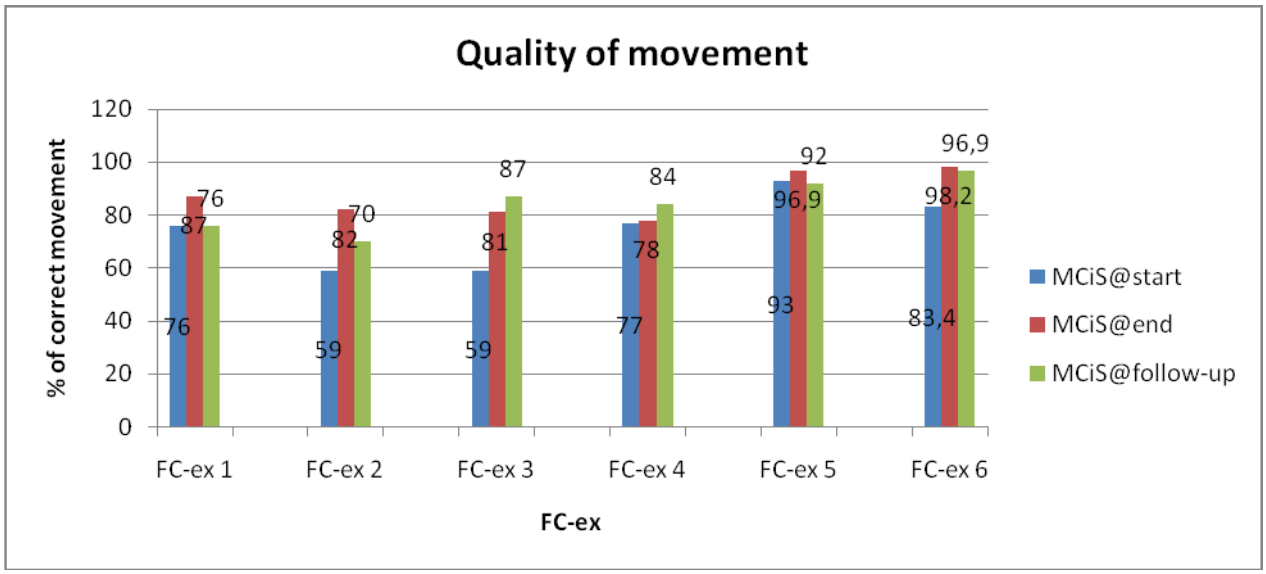

Figure 13: Quality of movement expressed as the percentage (%) of correct movement during the execution of exercises on Flexchair® (FC-ex). MCiS@start: evaluation of motor control in sitting at the start; MCiS@end: re-evaluation of motor control in sitting at the end; MCiS@follow-up: re-evaluation of motor control in sitting at 3-week follow-up.

In summary, these scores reflect improved movement patterns, spinal proprioception and neutral zone control in sitting post-intervention. At 3-week follow-up there was a decrease in quantity of movement of exercise 2 and quality of movement of exercises 1, 2, 5 and 6. Exercises 3 and 4 further improved.

2.5 Discussion

The aim of the present study was to develop a specific cognitive functional exercise program using a novel dynamic training device (Flexchair®) to improve sitting related LBP in a patient with a MCI-FP. This case report is the first attempt to demonstrate a classification-based targeted approach to improve sitting related LBP by a specific intervention in sitting.

2.5.1 Clinical outcome

The patient described in this case report would be 'classically' diagnosed as having non-specific CLBP based on the absence of clear neurological findings, radiological abnormalities, dominant non-organic features and signs suggesting serious underlying pathology (O'Sullivan

et al., 2005). Based on the classification system of O'Sullivan this patient was classified as having a FP of MCI (O'Sullivan, 2004).

