Faculteit Geneeskunde en Levenswetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Muscle strength adaptations of the trunk flexors and extensors after high-intensity interval training in persons with non-specific chronic low back pain

Sander Brion
Jeroen Frère

Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie, afstudeerrichting revalidatiewetenschappen en kinesitherapie bij musculoskeletale aandoeningen

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Belgium, 15-08-2017 B.S. and F.J.

Research context

Low back pain (LBP) is a common problem in the Western population, one in four persons appeals to healthcare within a six-month period. This group of patients is responsible for the greatest financial pressure on healthcare, for a high degree of work absenteeism and the demand for resources that offer psychosocial support (Kent and Keating 2005). The current treatment for low back pain is performed multidisciplinary, containing education and exercise therapy consisting of strength training, stabilization training and cardiovascular endurance training (Holtermann et al., 2014; Pinto et al., 2014 & Thomas et al., 1999). Although exercise therapy is widely used as a treatment for LBP, a lot of inconsistency still remains about which exercise intensity or which type of exercise is most effective for treatment of low back pain. Effects of high-intensity interval training (HIIT) has already been investigated earlier by the REVAL research group; Wens et. al (2015) looked at adaptations occurring in physical exercise capacity and muscle strength, in patients with Multiple Sclerosis following HIIT. Within this study, results showed that HIIT can be effective in increasing muscle strength, physical exercise capacity and reduce body fat percentage. When looking at muscle strength adaptations in healthy individuals following such type of training program, earlier research showed eight weeks of HIIT with a frequency of three times a week can effectively increase isokinetic as well as maximal voluntary isometric (MVC) muscle strength (Bruseghini et al., 2015).

Currently, there is little evidence about differences in maximal isometric muscle strength production of the trunk flexors and extensors for persons with non-specific chronic low back pain (NSCLBP) compared to healthy individuals. The purpose of this study was to determine the efficacy of an HIIT program on the maximal voluntary isometric contraction of persons with non-specific chronic low back pain. This randomized clinical trial is part of a more comprehensive clinical trial of Anouk Agten and Jonas Verbrugghe: "Structural and functional effects of a high-intensity training program in patients with non-specific chronic low back pain". Research was conducted at the University of Hasselt in rehabilitation research center (REVAL), located in Diepenbeek.

The promoter of this master thesis is dr. Pieter Van Noten and co-promotors are Anouk Agten and Jonas Verbrugghe. The subject of this master thesis was developed by promoter and co-promoters. The recruitment of participants and data acquisition were elaborated by Anouk Agten and Jonas Verbrugghe.

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Abstract

Background:

Low back pain is a commonly occurring, pathological condition for both sexes and all ages. This study aimed to investigate the effect of a high-intensity interval training (HIIT) program on maximal isometric strength of the trunk flexors and extensors, pain intensity and pain-related fear of movement in a non-specific chronic low back pain (NSCLBP) population. Further, inclusion of healthy controls enabled comparison for trunk strength production. At last, we evaluated if one of our four combinations of HIIT modalities resulted in a higher increase in trunk muscle strength than others.

Participants:

Fourteen persons experiencing NSCLBP were included in this 'randomized clinical trial' to evaluate the effect of HIIT on maximal isometric trunk flexion and extension. Sixteen healthy controls were included to compare for initial baseline characteristics. NSCLBP participants were randomly assigned to one of four different HIIT programs (HIIT stabilization, HIIT mobility, HIIT strength or HIIT combination) in which they received a custom 12-week training program.

Measurements:

Strength measurements were conducted before and after the 12-week intervention program. The Biodex Dynamometer System 3 Pro sampled maximal isometric torque of the trunk flexors and extensors in a semi-flexed and lumbar position. At baseline and after week six, an ergospirometry test was performed to determine and adjust the training intensity of the cardiovascular training modality. Self-reporting questionnaires were used to assess pain intensity (Numeric Pain Rating Score) and pain-related fear of movement (Tampa Scale for Kinesiophobia).

Results:

At baseline, NSCLBP participants had significantly less ($p=0.0199$) relative (normalized for body weight, Nm/Kg) isometric trunk flexion strength in a lumbar sitting position, compared to healthy controls. This difference in flexion strength disappeared after 12 weeks of HIIT accompanied with a significant improvement of pain intensity ($p=0.0010$) within our NSCLBP participants. Correlation analysis revealed that an increase in absolute maximal isometric

flexion strength (Nm) in a semi-flexed position was associated with an increase in body weight as well as a decrease in pain-related fear of movement. It was also found that an increase in relative (Nm/kg) maximal isometric trunk extension strength in a semi-flexed position was associated with a decrease in pain-related fear of movement. Measurements in a semi-flexed position also revealed significantly higher maximal isometric trunk flexion strength compared to a lumbar sitting position. A HIIT program consisting of cardiovascular and mobility modalities improved relative isometric trunk flexion strength significantly better (p=0.0497) in a lumbar seating position compared to a HIIT program consisting of cardiovascular and strength modalities.

Conclusion:

A 12-week HIIT program was successful in decreasing pain intensity for persons experiencing NSCLBP. Also, NSCLBP participants had significantly less relative isometric trunk flexion strength in a lumbar position in comparison to healthy controls pre-intervention. Although we found no significant increase in trunk flexion strength after our 12-week intervention for NSCLBP participants, differences in trunk flexion strength compared to healthy individuals were not present anymore post-intervention. Further research is needed to evaluate the influence of pain-related fear of movement and muscle fatigue on adaptations of trunk muscle strength in persons with NSCLBP following HIIT.

1. Introduction:

Low back pain is a common problem in the western world and is one of the leading causes of disability. Its lifetime prevalence is up to 84% of which 11-12% is disabled by low back pain (Airaksinen et al., 2006; Hayden et al., 2005). In 'the European guidelines for management of chronic non-specific low back pain' low back pain is defined as pain and discomfort, localized below the costal margin and above the inferior gluteal folds, with or without referred leg pain (Airaksinen et al., 2006). Three types of low back pain are defined according to its duration: acute low back pain only lasts for less than six weeks, subacute low back pain has a duration for longer than six weeks but less than 12 weeks and chronic low back pain persists for more than 12 weeks (Hayden et al., 2005).

Chronic low back pain is classified into two different subtypes: 'Specific chronic low back pain'(SCLBP), which is attributable to a recognisable known pathology (infection, tumour, osteoporosis, fracture, structural deformity, inflammatory disorders, radicular syndrome or cauda equina syndrome) and 'non-specific chronic low back pain'(NSCLBP), which is defined as a low back pain not attributable to a recognisable known pathology (Balagué et al., 2011; Kent and Keating 2005). Further, there is little scientific evidence on lifetime prevalence of NSCLBP. It is estimated that prevalence is approximate 23% of the earlier cited 84% (Airaksinen et al., 2006). Incidence is indifferent for gender, increases related to age and peaks in the age group between 45 to 60 years (NHG 2005). Sixty percent of the persons experiencing low back pain will develop a chronic-recurring pain pattern, which for one out of ten persons will remain permanent throughout their life (Kent and Keating 2005). NSCLBP is also responsible for a huge pressure on healthcare due to high rates of disability, work absenteeism and care-seeking behaviour for psychosocial support (Van Middelkoop et al., 2010; Kent and Keating 2005).

As NSCLBP differs from SCLBP, treatment is also substantially different since there is no known cause of the origin of the pain. When compared with healthy individuals, earlier research suggests that persons experiencing NSCLBP exhibit lower amounts of maximal isometric as well as isokinetic trunk flexion and extension strength. Also, weakness of these specific muscle groups has been found to be associated with the incidence of NSCLBP (Cho et al., 2014). Earlier research shows that conventional exercise therapy (CET), commonly referred to as 'a series of specific movements with the aim of training or developing the body by a routine practice or as physical training to promote good physical health' (Abenhaim 2000), can have a positive influence on overall health and muscle strength, as well as pain intensity and disability. Also, CET can increase the probability of returning to work (Hayden et al., 2005; Hayden et al., 2011). For these reasons, CET is currently the most commonly used type of conservative treatment for NSCLBP. Yet, there is no evidence that one particular type of exercise modalities is more effective than others (Van Middelkoop et al., 2010; Hayden et al., 2005).

There are various modalities of exercise therapy used to treat NSCLBP including strength training, stabilization training, endurance training and mobility training. Research indicates that CLBP can lead to physical inactivity, which can further result in physical deconditioning and subsequently to a greater functional disability. Further, low aerobic capacity can be associated with low back pain and is considered both a cause and consequence of chronic low back pain (Duque et al., 2011; Van Der Velde and Mierau 2000; Gordon and Bloxham 2016). However, there is still some inconsistency in current literature whether reconditioning by endurance training will improve functionality in persons with NSCLBP. Mobility training with emphasis on stretching of soft tissues such as muscles, ligaments, and tendons can also improve the flexibility of the lumbar spine, which in turn can result in significant reduction in low back pain and therefore improve disability (Gordon and Bloxham 2016). Research has shown that besides cardiovascular training, both lumbar stabilization and strength training of the trunk flexors and extensors can be effective in improving and preventing back pain complaints (Moon et al., 2013; Kim et al., 2011). This finding suggests that both stabilization and strength training are important modalities to include in a comprehensive intervention program for persons experiencing NSCLBP.

When investigating HIIT programs, Wens et al. (2015) found that high-intensity cardiovascular interval training combined with resistance training had a beneficial effect on muscle contractile characteristics and overall endurance in patients with Multiple Sclerosis. In musculoskeletal disorders, an eight-week resistance interval training protocol showed to be effective for reducing musculoskeletal pain symptoms as well as increasing trunk extension strength in persons with neck, shoulder and low back pain (Jay et al., 2011).

When compared with CET, HIIT might be more effective for improving cardiorespiratory fitness in healthy individuals (Nybo et al., 2010). However, there is still inconsistency within literature whether or not HIIT is superior over CET for NSCLBP in regards to cardiorespiratory fitness and skeletal muscle strength. Yet, Harts et al. (2008) found substantial better improvements in overall quality of life, disability and pain reduction in favour of HIIT compared to CET. Interestingly, prognosis for NSCLBP has also been shown to be less favourable for persons who exhibit higher levels of disability and pain intensity (Costa et al., 2009). If HIIT can be more successful than CET in improving those important prognostic factors, this type of training intervention might be an important tool in rehabilitating persons experiencing NSCLBP.

In this regard, the primary aim of this study was to determine the effects of a 12-week HIIT program on maximal isometric strength production of the trunk flexors and extensors. Secondary, it was investigated if there was a difference in trunk flexion and extension strength between NSCLBP participants and healthy controls and if so, if these differences might be related to pain intensity or pain-related fear of movement. Lastly, it was investigated if a certain combination of HIIT modalities were more effective than others.

2. Methods

2.1. General study design

This study is a 'randomized clinical trial' consisting of four intervention groups wherein the effect of high-intensity interval training (HIIT) on people with NSCLBP was investigated. In addition to these four intervention groups, a healthy control group was included to compare for initial baseline characteristics. Each intervention group received a different 12-week HIIT program. Intervention programs all consisted of a high-intensity cardiovascular training protocol and an additional specific exercise protocol: a strength exercise protocol, a stabilization exercise protocol, a mobilization exercise protocol or a combination of a strength and a stabilization exercise protocol. Isometric trunk extension and flexion torque were measured before and after a 12-week HIIT program using a Biodex dynamometer. The Biodex System 3 Pro dynamometer was used for all abdominal and back muscle strength tests with two different sitting positions. The semi-flexed test position (fig.1) aimed at both hip and lumbar joint muscles whereas a firm resistance pad was added and placed against both shins at the approximate level of the patellae-tendon insertion. The lumbar test position solely aimed at the lumbar flexors and extensors, as the pelvic girdle was fixed by an additional fixative. A firm resistance pad was placed dorsally approximately at level S1 – S3 of the spine. For both positions, participants were seated on a height-adjustable seat, with the hips placed in 90° flexion. Shoulders and trunk were strapped and fixated using Biodex dynamometer band straps. The semi-flexed position was performed before the continuation of the protocol to the lumbar position. Two minutes of rest were allowed between the execution of both test positions. Participants first performed 15 flexion and extension repetitions seated in the Biodex dynamometer as warming-up. After the warming-up, participants were verbally instructed to gradually built up to maximal isometric trunk extension and to attempt holding the maximal contraction for three seconds. After a 10 second rest, maximal isometric trunk flexion was performed in the same manner. Maximal isometric flexion and extension tests were both performed three times, with 30 seconds rest intervals in between.

Figure 1: Participant performing the Biodex testing (semi-flexed position)

2.2. Medical ethics

The study was approved by the medical ethical committee of Hasselt University and of Jessa Hospital (Hasselt, Belgium), (protocol 14.87/REVA14.12). The clinical trial was registered at clinicaltrials.gov (NCT02786316).

2.3. Participants

Participants were recruited through local advertisement, flyers and social media. Persons with low back pain who met in- & exclusion criteria were informed in depth about the study by a physician during the first intake session. When agreed upon participation, subjects received an information and agreement document. Subjects who submitted this document within one week were included as a study participant (n=16). Healthy controls (n=16) were recruited to compare for demographic baseline characteristics in weight, height and age. Following sociodemographic information was withdrawn from all the included participants:

- Gender
- Age
- Education
- Weight
- Height
- Social & work situation
- Lifestyle habits
- Medical history
- Time since onset of low back pain

- Rehabilitation history (global and low back pain specific)
- Medication usage for low back pain (yes/no, type, dosage)
- Work accident, work accident in relation to low back pain
- Average work hours/week
- Time of sitting/standing/moving at work

2.4. In- & exclusion criteria

Inclusion criteria for all intervention groups:

- Main disability: non-specific chronic low back pain
    - Low back pain is defined as pain in the region between the lowest rib and upper gluteal fold, with or without radiation pain in the leg ('European guideline for the treatment of non-specific chronic low back pain').
    - Chronic: current episode >12 weeks
    - Non-specific: Pain symptoms are not attributable to a known cause or pathology.
- Oswestry Disability Index: disability score > 20%
- Physical Activity Scale For Individuals With Physical Disabilities <30
- Age: 25-60 years
- Understanding Dutch language (spoken and written)

Exclusion criteria for all intervention groups:

- Invasive spine surgery in the last eighteen months (arthrodesis will always be excluded; micro surgery is allowed)
- Radiculopathy
- Comorbidity: Paresis or sensory dysfunction due to neurological cause, diabetes mellitus, rheumatoid arthritis, increase in pain VAS >3/10 and pain levels above 8/10 in the last twenty-four hours
- Present compensatory complaints and/or work invalidity <6 months
- Rehabilitation or exercise therapy for low back pain in the last 6 months

Inclusion criteria for healthy controls:

- No chronic low back pain (continuous low back pain >12 weeks)
- No acute low back pain with VAS >8/10 in the last twenty-four hours.
- Age: 25-60 years
- Understanding Dutch language (spoken and written)

Exclusion criteria for healthy controls:

- Rehabilitation or exercise therapy for an acute pathology in the last 6 months

2.5. Procedure

NSCLBP participants were randomly assigned to one of four intervention groups which all received a custom 12-week training program, adapted to their physical capabilities. All training programs primarily consisted of a cardiovascular HIIT modality, aimed to improve cardiovascular endurance. In addition, each intervention group performed different complementary modalities aimed at predominantly increasing muscle strength, muscle control, strength-endurance and/or mobility of the trunk.