The outcome is based on a comparison of the variables 'pain' [Visual Analogue Scale (Williamson and Hoggart, 2005)], 'disability' [Revised-Oswestry Disability Index (Hudson-Cook et al., 1989)], 'quality of life' [36-Item Short Form (McHorney et al., 1994)], 'fear avoidance' [Tampa Scale of Kinesiophobia (Kori et al., 1990)] and 'back muscle endurance' [Modified Biering-Sorensen test (Demoulin et al., 2006)] measured pre-intervention, post-intervention and at 3-week follow-up. These results are supporting evidence that this specific intervention in sitting using the Flexchair® markedly improved the sitting related LBP in this patient with a MCI-FP, a common LBP pattern. The scores reflect a clinically relevant decrease in pain and disability post-intervention and at 3-week follow-up. The score on the TSK/68 pre-intervention did not indicate a significant fear avoidance. This could be explained by the fact that the questions of the TSK/68 are not patient specific. On the other hand, the capacity of this cognitive functional exercise program to impact on cognitive aspects of the MCI-FP LBP disorder was highlighted by the documented reductions in fear avoidance post-intervention and at 3-week follow-up (Figure 10). Quality of life increased clinically relevant post-intervention and at 3 week follow-up. Back muscle endurance was reduced pre-intervention and improved clinically relevant post-intervention and at 3-week follow-up. The reduction of back muscle endurance in patients with flexion-related LBP disorders has been reported previously (O'Sullivan et al., 2006). For this patient it is not known whether motor control changes lead to pain or whether pain caused the changes in motor control. It is hypothesized that the improvement in pain intensity and disability was primarily due to the improvement in spinal motor control, which in turn reduced the peripheral nociceptive drive of pain. In light of these clinically relevant changes it is also important to note that there was an increase in hours a day sitting (working on a desk) because of vacation of a colleague during the 3 weeks following the intervention. This could be an explanation for the clinically relevant decrease of the score on the subscale 'role limitations due to physical health problems' of the SF-36 at 3-week follow-up.

2.5.2 Evaluation Motor Control in Sitting (MCiS)

The scores on quantity and quality of movement of MCiS@start reflected a MCI of the lumbar spine with a functional loss of motor control resulting in an overshoot in the provocative flexion-zone in the sagittal plane. A study by Dankaerts et al. (2006),

investigating a classification method for non-specific CLBP patients with MCI, found that patients with a MCI-FP indeed present with functional loss of motor control into flexion. It is reasonable to assume that this can result in an excessive abnormal flexion strain during prolonged activities (e.g. sitting). The patient had minimal neutral spine control and while proprioception was not directly measured, the results on the MCiS testing likely reflects proprioceptive deficits of the lumbar spine. This would be consistent with O'Sullivan et al. (2003) who reported decreased proprioception in patients with a FP. The results of this study indicate that subjects with a clinical diagnosis of FP-MCI demonstrate an inability to reposition the lumbar spine accurately into a neutral spine posture while seated. Further analysis of the scores of MCiS@start confirmed the diagnosis of FP of MCI. A systematic 'overshooting' into the provocative flexion zone (kyphosis of the lumbar spine) was seen.

A change in movement patterns of the patient was seen during MCiS@end. The scores on quantity and quality of movement improved post-intervention, indicating that the initial altered motor control was improved, likely reflecting an improvement of spinal proprioception. The patient was adopting more neutral zone postures during testing.

The scores on quantity and quality of movement were mostly maintained (or further improved) at 3-week follow-up. Although there were some exceptions of decreased scores. This could be explained by less practicing of the home exercises and the absence of a therapist to give feedback and to motivate the patient.

Based on these results it can be concluded that this specific cognitive functional exercise program improved the sitting related LBP in this patient with a MCI-FP. The Flexchair® seems very promising for training patients with specific sitting related LBP.

2.5.3 Limitations and recommendations for further studies

There are several limitations to the present study. Firstly, the implications of the patient's outcomes are limited and can not be generalized across a lager sample because this study is a case report. Multiple case studies are necessary to investigate the ability of the measurements to detect clinically relevant changes before and after the intervention targeting the underlying mechanism of FP MCI. Following these multiple case studies, a RCT based study is needed to investigate targeted versus non-targeted intervention for the FP subgroup based on clinical relevant outcome measurements.

A second limitation is based on the duration of intervention and follow-up period. The question 'is there a lasting effect of improvement in these outcome variables on long-term?' remains unanswered. It is well known that the nature of LBP disorders is often a chronic fluctuating problem with intermittent flares (Croft et al., 1998; Burton et al., 2004). Therefore, a longer intervention period and longitudinal follow-up is necessary. A next step in the autonomous phase of the cognitive functional exercise program would be practicing the exercises on the Flexchair® without the use of the visual feedback system. Indeed, Radebold et al. (2001) suggests that in the absence of visual feedback the remaining sensory input systems are more challenged. Another possibility to increase the difficulty of the exercises in the autonomous phase could be by altering the sensor correction factor (increasing the sensitivity of movement). Since longitudinal follow-up is essential, the patient is currently still under further follow-up investigation. Reporting on this is beyond the scope of this academic thesis.

2.6 Conclusion

This case study illustrates the use of a specific intervention using a novel dynamic training device (Flexchair®) to improve the sitting related LBP in a patient with a MCI-FP. This 3 week intervention was associated with clinical meaningful reductions in pain, disability and movement-based fear post-intervention. For quality of life and back muscle endurance there was a clinically relevant increase post-intervention. Quantity and quality of movement measured post-intervention reflected improved movement patterns, spinal proprioception and neutral zone control in sitting. These clinically relevant changes were mostly maintained (or further improved) at 3-week follow-up. To validate this approach, further research in the form of RCT based studies is required, comparing this novel intervention to other approaches. This is essential before its widespread use can be advocated.