Intervention group one performed a cardiovascular HIIT protocol, followed by a strength exercise protocol (HIIT-strength group).

The second intervention group performed a cardiovascular HIIT protocol, followed by a stabilization exercise protocol (HIIT-stabilisation group).

Intervention group three performed a cardiovascular HIIT protocol followed by a mobilization exercise protocol (HIIT-mobilization group).

The fourth Intervention group performed a cardiovascular HIIT protocol, followed by both a strength and a stabilization exercise protocol (HIIT-combination group).

Training intensity for cardiovascular HIIT was determined by a preceding ergospirometry test. Appropriate load for muscle strength training was determined by one- to three-repetition-maximum testing. Initial starting intensity for stabilization exercises was set by the researchers and progressively increased in difficulty over the course of the program. Figure 8 (flowchart) represents an overview of the procedure.

2.5.1. Training programs for intervention groups

Cardiovascular HIIT:

The cardiovascular HIIT started after an eight-minute warm-up bicycling at low-intensity after which a series of five submaximal effort bicycle sprints, interspersed with one minute active recovery, was performed on a Techno Gym trainer. The duration of the submaximal sprint was set at one minute for the first 2 weeks and was gradually increased afterwards by 10 seconds each week (week one and two=60s sprint, week three=70s sprint, etc.). Six weeks into the intervention program, sprint duration was reset to one minute, but training intensity was adjusted to the corresponding ergospirometry test performed at the beginning of week six. From here, sprinting duration was also increased at a faster rate, so participants reached one minute and 50 seconds sprint intervals during the 12th week of the training program.

Strength training – exercises:

Following exercises were performed for one set, aiming between 10 to 12 repetitions, alternated between upper and lower body movements.

- Vertical traction: bilateral vertical compound movement performed using a machine, predominantly targeting m. latissimus dorsi and m. biceps brachii.
- Chest-press: bilateral compound pressing movement performed using a machine, predominantly targeting m. pectoralis major, m. pectoralis minor and m. triceps brachii.
- Leg-press: bilateral compound pressing movement performed using a machine, predominantly targeting m. quadriceps femoris, m. biceps femoris, semitendinosus and semimembranosus.
- Arm-curl: bilateral isolation movement performed using a machine, predominantly targeting m. biceps brachii.
- Leg-extension: unilateral isolation movement performed using a machine, predominantly targeting m. quadriceps femoris.
- Leg-curl: unilateral isolation movement performed using a machine, predominantly targeting m. biceps femoris, semitendinosus and semimembranosus.

Every exercise was performed under constant observation and correction of accompanying researchers. Sixty to eighty seconds passive recovery were held between exercises. Training intensity was determined by one repetition maximum (RM) testing for each exercise during the first two weeks and was set at 80% of one RM.

Stabilization exercises:

- Bridging: isometric bodyweight movement in a supine position with the base of the feet in touch with the ground. Participants brought both hips to 0° extension, predominantly targeting m. gluteus maximus.
- Clamming: isometric unilateral side lying movement with hips and knees in 90° flexion. Participants brought the overlying hip to 45° exorotation, predominantly targeting m. gluteus medius.
- Bird-dog: isometric bodyweight movement in a prone position with the arms extended in front. Participants extended and raised opposing arm and leg simultaneously off the ground, predominantly targeting m. erector spinae.
- Planking: isometric bodyweight movement with both forefeet and elbows as contact points with the surface. Participants held their hips parallel and in line with both shoulders and feet, predominantly targeting m. rectus abdominis and erector spinae.
- Side planking: isometric unilateral bodyweight movement in side lying position with underlying foot and elbow as contact points with the surface. Participants held their hips parallel and in line with the upper shoulder and foot, predominantly targeting m. gluteus medius.
- Rowing: isometric movement in standing position with both knees in 20° flexion. Participants retracted both scapulae simultaneously while resisted by a theraband, predominantly targeting m. trapezius, latissimus dorsi and rhomboids.

Each exercise was performed for 10 repetitions, with each repetition consisting of a 10-second isometric contraction. For each exercise, four to five up-scaling progressions were selected to increase difficulty over the course of the program. Participants started with an intensity chosen by the accompanying researcher during week one. If a specific exercise was performed correctly over two consecutive training sessions, the difficulty was increased by one progression for that exercise. Resistance was increased by increasing load (body weight) and/or theraband resistance bands.

Mobilization exercises:

- Gluteus maximus: unilateral mobilization movement in supine position. Participants held equilateral hip and knee in maximal flexion, predominantly targeting m. gluteus maximus. This was performed twice on each side for 30 seconds.
- Gluteus medius: unilateral mobilization movement in upright sitting position. Participants crossed both legs with one foot flat on the ground while the opposing hand pulled their knee towards the ground, predominantly targeting m. gluteus medius. This was performed twice each side for 30 seconds.
- Lower-trunk: unilateral mobilization movement in supine position. Participants held both knees and hips in 90° flexion and passively brought both knees to one side while the trunk remained stationary, predominantly targeting mobility of the lumbar spine. This was performed twice each side for 10 repetitions.
- Frontal abdominals: mobilization movement in prone position. Participants placed both hands shoulder width in front with the arms in full extension and the hips in touch with the ground, predominantly targeting m. rectus abdominis. This was performed twice for 30 seconds.
- Thoracic mobilization: mobilization movement in upright sitting position. Participants sat upright in a chair with thoracolumbar back support and both hands placed behind the neck. Thoracic extension was performed actively, predominantly targeting mobility of the thoracic spine. This was performed twice for 10 repetitions
- Side abdominals: mobilization movement in knee-sitting position. Participants placed one leg in front of them with corresponding hip and knee in 90° flexion. The opposite arm was fully extended overhead and side bending was performed passively to the side of the leg that was placed in front, predominantly targeting abdominal internal and external oblique muscles. This was performed twice each side for 30 seconds.

2.5.2. Questionnaires

Participants with NSCLBP were instructed to answer questionnaires regarding pain intensity (Numeric Pain Rating Score; NPRS) and pain-related fear of movement (Tampa Scale for Kinesiophobia; TSK). These questionnaires were filled-out at the following times:

- During the intake session, after performing the ergospirometry test (baseline measurement)
- Within the following week of completing the 12-week intervention program (post-intervention measurement)

Questionnaire 1: Numeric Pain Rating Score (NRPS)

The participant can score the pain intensity he/she is presently aware of at that time. It is a numeric scale with eleven scores (0-10), where '0' is equal to 'no pain' and '10' represents 'worst pain imaginable'. A difference in score of minimal two points is considered significant and clinically relevant.

Questionnaire 2: Tampa Scale for Kinesiophobia (TSK)

This reliable and valid questionnaire (17 items) displays pain-related fear of movement for patients with low back pain. Every single item has to be scored on a four-point scale. A total score of more than 37 points is considered a cut-off score and represents high fear of movement.

2.5.3 Statistical analysis

Data analysis was performed using JMP Pro 12.2.0 software and according to the intention-to-treat principle. Because of the small sample sizes within this study, data were analysed using three different nonparametric tests. First, a baseline comparison between healthy controls and NSCLBP participants was conducted for demographic distribution of age, length and trunk strength. Results were collected using Wilcoxon/Kruskal-Wallis test. Secondly, analysis of treatment effect was performed for all intervention groups using Wilcoxon Signed Rank test for Matched Pairs. Delta-values of treatment effect were then used to analyze for possible correlations with NPRS, TSK and body weight (Δ) using a multivariate nonparametric Spearman's $\boldsymbol{\rho}$ test. These delta-values (Δ) represent the differences in value between post-intervention (T2) and baseline tests (T0). Further, post-intervention analysis of trunk strength values for NSCLBP participants were again compared to baseline trunk strength of healthy controls by Wilcoxon/Kruskall-Wallis. Finally, a nonparametric comparison was made for each pair of HIIT groups for effect of intervention using the Wilcoxon method.

3. Results

3.1. Participant characteristics:

In total, 32 persons who met in- & exclusion criteria for healthy or NSCLBP were included. During the course of the study, drop-out occurred for two NSCLBP participants who failed to complete the 12-week intervention program due to personal reasons. Further, no NSCLBP participants had to pause or stop the assigned intervention protocol as for the result of increasing low back pain. As of this, data from 30 participants were used for further statistical analysis. The baseline characteristics for healthy (n=16) and NSCLBP (n=14) participants are shown in table 1. Wilcoxon Signed Ranks tests showed no significant baseline differences between groups for age, weight or length.

Table 1: Comparison participants baseline characteristics

Characteristics	Control group	Intervention group
Number (F/M)	16 (9/7)	14 (7/7)
Age (y)	39,7 ± 7,9	45,6 ± 7,7
Weight (Kg)	76,7 ± 10,8	75,9 ± 12,3
Length (Cm)	174,5 ± 7,9	174,7 ± 7,8

NOTE: Values are mean ± standard deviation (SD).
*** p < 0.05 for between-group differences in participant characteristics.**

3.2. Baseline comparison healthy – NSCLBP participants

Healthy and NSCLBP participants were compared for baseline values of maximal isometric torque for trunk flexion/extension in semi-flexed position and lumbar position. No difference was found in semi-flexed position between healthy and NSCLBP participants for absolute maximal isometric torque (Nm) and relative maximal isometric torque (Nm/Kg body weight) in flexion and extension. Lumbar maximal isometric torque showed no significant difference for extension or flexion when looked at absolute torque values. However, when normalized for body weight, NSCLBP participants had significant less maximal trunk flexion torque (Nm/kg body weight; p=0.0199) compared to healthy controls.

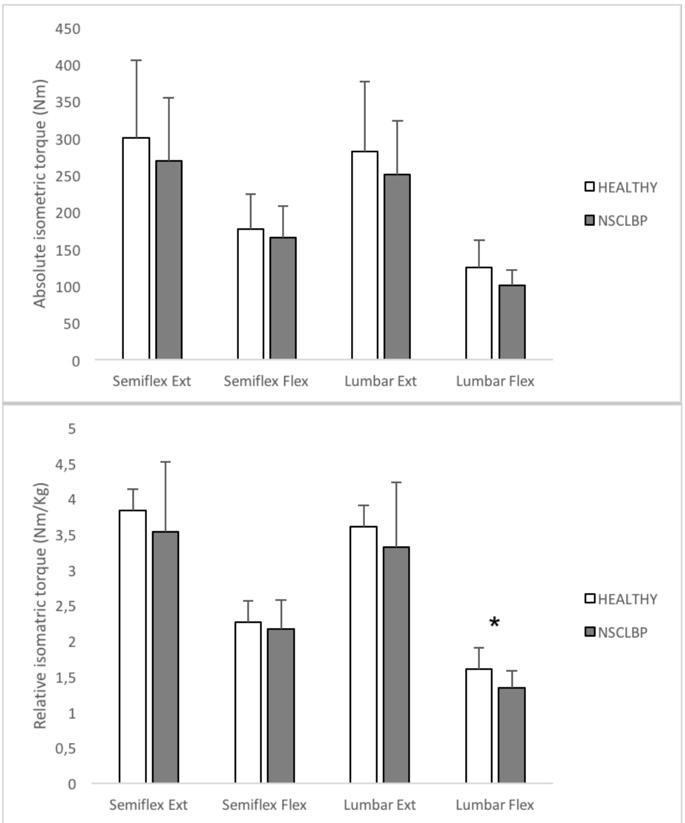


Figure 2: Baseline comparison healthy - NSCLBP. Mean ± 1SD for absolute (top) and relative to body weight (bottom) torque. *: p>0.05 for difference between H and NSCLBP for flexion or extension in a specific position.

3.3. Within-group comparison NSCLBP pre – post

Pre- and post-intervention values of maximal isometric torque (Nm) for trunk flexion/extension were compared in a semi-flexed and lumbar position for NSCLBP participants. No difference was found for semi-flexed or lumbar position for absolute maximal (Nm) or relative (Nm/Kg body weight) isometric torque for both flexion and extension.

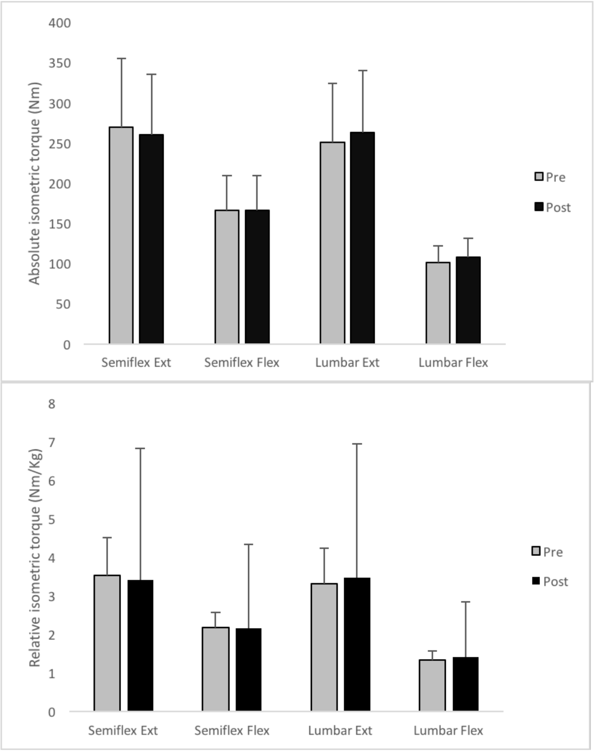


Figure 3: The effect of HIIT on maximal isometric torque (Nm). Mean ± 1SD for absolute (top) and relative to body weight (bottom) torque. *: p>0.05 for difference between pre- and post-intervention tests for flexion or extension in a specific position.

Pre- and post-intervention differences of NPRS and TSK questionnaire scores were also compared within-groups. Statistical analyses revealed significant improvements in NRPS scores (p=0.0010). Statistically, there were no significant changes observed for TSK scores.