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APPENDIX

1 PowerPoint presentation info session

2 Evaluation of Motor Control in Sitting

3 Manual Therapy: guidelines for authors

1 PowerPoint presentation info session

Zitgerelateerde lage rugpijn

Infosessie

1

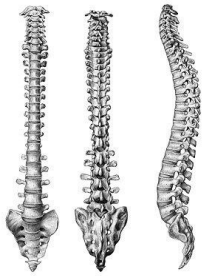
Inhoud

- Anatomie
- Zithouding
- Langdurig zitten
- Flexiepatroon
- Conclusie
- Planning

2

Anatomie

De wervelkolom



Lordose cervicaal

Kyfose thoracaal

Lordose lumbaal

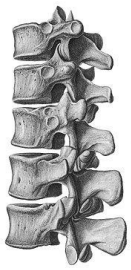
Kyfose sacraal

3

Anatomie

De wervels

- Wervellichaam
- Wervelboog
- Facetgewrichten
- Uitsteeksels
- Tussenwervelschijf

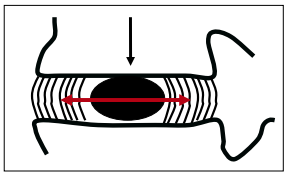


4

Anatomie

De tussenwervelschijf (discus)

- Schokdemper
- 2 delen:
  - Annulus: ringen
  - Nucleus: gelei-achtige kern
- Belang van beweging en nachtrust

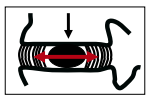


5

Anatomie

De tussenwervelschijf (discus)

- Neutrale zone
  - Spieractivatie
  - Veilige zone voor belasting
- Einde van de bewegingsbaan
  - Spierrelaxatie
  - Risico bij hoge en aangehouden belasting

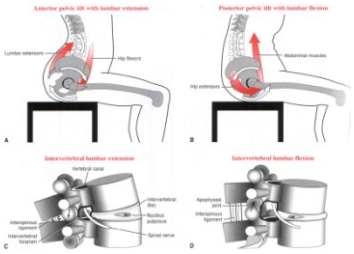


6

Anatomie

De tussenwervelschijf (discus)

De positie van het bekken heeft een invloed op de lumbale wervelkolom

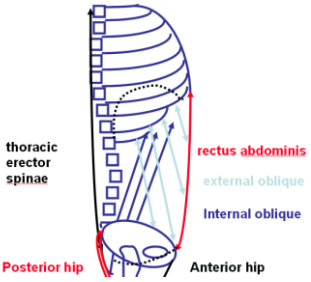


7

Anatomie

De spieren

- Globale spiersysteem
  - Grote krachten op de wervelkolom
  - Geen directe invloed op de wervels
  - Functie: beweging

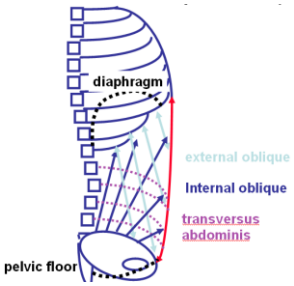


8
(Bergmark, 1989)

Anatomie

De spieren

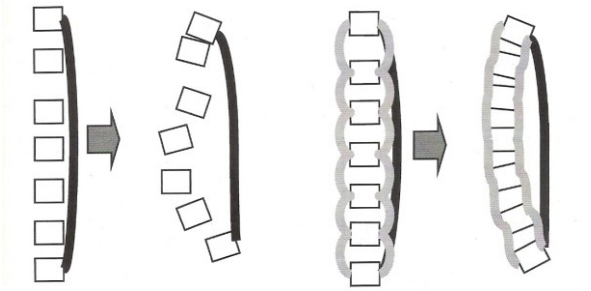
- Lokale spiersysteem
  - Ligt dicht bij de wervels
  - Functie: stabilisatie



9
(Bergmark, 1989)