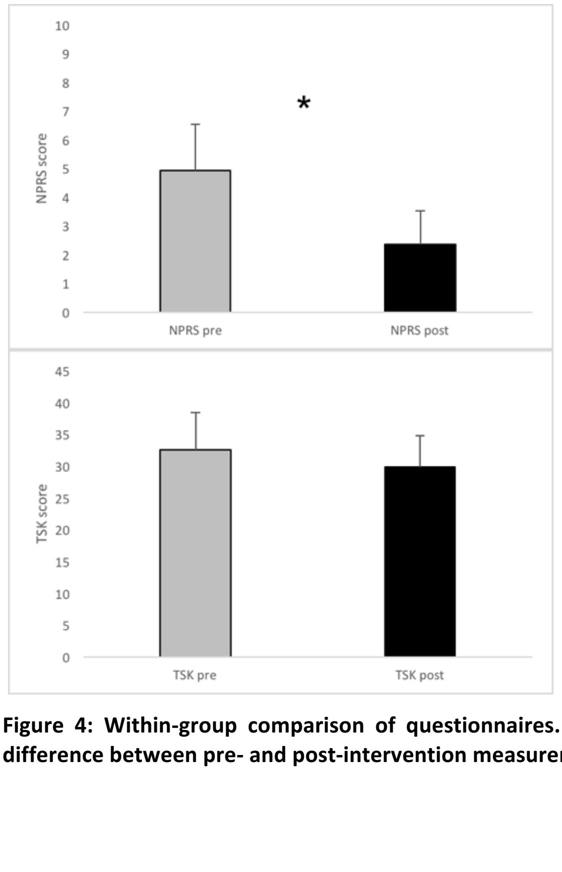


Figure 4: Within-group comparison of questionnaires. Mean ± 1SD for NPRS (top) and TSK (bottom). *: p<0.05 for difference between pre- and post-intervention measurements.

To determine if pain intensity, pain-related fear of movement or body weight had an influence on maximal isometric torque (delta-values), analysis was performed for possible correlations. The increase in absolute maximal isometric torque (Nm) for extension as well as relative flexion and extension torque were positively correlated with a decrease in pain-related fear of movement in a semi-flexed position. A significant correlation was found for an increase in absolute maximal isometric flexion torque (Nm) and higher body weight in a semi-flexed position.

Table 2: Correlations between isometric torque differences and pain, pain-related fear of movement or body weight (Δ-values).

Parameters	Correlation (spearman's ρ)	P-value
Semiflex ext - NPRS	-0,1909	0,5133
Semiflex flex - NPRS	-0,1633	0,5769
Semiflex ext - TSK	0,5989	**0,0236***
Semiflex flex - TSK	0,6460	0,0126
Lumbar ext - NPRS	0,2733	0,3444
Lumbar flex - NPRS	0,4573	0,1002
Lumbar ext - TSK	0,5066	0,0645
Lumbar flex - TSK	0,3204	0,2640
Semiflex ext rel - NPRS	-0,1711	0,5586
Semiflex flex rel - NPRS	-0,2622	0,3652
Semiflex ext rel- TSK	0,5991	**0,0236***
Semiflex flex rel - TSK	0,6857	**0,0068***
Lumbar ext rel - NPRS	0,2250	0,4394
Lumbar flex rel - NPRS	0,3743	0,1873
Lumbar ext rel - TSK	0,5308	0,0508
Lumbar flex rel - TSK	-0,0022	0,9939
NPRS - TSK	-0,0268	0,9276
Semiflex ext - weight	-0,1476	0,6146
Semiflex flex - weight	0,5491	**0,0420***
Lumbar ext - weight	0,1764	0,5463
Lumbar flex - weight	0,3789	0,1816

NOTE: Δ-values: T2 - T0. +: increase; -: decrease. *: p<0.05

3.4. Between-group comparison baseline control – post intervention

In the comparison of post-intervention values from NSCLBP participants with baseline values from healthy controls, no significant differences were found for absolute maximal isometric torque (Nm) and relative maximal isometric torque (Nm/ Kg body weight) in a semi-flexed or lumbar position.

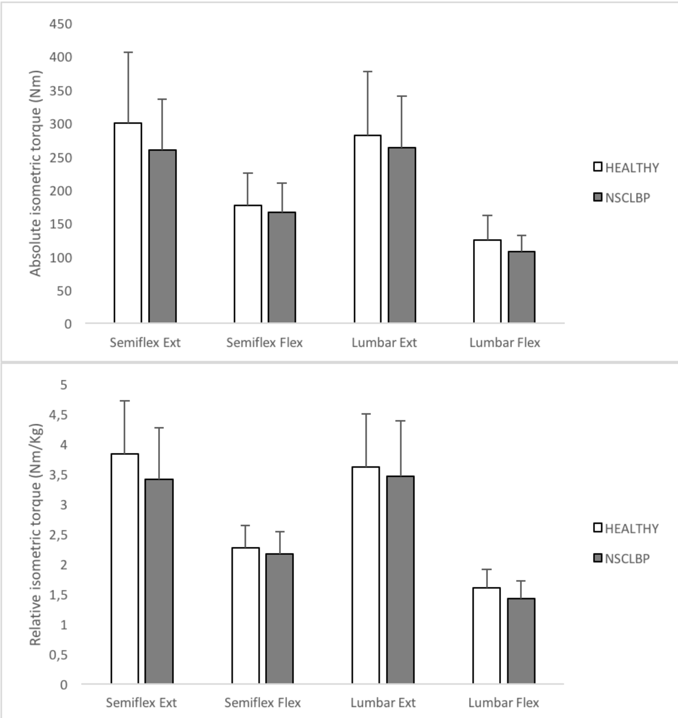


Figure 5: Comparison between baseline measurements healthy and post intervention measurements NSCLBP. Mean ± 1SD for absolute (top) and relative to body weight (bottom) torque. *: p>0.05 for difference between H and NSCLBP for flexion or extension in a specific position.

3.5. Comparison between semi-flexed position and lumbar position

A significant difference was found for absolute and relative maximal isometric flexion torque for NSCLBP participants and healthy controls ($p<0.0001$) in both pre- and post-intervention tests ($p=0.0001$) in favour of the semi-flexed position. Statistical analysis also showed that pre-intervention NSCLBP participants were able to produce significantly more absolute ($p=0.0476$) as well as relative ($p=0.0359$) trunk extension torque in a semi-flexed position compared to a lumbar position.

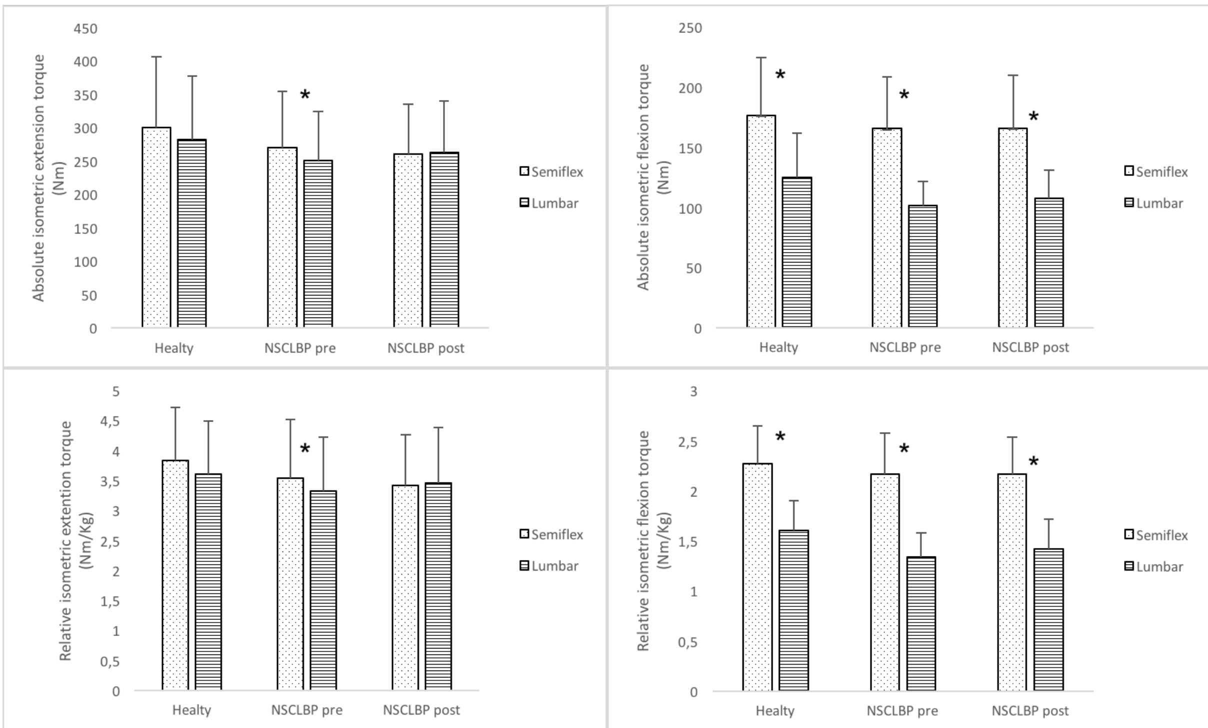


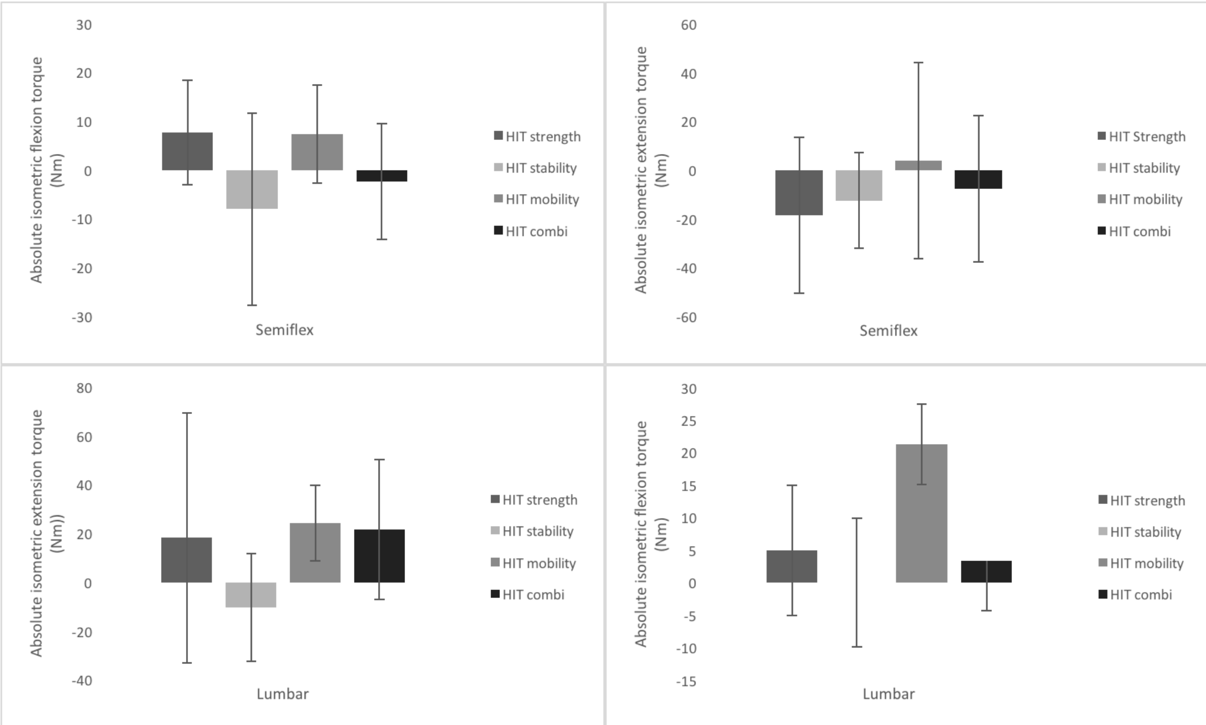
Figure 6: Comparison between semi-flexed position and lumbar position for maximal isometric torque. Mean ± 1SD for absolute (top; left/right) and relative to body weight (bottom; left/right) torque. *p<0.05 for difference between positions

3.6. Between-group comparison HIIT

Intervention groups were compared for between-group baseline values of maximal isometric torque for trunk flexion/extension in semi-flexed position and lumbar position. Delta values (ΔT2-T0) of MVC for trunk flexion/extension within these positions were compared for between-group differences in the effect of the intervention.

Comparison between baseline measurements of HIIT groups in semi-flexed and lumbar position revealed no significant difference for absolute maximal isometric torque (Nm) and relative maximal isometric torque (Nm/ Kg body weight) for both flexion and extension. After comparing the effect of interventions for between-group differences, it was shown that the HIIT mobility group made a significant greater improvement in maximal isometric flexion torque (relative to body weight) in a lumbar position compared to the HIIT strength group ($p=0.0497$; respectively).

A.



B.