Anatomie

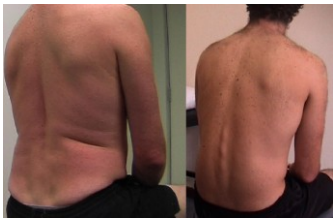
De spieren



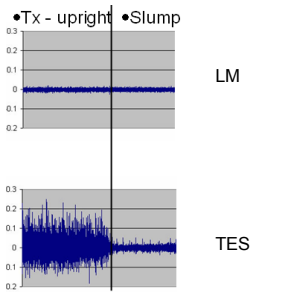
10

Zithouding

Houding en spieractivatie



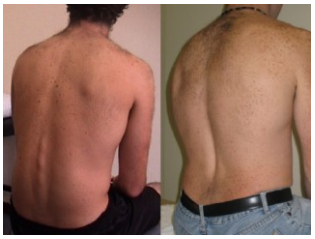
Tx-Upright Slump



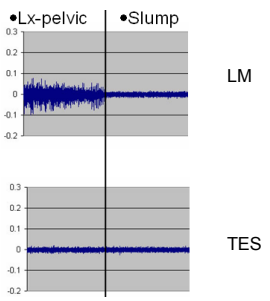
11
(O'Sullivan, Dankaerts et al.,2006)

Zithouding

Houding en spieractivatie



Slump Lx-pelvic

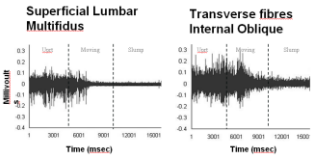


12
(O'Sullivan, Dankaerts et al.,2006)

Zithouding

Flexie Relaxatie Fenomeen

- Wanneer stopt de spieractiviteit van het lokale systeem in zit?

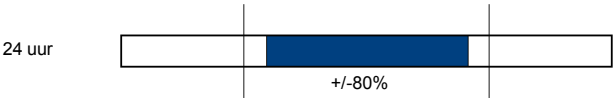


13

(O'Sullivan, Dankaerts et al.,2006)

Langdurig zitten

Hoeveel zitten we op een dag (met een slechte houding)?

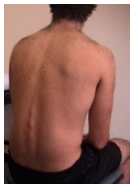


- In de auto
- Aan tafel
- Op het werk
- …

14

Flexiepatroon

Kenmerken



- Meest voorkomend
- Lumbale kyfose
- Verlies van motorische controle bij buiging (flexie) van de wervelkolom
- Zitten in een positie op het einde van de bewegingsbaan
- Alle flexiegerelateerde houdingen/bewegingen lokken de pijn uit

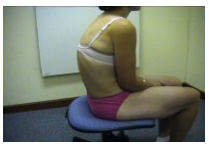
15

(O'Sullivan, Dankaerts et al.,2006)

Flexiepatroon

Uitlokkende houdingen/bewegingen

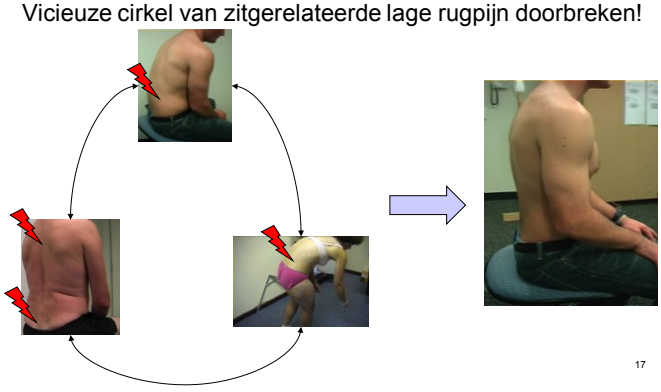
- Langdurig zitten
- Stofzuigen
- Veters binden
- Papiertje oprapen
- Auto rijden
- …



16

Conclusie

Vicieuze cirkel van zitgerelateerde lage rugpijn doorbreken!



17

Conclusie

Stabiliserende spieren correct leren gebruiken

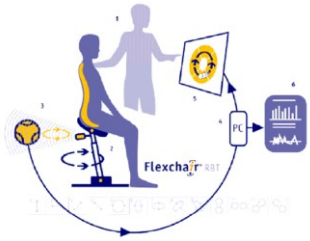
- M. transversus abdominis
- Mm. multifidi
- Bekkenbodemspieren
- Mm. gluteï

18

Conclusie

Flexchair®

- Trainen rond een evenwichtssituatie
- Driedimentioneel mechanisme
- Visuele feedback



19

Planning

Cognitieve functionele oefentherapie

- 6 sessies van 30 minuten op de Flexchair® (2 sessies/week)
- Huiswerkoefeningen op een zitschijf
- Controletests aan het begin van elke sessie

20

2 Evaluation of Motor Control in Sitting

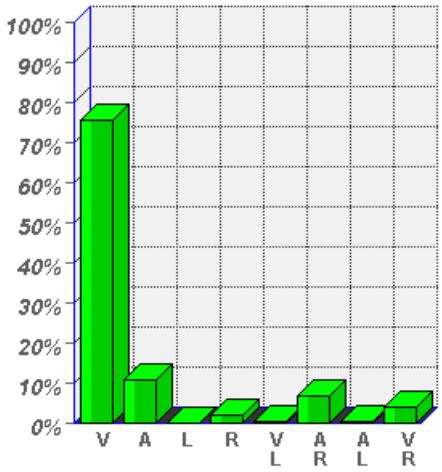
Evaluation of Motor Control in Sitting pre-intervention