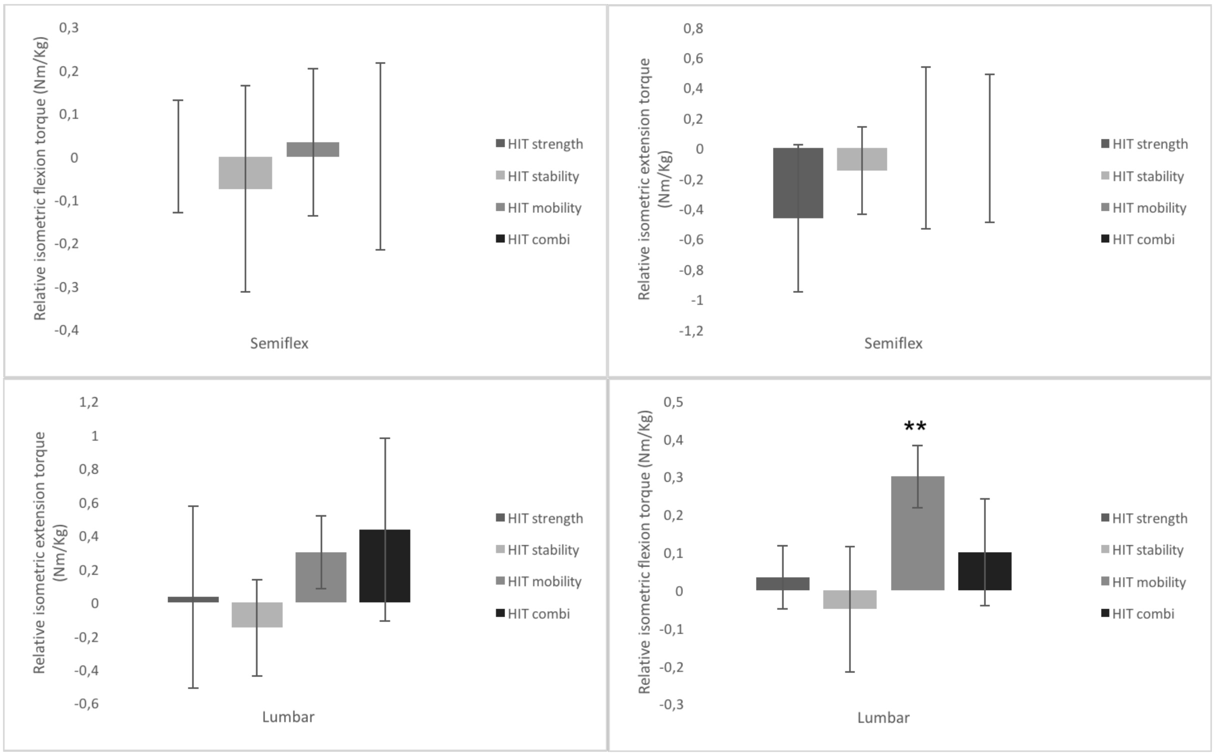


Figure 7: Comparison for between-group differences in effect of intervention. Mean Δ-value (T2-T0) ± 1SD for absolute (A) and relative to body weight (B) torque. *: HIIT strength – HIIT stability ($p<0.05$); **: HIIT strength – HIIT mobility ($p<0.05$); *: HIIT strength – HIIT combi ($p<0.05$); ****: HIIT stability – HIIT mobility ($p<0.05$); *****: HIIT stability – HIIT combi ($p<0.05$); ******: HIIT mobility – HIIT combi ($p<0.05$).**

4. Discussion

The primary focus of this study was to determine the effect of a 12-week HIIT program on the maximal voluntary isometric contraction of the trunk flexors and extensors in a semi-flexed and lumbar sitting position. Secondary, it was investigated if there was a difference in MVC between NSCLBP participants and healthy controls and if so, if these differences might be related to pain intensity or pain-related fear of movement. Lastly, it was investigated if certain combinations of HIIT modalities were more effective than other.

A significant difference was observed between healthy controls and NSCLBP participants at baseline for maximal isometric flexion strength relative to body weight in a lumbar position. This significance later disappeared in the post-intervention analysis. This finding might be explained due to the nature of the strength and stabilization training program. Within these training modalities, activation of abdominal musculature was required in almost every exercise. This likely resulted in a training response for the trunk flexors, although trunk flexion strength did not increase significantly in NSCLBP participants following the 12-week HIIT program. Earlier research stated that high pain-related fear of movement and pain intensity in chronic low back pain patients can interfere with their capability to produce a MVC of back muscles (Larivière et al., 2003; Oddsson and De Luca 2003). Nonetheless, mean scores of the TSK questionnaire showed no high pain-related fear of movement for NSCLBP participants at baseline. Thus so, it is suggested that pain-related fear of movement had no influence on the evaluation of maximal isometric strength production in this study. Exceptionally, we'd like to state that three participants scored more than 37 points on the TSK questionnaire at baseline. This finding clinically represents a high pain-related fear of movement for these individuals. It was noted that these specific individuals also had the greatest reduction in pain-related fear of movement and scored less than 37 points on the TSK questionnaire after the 12-week intervention.

There were no significant differences found for MVC of the trunk flexors and extensors within NSCLBP participants following our 12-week HIIT program. Since the initial significant strength differences between healthy and NSCLBP participants disappeared in the post-intervention analysis, it is suggested that these initial baseline differences between healthy and NSCLBP participants were rather minimal.

Previous research on trunk muscle strength by Cho et al. (2014) suggested that persons experiencing NSCLBP exhibit lower amounts of maximal isometric flexion and extension strength compared to healthy individuals. These findings are slightly in contrast with our study, where only relative isometric flexion strength in a lumbar position at baseline was found to be significantly different from healthy controls. Insignificant differences within our study may possibly be allocated to low scores of self-reported pain intensity of NSCLBP participants at baseline. It is possible NSCLBP participants had a rather low pain intensity and aggravation of back pain was not severe enough at the time they started the intervention program. Although mean scores of pain intensity improved significantly following the 12-week program, two participants did not improve individually and one participant even reported an increase in pain intensity. Since baseline characteristics were not significantly different between healthy controls and NSCLBP participants for age, height and length, further possible differences are likely the result of the small sample size of both groups instead of real discrepancies.

Earlier research by Jay et al. (2011) found that resistance HIIT with a frequency of three times a week for eight weeks can increase trunk extension MVC in people with musculoskeletal disorders, including persons experiencing low back pain. This differs from our study, where participants trained for a duration of 12 weeks with a frequency of only two times a week. In this regard, a lower training frequency rather than the duration of the training program itself might be a contributing factor to the insignificant changes found for trunk muscle strength within our study. Also, HIIT used within the study from Jay et al. (2011) didn’t include cardiovascular training, whereas this specific modality was prominently present within all our intervention programs. Additionally, cardiovascular HIIT was always performed at the beginning of each training session, possibly pre-exhausting participants for upcoming strength and stabilization training and thus so, possibly diminishing training responses coming forth from these specific modalities. Yet, results within our study show similarities with findings from Harts et al. (2008), who also found no significant improvements for maximal trunk extension in NSCLBP participants completing a 24 week HIIT program. Participants in this study only increased their maximal isometric trunk extension with 24 Nm, compared to a 12 Nm increase for lumbar position and a 10 Nm decline for semi-flexed position within our 12-week study.

Previous literature by Steele and Bruce-low (2012) stated the importance of isolation exercises for specific improvements in muscle strength production for corresponding muscle groups. Looking at the strength-training modality within our study, no isolation exercises were performed which specifically targeted trunk flexion or extension muscles. Thus so, insignificant improvements in trunk strength might also be due to a lack of strength isolation exercises for these specific muscle groups, as between-group comparison also showed no significant trunk strength improvements for HIIT-stability over the HIIT-mobility group.

Within this study, there are certain limitations that can be addressed which possibly affected post-intervention tests. First, sample size of both NSCLBP and healthy controls only reached 14 participants for NSCLBP and 16 for healthy controls, which resulted in insufficient statistical power to conclude any hard evidence from the results of this study. Because of this small sample size, outlier values could have had a greater influence on the performed data-analysis and study results. Secondly, included participants within the academic year 2016 – 2017 seldom had the same accompanying researcher assisting them during training sessions. The variation in accompanying researchers might have led to different points of cueing, attention, difference in counting-speed during stabilization exercises and further, decision making whether or not participants should perform more difficult progressions during the course of the training program.

Further, both healthy and NSCLBP participants were able to produce significantly more strength in a semi-flexed sitting position compared to a lumbar position. This was likely due to the fact that the semi-flexed position aimed at recruiting both hip and lumbar flexors and extensors. The lumbar position solely aimed at the lumbar flexors and extensors, as the pelvic girdle was fixed by an additional fixative. To account for possible increased or decreased recruitment of trunk muscles within these positions during testing moments, surface electromyography (sEMG) is a frequently used measurement tool to observe for differences in muscular activation between NSCLBP and healthy persons (Miura et al., 2014). However, sEMG was not available for our evaluations and therefore differentiation of back and abdominal musculature was not accounted for within this study.

Lastly, reliability and validity of the Biodex Dynamometer are currently under investigation. Thus, possible errors of measurement were not accounted for within this study and might be of influence when testing maximal isometric trunk flexion and extension strength using the semi-flexed and lumbar sitting position in this apparatus. An isometric test procedure was opted as the most preferable to measure for maximal voluntary contraction of the trunk, as the psychological component of performing isokinetic movements against resistance could provoke back pain symptoms in persons with NSCLBP. Also, because of the likelihood of physical deconditioning in persons with NSCLBP, a test procedure demanding less physical effort could be experienced as more comfortable. In an earlier conducted literature study for this master thesis, evidence was found for the importance of repeated baseline measurements to reduce possible learning effects carrying over to post-intervention tests (Gruther et al., 2009). It was suggested that second baseline measurements one to two days after initial measurements are more reliable and possibly diminish these learning effects. However, implementing this method is time-consuming and therefore mostly infeasible in clinical practice.

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6. Appendix

Table 2. Outcome measures baseline

	Control group (n=16)	Intervention group (n=14)	p-value
Semiflex (Nm)			
Extension	300.6 ± 105.2	269.6 ± 85.2	0.6474
Flexion	176.6 ± 48.4	165.6 ± 43.2	0.6623
Lumbar (Nm)			
Extension	281.9 ± 95.4	250.9 ± 72.9	0.5745
Flexion	124.8 ± 36.9	101.5 ± 20.1	0.0922
Semiflex relative (Nm/kg)			
Extension	3.8 ± 0.9	3.5 ± 1.0	0.7705
Flexion	2.3 ± 0.4	2.2 ± 0.4	0.4513
Lumbar relative (Nm/kg)			
Extension	3.6 ± 0.9	3.3 ± 0.9	0.7233
Flexion	1.6 ± 0.3	1.3 ± 0.2	0.0199*

NOTE: Values are mean ± standard deviation (SD)
*p<0.05

Table 3. Outcome measures baseline control group - post intervention group

	Control group pre (n=16)	Intervention group post (n=14)	p-value
Semiflex (Nm)			
Extension	300.6 ± 105.2	259.9 ± 75.5	0.4542
Flexion	176.6 ± 48.4	166.1 ± 43.7	0.5745
Lumbar (Nm)			
Extension	281.9 ± 95.4	262.9 ± 77.3	0.8516
Flexion	124.8 ± 36.9	108.0 ± 23.4	0.2794
Semiflex relative (Nm/kg)			
Extension	3.8 ± 0.9	3.4 ± 0.9	0.2979
Flexion	2.3 ± 0.4	2.2 ± 0.4	0.5034
Lumbar relative (Nm/kg)			
Extension	3.6 ± 0.9	3.5 ± 0.9	0.9834
Flexion	1.6 ± 0.3	1.4 ± 0.3	0.2020

NOTE: Values are mean ± standard deviation (SD)
*p<0,05

Table 4. Outcome measures intervention group pre vs post

	Intervention group pre (n=14)	Intervention group post (n=14)	p-value
Semiflex (Nm)			
Extension	269.6 ± 85.2	259.9 ± 75.5	0.3258
Flexion	165.6 ± 43.2	166.1 ± 43.7	0.6971
Lumbar (Nm)			
Extension	250.9 ± 72.9	262.9 ± 77.3	0.3572
Flexion	101.5 ± 20.1	108.0 ± 23.4	0.0906
Semiflex relative (Nm/kg)			
Extension	3.5 ± 1.0	3.4 ± 0.9	0.3472
Flexion	2.2 ± 0.4	2.2 ± 0.4	0.8937
Lumbar relative (Nm/kg)			
Extension	3.3 ± 0.9	3.5 ± 0.9	0.5271
Flexion	1.3 ± 0.2	1.4 ± 0.3	0.1558
NPRS	4.9 ± 1.6	2.4 ± 1.2	0.0010*
TSK	32.6 ± 5.8	29.9 ± 5.1	0.1130

NOTE: Values are mean ± standard deviation (SD)
NA: not applicable; TSK: Tampa scale of Kinesiophobia (/68); NPRS: Numeric pain rating scale(/10)
*p<0.05

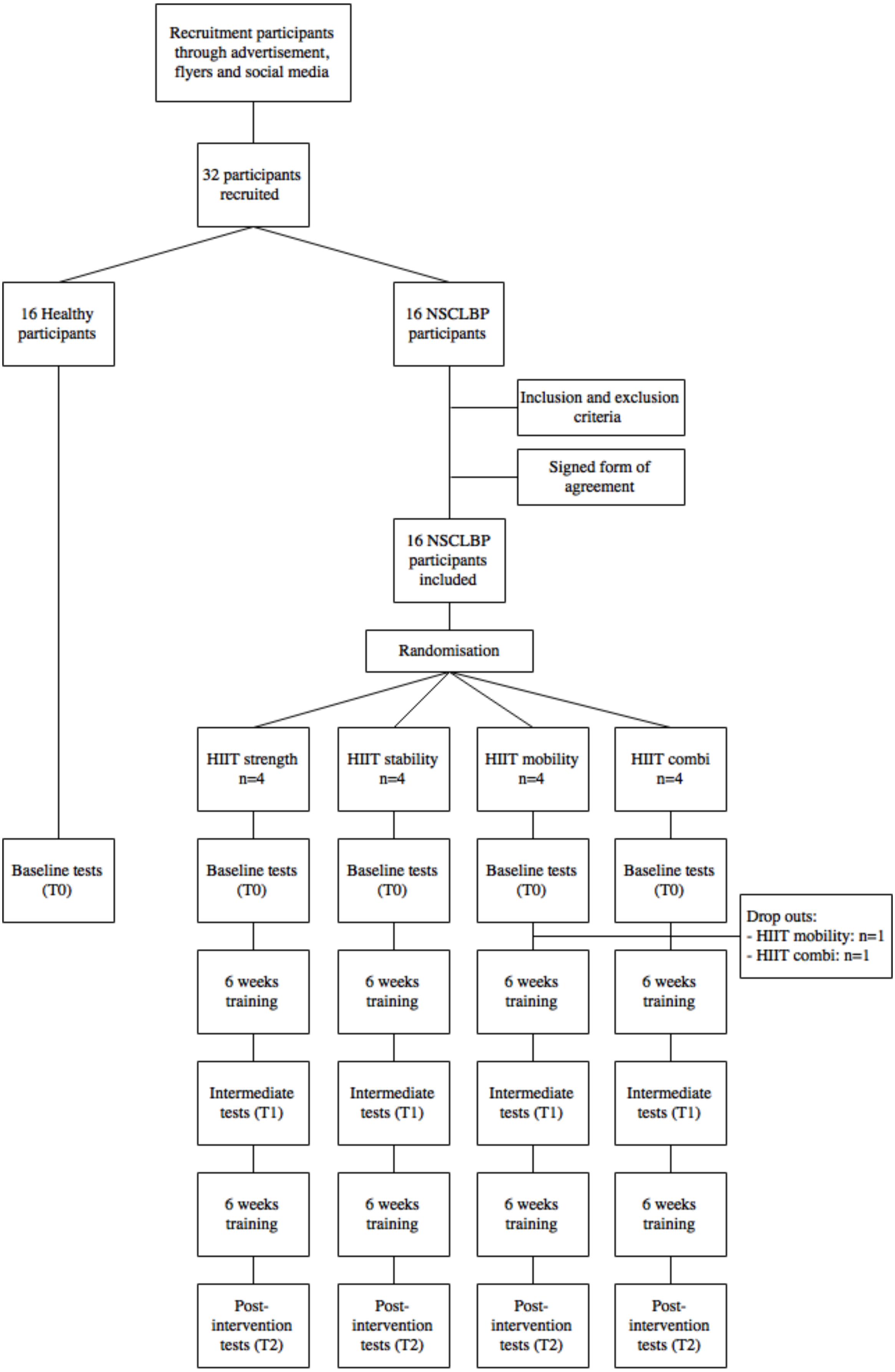

Figure 8: Flowchart

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Richting: **master in de revalidatiewetenschappen en de kinesitherapie-revalidatiewetenschappen en kinesitherapie bij musculoskeletale aandoeningen**
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