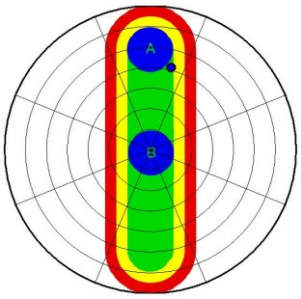
Exercise 1

Quantity of movement:

Number of executions in 2 minutes: 18

Quality of movement:



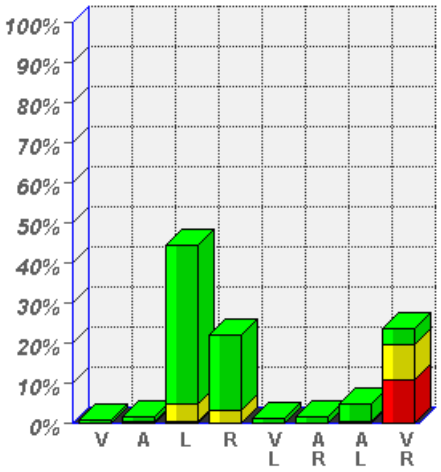


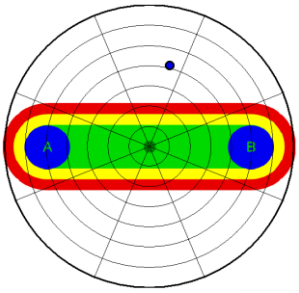
Exercise 2

Quantity of movement:

Number of executions in 2 minutes: 0

Quality of movement:



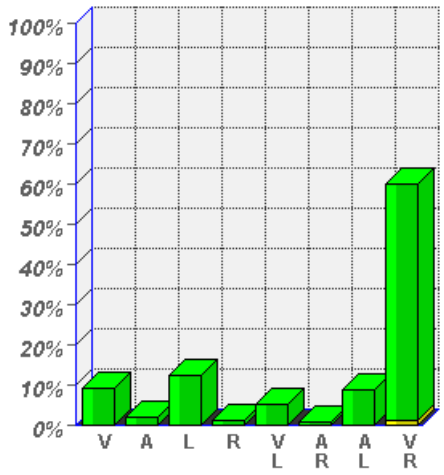


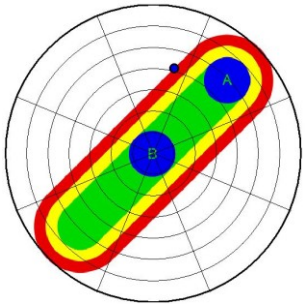
Exercise 3

Quantity of movement:

Number of executions in 2 minutes: 15

Quality of movement:



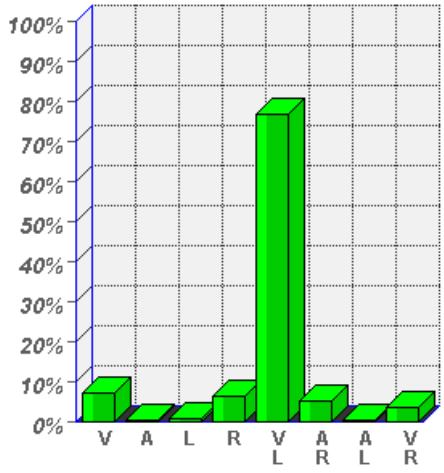


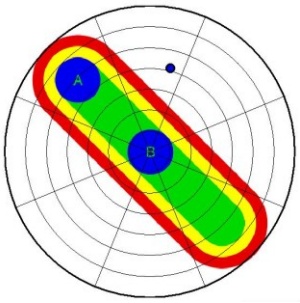
Exercise 4

Quantity of movement:

Number of executions in 2 minutes: 23

Quality of movement:



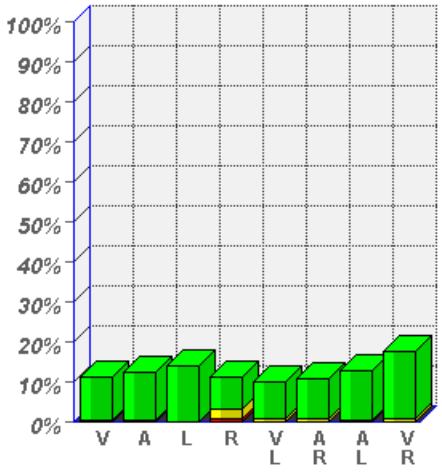


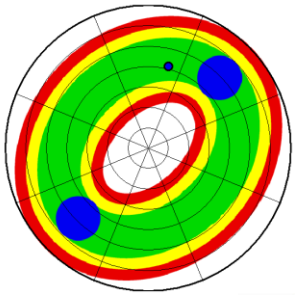
Exercise 5

Quantity of movement:

Number of executions in 2 minutes: 5

Quality of movement:



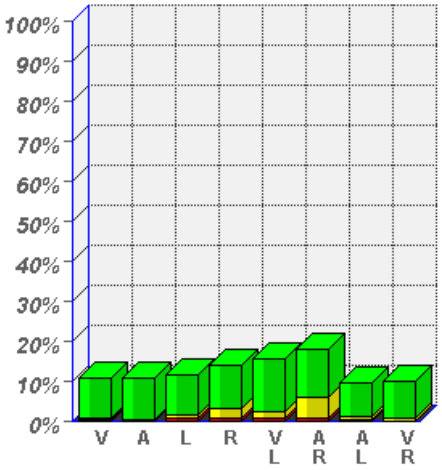


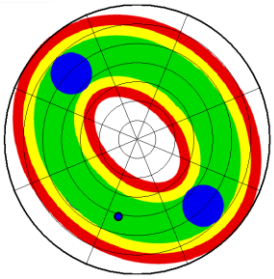
Exercise 6

Quantity of movement:

Number of executions in 2 minutes: 5

Quality of movement:





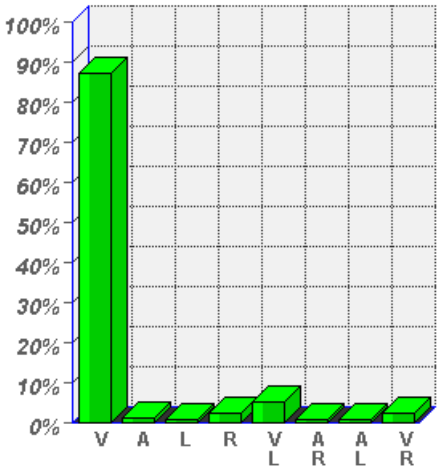
Re-evaluation of Motor Control in Sitting post-intervention

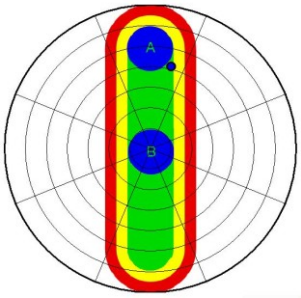
Exercise 1

Quantity of movement:

Number of executions in 2 minutes: 35

Quality of movement:



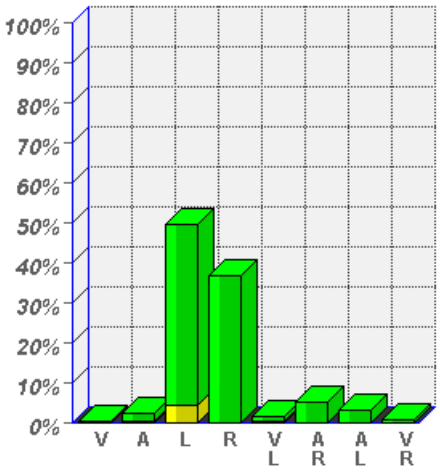


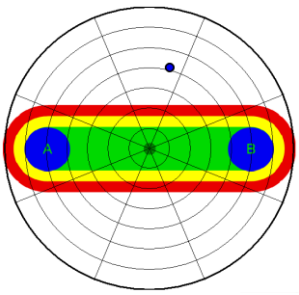
Exercise 2

Quantity of movement:

Number of executions in 2 minutes: 15

Quality of movement:



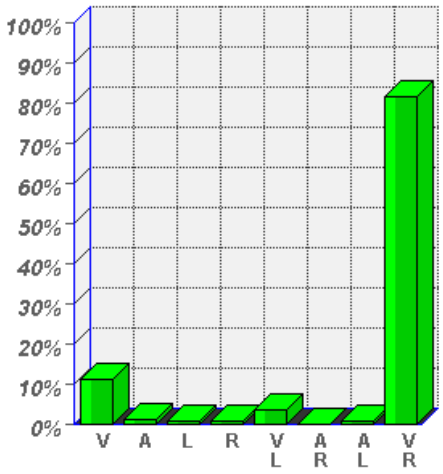


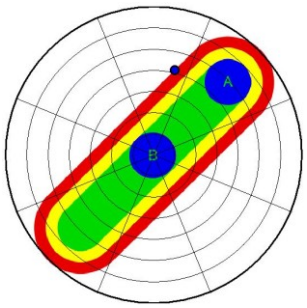
Exercise 3

Quantity of movement:

Number of executions in 2 minutes: 37

Quality of movement:



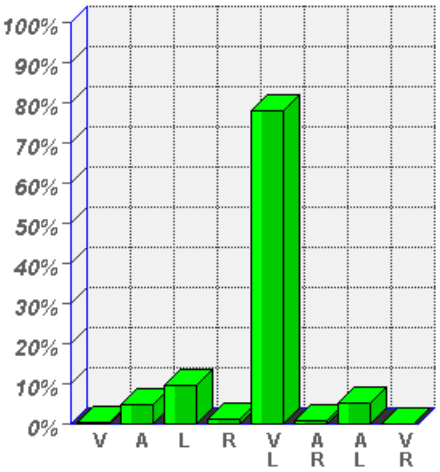


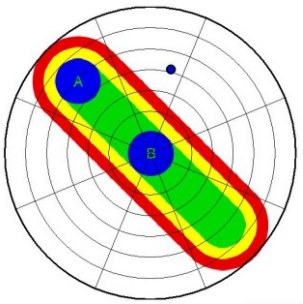
Exercise 4

Quantity of movement:

Number of executions in 2 minutes: 40

Quality of movement:



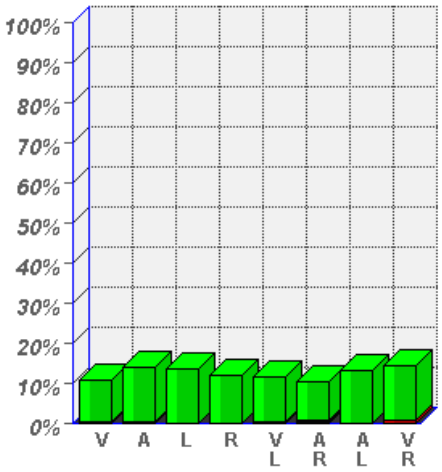


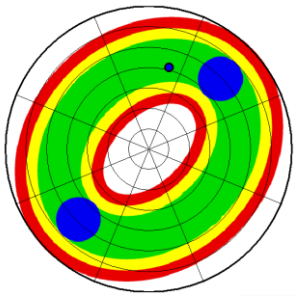
Exercise 5

Quantity of movement:

Number of executions in 2 minutes: 12

Quality of movement:



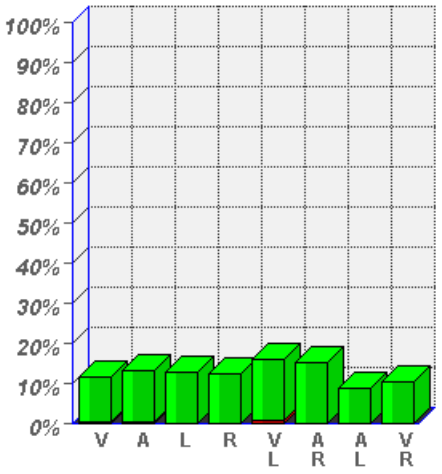


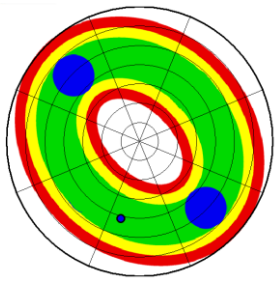
Exercise 6

Quantity of movement:

Number of executions in 2 minutes: 11

Quality of movement:





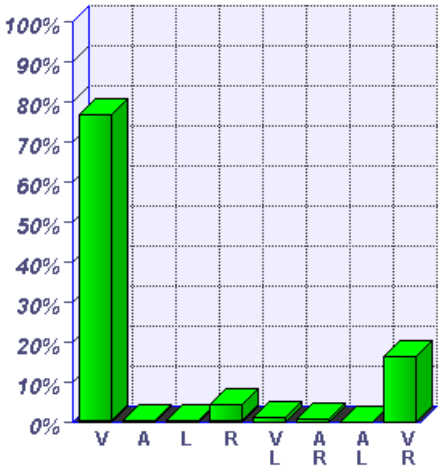
Re-evaluation of Motor Control in Sitting at 3-week follow-up

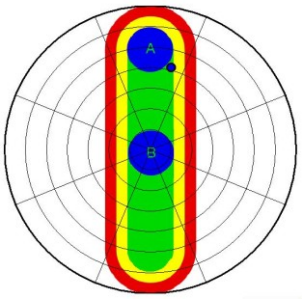
Exercise 1

Quantity of movement:

Number of executions in 2 minutes: 37

Quality of movement:



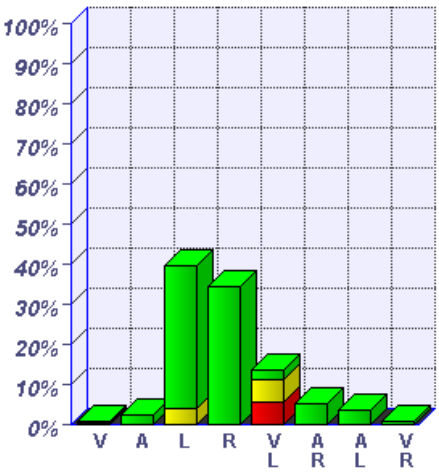


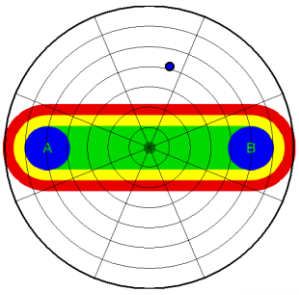
Exercise 2

Quantity of movement:

Number of executions in 2 minutes: 2

Quality of movement:



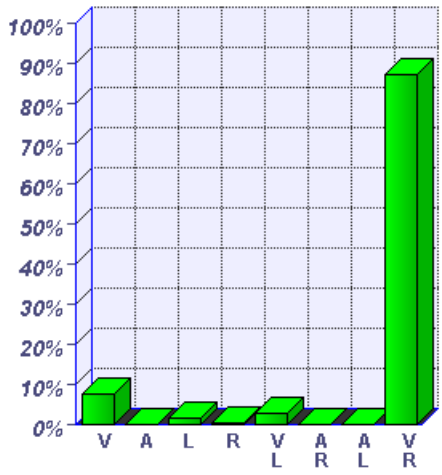


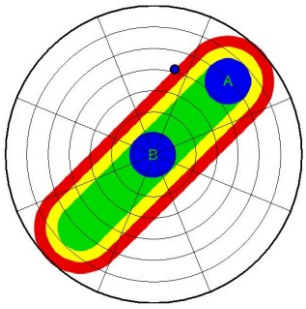
Exercise 3

Quantity of movement:

Number of executions in 2 minutes: 46

Quality of movement:



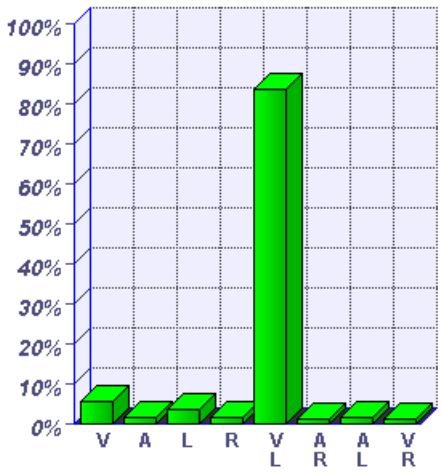


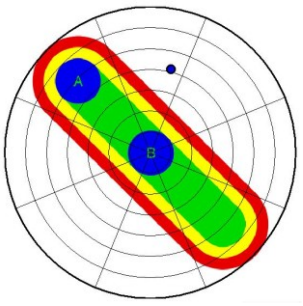
Exercise 4

Quantity of movement:

Number of executions in 2 minutes: 44

Quality of movement:



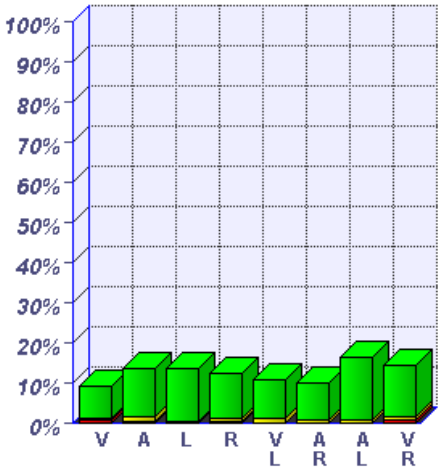


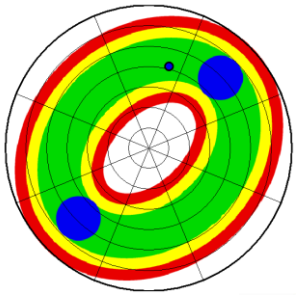
Exercise 5

Quantity of movement:

Number of executions in 2 minutes: 12

Quality of movement:





Exercise 6

Quantity of movement:

Number of executions in 2 minutes: 13

Quality of movement: