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Feasibility of high intensity training in nonspecific chronic low back pain: A clinical trial

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Abstract.
BACKGROUND: Although low to moderate intensity exercise therapy is a predominant part of rehabilitation in nonspecific chronic low back pain (NSCLBP), effect sizes are small and optimal exercise modalities/intensities are unclear. Conversely, effects of high intensity training have not yet been investigated in this population.
OBJECTIVE: The aim of this study is to investigate the feasibility of high intensity training (HIT) and to explore the magnitude of the effects of a HIT program may have on exercise capacity and disease related outcome measures compared to conventional therapy for persons with NSCLBP.
METHODS: In this non-randomized controlled feasibility study, treatment satisfaction, adherence, disability, pain, physical activity, body composition, exercise capacity and self-reported motivation, were assessed in persons with NSCLBP, before (PRE) and after (POST) 6 weeks (12 sessions, 1.5 hours/session, 2 x/week) of high intensity cardiovascular (100% VO_{2Max}) and high load resistance (80% 1RM) training (HIT, $n = 10$) and compared to average intensity/load (60% VO_{2max}) conventional physical therapy (CON, $n = 10$).
RESULTS: At PRE, CON and HIT did not differ, except for gender ratio and lean mass. Compared to CON, HIT retained motivation to rehabilitate better (HIT: $+3\%$; CON: -25%) and had higher therapy adherence ($+16\%$) during the study course. No adverse events were noted in both groups. Whereas disability reduced in both groups (HIT: -10.4%; CON: -8.3%), peak workload ($+7.0\%$), time to exhaustion ($+9.5\%$), and activity level ($+5.6\%$) only improved in HIT.
CONCLUSIONS: High intensity exercise therapy appears to be a feasible rehabilitation approach in NSCLBP. Outcomes improved following the HIT protocol, warranting the investigation of its effectiveness in future large scale RCT studies.

Keywords: Low back pain, rehabilitation, high intensity, exercise therapy

1. Introduction

At present, the most frequent musculoskeletal cause of functional disability is low back pain [1,2]. It occurs in all male and female age groups and peaks between 30 and 65 years. In approximately 90% of the cases, symptoms are of nonspecific origin [3]. Ultimately 23% of all persons with low back pain will develop nonspecific chronic low back pain (NSCLBP) [4].

Exercise therapy is an important component of NSCLBP treatment [5]. However, the effects of specific exercise therapy types such as motor control therapy [6], core stability training [7] and aerobic conditioning training [8], are small and recommendations for rehabilitation are inconsistent. Furthermore, exercise therapy program guidelines are lacking informa-

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tion with regard to training components (frequency, intensity, time, type) [5,9,10].

Because persons with chronic low back pain show reduced exercise capacity [11–13], therapy programs enhancing the exercise capacity of persons with chronic low back pain are currently under investigation [14,15].

In healthy persons, higher intensity training (HIT) programs such as high intensity interval training and high intensity resistance training efficiently improve exercise capacity and a wide range of health-related outcomes [16–18]. In persons with acute and chronic disorders such as aortic aneurysms [19], multiple sclerosis [20], heart failure [21], COPD [22] and cardiometabolic diseases [23], HIT has already been safely and successfully applied to improve exercise capacity and muscle strength as well as a wide variety of specific functional outcomes. A recent study by Ryan et al. advocated the potential benefit of high intensity training for the prevalence and management of chronic musculoskeletal pain [24]. Specifically in chronic low back pain, high intensity isolated erector spinae training showed increased lumbar strength [25,26] and high intensity continuous cardiovascular training [27] improved fitness and disease related outcomes such as pain intensity and disability. Thorough investigation of the combination of high intensity strength and high intensity cardiovascular training, in comparison to regular/conventional rehabilitation, however, has not been performed yet.

The present study aims to evaluate the feasibility of HIT rehabilitation in NSCLBP and to explore the magnitude of the effects of a HIT program on exercise capacity and disease related outcomes compared to conventional rehabilitation therapy.

2. Materials and methods

2.1. Participants

Following detailed information and informed written consent, 20 participants were recruited from the department of Physical Medicine and Rehabilitation at the Jessa Hospital (Campus Virga Jesse, Hasselt, Belgium). Inclusion criteria were (1) medically diagnosed with nonspecific chronic low back pain [3], (2) $>$18 years old, and (3) able to understand Dutch (spoken and written). Exclusion criteria were (1) invasive surgery at the lumbar spine in the last 18 months, (2) radiculopathy, (3) co-morbidities: paresis and/or sensory impairments, diabetes mellitus, rheumatoid arthritis, pregnancy, an increase of pain of 3 points with a result of $>$8/10 on the Numeric Pain Rating Scale (NPRS) [28] in the last 48 hours, (4) ongoing compensation claims and/or (work) disability $>$6 months, and/or (5) rehabilitation/exercise therapy program for chronic low back pain in the past 6 months. 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).

2.2. Study design

This feasibility study used a nonrandomized controlled trial design. Following study admission, participants were allocated to an experimental (HIT, $n = 10$) or to a conventional (CON, $n = 10$) group. Because of practical reasons (staff availability) HIT participants were recruited first. As no similar studies have been published using this type of HIT protocol in patients with NSCLBP, it was impossible to perform a power analysis. Therefore, group sample size was based on pilot study guidelines from Hertzog [29]. Participant characteristics obtained at baseline were age (year), gender, time since onset of low back pain (year) and medication use (yes/no). Subsequently, baseline (PRE) exercise capacity (maximal graded exercise test), body composition (DEXA), motivation (MVAS), satisfaction (SVAS), pain intensity (NPRS), functional disability (RMDQ), physical activity (Physical Activitiy Scale for Individuals with physical disabilities (PASIPD) and accelerometry), kinesiophobia (TSK), and quality of life (SF36) were assessed. The administrators of the exercise capacity test and DEXA were blinded for group allocation, and were not involved in the training or data analyses. Self-reported measures were completed under the supervision of a researcher after extended oral explanation in a separate room at the facility. Next, participants were enrolled in a 6-week (2/w, 1.5 h per session) CON or HIT exercise therapy rehabilitation program at the Jessa Hospital (Department of Physical Medicine and Rehabilitation, Hasselt, BE). *CON training* consisted of individualized sessions, supervised by local physiotherapists. CON training sessions consisted of cardiovascular training (cycling, cross-training and/or treadmill walking, 60–65% HR_{max}, $\sim$ 50 min) and exercise therapy addressing inherent motor control impairments (i.e. proprioceptive neutral positioning of the lumbar spine, pelvic tilt movements) and strengthening and

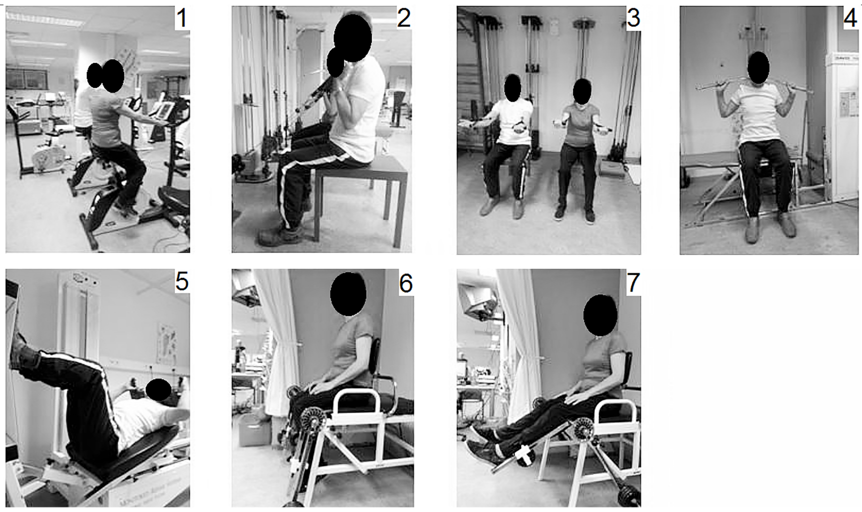

Fig. 1. Exercise program in HIT group: 1) high intensity interval cardio, 2) biceps curl, 3) chest press, 4) vertical traction, 5) leg press, 6) leg extension, 7) leg curl.

stabilizing of the trunk region (i.e. unstable posture corrections, plank and bridge variations [30]). Progression of the exercise therapy was determined individually based on patient improvement. *HIT training* consisted of individualized sessions, supervised by the investigators. HIT training consisted of HIT interval cardio training on a cycle ergometer based on a protocol by Wens et al. [20] and high load whole body resistance training. Special attention was paid to good postural control of the lower back during the whole training protocol. After a five minute cycle ergometer warm up HIT interval cardiovascular training started comprising five one minute bouts at maximal effort (bicycle resistance was set at VO_{2max} workload), separated by one minute of rest. High intensity cycling bouts weekly increased by 10 seconds up to one minute and 50 seconds in week six. Recovery time (one minute) between bouts remained stable. High load resistance training consisted of three upper body and three lower body exercises (Fig. 1). All exercises were executed without back support and with an active upright posture, to stimulate core muscle activation during extremity training. Before starting high load resistance training, a one repetition maximum (1RM) testing was performed for every exercise. The amount of weight used in the exercises was adjusted to 80% 1RM, as this is stated as the optimal load for muscular hypertrophy [31]. Participants started the training program by executing each resistance exercise once. After three habituation sessions the participants progressed to doing each resistance exercise twice. Participants were instructed to aim at 8–12 repetitions for each exercise. Researchers decreased the weight when the patient wasn't able to perform 8 repetitions and increased the exercise weight when the patient was able to perform 12 repetitions with correct form in two consecutive sessions. At the end of every therapy session BORG scales to evaluate training burden were filled in and number of weeks completed ($\geqslant$ 1 session/week), number of sessions completed, and absence due to low back pain or therapy independent reasons were registered to assess therapy adherence. Following 6 weeks of CON or HIT exercise therapy, POST measurements (with addition of assessment of the Intrinsic Motivation Inventory [32]) were performed similar to PRE.

2.3. Measurements

2.3.1. Feasibility measures

Motivation for rehabilitation and satisfaction with rehabilitation was assessed by the Motivation Visual Analog Scale (MVAS) and Satisfaction Visual Analog Scale (SVAS). These nominal scales consist of a line indicating eleven successive scores (0–10), whereby zero means 'no motivation/satisfaction' and ten means 'very high motivation/satisfaction'.

Intrinsic motivation was assessed by the Intrinsic motivation inventory (IMI) [32]. This is a nominal 35 item questionnaire that assesses the multidimensional subjective experience while performing a certain activity yielding six subscales (interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, and perceived choice), with the possibility of independent scoring for each scale and a general scoring. A higher score correlates to higher intrinsic motivation (total range 35–245).

Therapy adherence. Therapy adherence was evaluated by counting the amount of completed therapy sessions within the six week protocol. Non-therapy related disease or work-related absence was not seen as non-adherence as long as another session was planned to compensate for this within the six week span of the study.

2.3.2. Exercise capacity and body composition measures

Exercise capacity. Exercise capacity was evaluated by a continuous graded maximal cycle test (70 rpm) to volitional fatigue on an electronically braked cycle ergometer (eBike Basic, General Electric GmbH, Bitz, Germany) to evaluate maximal workload (W_{max}), and time to exhaustion (TTE). Participants started at a low workload that gradually increases after each completed minute (♂: 30 W + 15 W/min, ♀: 20 W + 10 W/min). Maximal oxygen uptake (VO_{2max}), expiratory volume (VE), and respiratory exchange ratio (RER) and heart rate were determined through breath-by-breath gas exchange analysis [33] (Jaeger Oxycon®, Erich Jaeger GmbH, Germany) and heartrate monitoring (Polar®, Finland).

Body composition. Body weight was obtained through a standardised one decimal electronic scale. Length was obtained through a standardised wall ruler. Body Mass Index (BMI) was calculated on the basis of the previous measures. Lean tissue mass (LTM) and body fat were obtained using Dual Energy X-ray Absorptiometry [34] (DEXA, GE, Hologic Series Delphi-A, USA).

2.3.3. Condition related measures

Pain intensity was assessed by the Numeric Pain Rating Scale (NPRS) [28]. This is a nominal scale indicating the amount of pain at a certain moment. It consists of a line indicating eleven successive scores (0–10), whereby zero means ‘no pain’ and ten means ‘worst pain imaginable’.

Functional disability. The Roland Morris Disability Questionnaire (RMDQ) [35] is an ordinal 24 item questionnaire for evaluating the disability level of a person with low back pain with regards to activities of daily living. A higher score (range 0–24) correlates to a higher level of disability.

Subjective activity level was assessed by the Physical Activities Scale for Individuals with Physical Disabilities (PASIPD) [2,36]. This is a nominal 12 item questionnaire that gives information about leisure, household and work related physical activity over the preceding 7 days. Respondents are asked to report the number of days and average hours in a day spent engaging in activities. The metabolic equivalent (MET) * hours/week can be calculated. Scores range from zero (no activity) to over 100 METh/week (very high).

Objective activity level was evaluated by using three accelerometers (Actigraph GT3X+) worn at the left and right wrist, and at the hip. This allowed for differentiation of meaningful upper limb activities (movement of upper extremities without hip involvement) and walking activities (simultaneous upper extremity and hip movement), as it was hypothesized that this can provide more sensitive data to evaluate and differentiate changes in activity level. Assessment consisted of continuous recording over three consecutive days [37], including minimally two weekdays. Only daytime activity (waking hours) was recorded. Patients were instructed to take off the accelerometers during the nightly sleeping hours. Sample frequency of the GT3X+ was 30 Hz, epoch time was 1 second. Specific characteristics of the Actigraph GT3X+ algorithm are presented elsewhere [38]. Total activity time (in seconds), total activity power (in Activity counts [39]), and total time active (in % of three days) were calculated from raw accelerometer data (MathWorks Matlab coding) for upper and lower extremity activity analysis.

Pain-related fear of movement was assessed by the Tampa Scale for Kinesiophobia (TSK) [40]. This is an ordinal 17 item questionnaire that measures pain-related fear of movement for persons with musculoskeletal pain. A higher score relates to more pain-related fear (total range 17–68).

Quality of life was assessed by the Short Form Health Survey (SF-36) [41]. This is an ordinal 36 item questionnaire to evaluate health related quality of life. It consists of eight subscales (vitality, physical functioning, bodily pain, general health perceptions, physical role functioning, emotional role functioning, social role functioning, and mental health) with independent scorings. A higher score (range 0–100) correlates with positive health.

2.4. Statistical analysis

To analyse data, nonparametric statistics (JMP Pro 12.0, SAS Institute Inc, Cary, USA) were used. Between group differences at baseline were analysed using Mann-Whitney U test and PRE-POST test com-

Table 1
Participant characteristics

	CON ($n = 10$)	HIT ($n = 10$)
Age (years)	46.5 (35.5–48.8)	38.5 (31.8–47.0)
Gender (% male)	20	70†
BMI	24.2 (22.4–27.3)	26.3 (23.3–28.3)
Work status (% yes)	70	78
Time onset (years)	9.3 (2.0–16.0)	4.0 (1.0–2.0)
Smoking (% yes)	11	11
Medication (% yes)	67	44

Values are reported as median (interquartile range). $^{\dagger}p < 0.05$ compared to CON.

parison was performed using Wilcoxon signed ranks test. The threshold for statistical significance was set at 0.05.

3. Results

3.1. Subject characteristics

With regard to subject characteristics at baseline (Table 1), none differed significantly between groups, except gender ratio.

3.2. Measurements

With regard to outcome measurements at baseline (Tables 2–5), none differed significantly between groups, except lean mass.

3.2.1. Feasibility measures (Table 2)

Motivation for rehabilitation and satisfaction with rehabilitation. Compared to PRE, no differences in motivation were seen within groups. However, compared to CON, HIT retained motivation better (HIT: +3%; CON: −25%).

Therapy adherence, drop out and adverse events. Compared to CON, therapy adherence was higher in HIT (+16%). A drop out of two particpants was noted (both CON subjects). They dropped out for reasons not related to the study. No adverse events were noted in both groups during the training sessions or testing protocols.

Intrinsic motivation. Intrinsic motivation was only measured at POST. HIT showed comparable values to CON in all of the subscales, and with regard to intrinsic motivation as a whole, after 6 weeks of therapy.

3.2.2. Exercise capacity and body composition measures (Table 3)

Exercise capacity. Compared to CON, HIT did not improve patients' exercise capacity more. However, compared to PRE, HIT improved W_{max} (+7.0%) and TTE (+9.5%) whereas these outcomes remained stable in CON (Wmax: +4.9%; TTE: +3.6%). Neither Con nor HIT affected VO_{2max}.

Body composition. Compared to CON, HIT did not improve lean body mass. Compared to PRE, lean body mass did not improve for any of the groups (HIT: +1.25%; CON: +2.4%).

3.2.3. Disease related measures (Tables 4 and 5)

Pain intensity. Compared to CON, HIT did not decrease pain intensity. Moreover, compared to PRE, pain intensity did not change in both groups (HIT: −15.5%; CON: −5.0%).

Functional disability. Compared to CON, HIT did not decrease functional disability. Compared to PRE, functional disability decreased in both groups (HIT: −10.4%; CON: −8.3%).

Subjectively measured activity level. Compared to CON, HIT did not improve subjective activity level. However, compared to PRE, HIT improved subjectively measured activity level (HIT: +5.6%) and remained stable in the control group (CON: +4.0%).

Objectively measured activity level. Compared to CON, HIT did not improve total activity time, total activity power or total time active in wrist or hip movement. Compared to PRE, total activity time, total activity power or total time active in wrist or hip movement did not improve for any of the groups.

Pain related fear of movement. Compared to CON, HIT did not improve pain related fear of movement. Moreover, compared to PRE, pain related fear of movement did not decrease in both groups.

Quality of life. Compared to CON, HIT did not improve quality of life; However, compared to PRE, HIT improved four subscales of the SF-36: role limitations physical, role limitations emotional, social functioning and pain. CON remained stable.

4. Discussion

The first aim of this study was to evaluate the feasibility of a high intensity training (HIT) program for the rehabilitation of persons with nonspecific chronic low back pain (NSCLBP). Firstly, motivation to rehabilitate was assessed because keeping motivation high is important to ensure therapy success [42,43]. Although motivation was high at the start for both groups, it dropped in the conventional therapy group (CON) during the study course, while it remained high in

Table 2
Feasibility related outcomes

	CON ($n = 8$)			HIT ($n = 10$)		
	PRE	POST	Δ	PRE	POST	Δ
MVAS (0–10)	8.0 (8.0–9.5)	8.0 (6.0–9.0)	−2 (−3.5;−0.5)	9.5 (8.0–10.0)	10.0 (8.5–10.0)†	0 (0;1)
SVAS (0–10)	–	8.0 (7.0–9.0)	–	–	9.0 (8.0–9.5)	–
Therapy adherence (0–12)	–	10.0 (8.0–11.0)	–	–	12.0 (10.5–12.0)†	–
IMI (35–245)	–	181.5 (167–187.8)	–	–	186.5 (163.8–195.5)	–
Interest/enjoyment (1–7)	–	6.1 (5.1–6.5)	–	–	5.9 (5.1–6.3)	–
Perceived competence (1–6)	–	5.1 (4.8–5.8)	–	–	5.0 (4.0–5.5)	–
Effort/importance (1–5)	–	6.6 (6.3–7.0)	–	–	6.2 (5.6–6.6)	–
Pressure/tension (1–5)	–	2.0 (1.2–2.3)	–	–	2.1 (1.4–3.4)	–
Value/usefulness (1–7)	–	6.4 (5.1–7.0)	–	–	5.9 (5.8–6.2)	–
Relatedness (1–5)	–	5.1 (4.3–5.8)	–	–	5.1 (4.3–5.4)	–

Values are reported as median (interquartile range) and represent the Motivation Visual Analogue Scale (MVAS), Satisfaction Visual Analogue Scale (SVAS), and Intrinsic Motivation Inventory (IMI) scores before (PRE) and after (POST) 6 weeks of conventional exercise therapy (CON, 50–60% VO_{2max} cardio training + moderate intensity stabilization exercises) or high intensity exercise therapy (HIT, > 80% 1RM resistance training + 100% VO_{2max} interval cardio training). Δ: median difference. $^{*}p < 0.05$ compared to PRE. $^{\dagger}p < 0.05$ compared to CON.

Table 3
Exercise capacity and body composition outcomes

	CON ($n = 8$)			HIT ($n = 10$)		
	PRE	POST	Δ	PRE	POST	Δ
W_{Max} (Watt/kgBW)	2.1 (1.8;3.0)	2.3 (1.7;3.3)	0.2 (0.1;0.3)	2.7 (2.0;3.1)	2.8 (2.1;3.3)*	0.2 (0;0.3)
TTE (s)	686 (618;1005)	713 (626;1036)	27 (−7;80)	822 (682;995)	922 (677;1014)*	70.5 (1.8;115)
VO_{2max} (l/kg/min)	26.4 (22.9;40.1)	29.2 (22.5;40.2)	−0.8 (−4.0;4.6)	34.9 (24.7;37.9)	36.1 (25.1;40.4)	0.9 (−0.4;2.2)
Lean mass (kg)	41.4 (40.0;46.2)	41.7 (40.0;47.4)	1.07 (0.10;2.40)	55.9 (48.5;68.6)†	56.2 (50.2;70.5)*	0.61 (−0.56;1.87)

Values are reported as median (interquartile range) and represent maximal cycling resistance (W_{max}), time to exhaustion (TTE), maximal oxygen uptake (VO_{2max}) and lean mass, before (PRE) and after (POST) 6 weeks of conventional exercise therapy (CON, 50–60% VO_{2max} cardio training + moderate intensity stabilization exercises) or high intensity exercise therapy (HIT, HIT, > 80% 1RM resistance training + 100% VO_{2max} interval cardio training). Abbreviations: BW: body weight. Δ: median difference. $^{*}p < 0.05$ compared to PRE. $^{\dagger}p < 0.05$ compared to CON.

Table 4
Disease related outcomes

	CON ($n = 8$)			HIT ($n = 10$)		
	PRE	POST	Δ	PRE	POST	Δ
RMDQ (0–24)	11.5 (5.8;16.5)	7.0 (3.5;13.8)*	−3 (−3;1.8)	8.5 (6.3;11.3)	5.5 (2.8;9.3)*	−1 (−5;0)
NPRS (0–10)	7.0 (2.8;8.8)	6.0 (4.0;7.0)	−1 (−2.8;1)	6.5 (4.5;7.0)	3.0 (1.8;7.0)	−1 (−4.5;0.8)
PASIPD (MET)	13.9 (4.2;17.7)	20.3 (11.9;24.1)	5.9 (2.1;14.9)	7.5 (5.4;21.6)	20.2 (12.2;28.9)*	6.9 (2.1;13.4)
TSK (17–68) SF36	40.0 (36.5;44.0)	36.0 (31.8;40.5)	−2 (−10.8;1.8)	42.0 (38.0;44.0)	35.0 (27.5;42.5)	−4 (−7.5;1)
Physical function	55.0 (33.8;77.5)	42.5 (31.3;93.8)	−5 (−7.5;11.3)	73.6 (39.4;81.3)	85.0 (43.8;91.3)	7.5 (−3.1;11.3)
Role limitations (P)	25.0 (0.0;100.0)	12.5 (0.0;100.0)	0 (−37.5;62.5)	25.0 (0.0;54.2)	50.0 (25.0;100.0)*	25 (−8.3;87.5)
Role limitations (E)	66.6 (0.0;100.0)	83.4 (0.0;100.0)	0 (−33.3;25)	50.0 (0.0;100.0)	100.0 (83.4;100.0)*	33.3 (0;66.7)
Energy	45.0 (37.8;56.3)	57.5 (46.3;65.0)	7.5 (0;20.4)	45.0 (32.5;55.0)	52.5 (33.8;75.0)	2.5 (−5;20.4)
Emotional wellbeing	58.0 (47.0;74.0)	70.0 (61.0;79.0)	4 (−2;29)	64.0 (55.0;72.0)	72.0 (55.8;84.0)	10 (−8.3;19)
Social functioning	50.0 (50.0;90.6)	75.0 (56.3;84.4)	0 (−12.5;28.1)	62.5 (59.4;87.5)	87.5 (81.3;100.0)*	18.8 (0;30)
Pain	40.0 (24.4;67.5)	45.0 (37.5;55.0)	5 (−8.1;13.1)	46.3 (34.4;55.6)	68.8 (45.0;82.5)*	17.5 (−2.5;36.9)
General health	47.5 (42.5;82.5)	62.5 (47.5;73.8)	7.5 (−7.5;16.3)	62.5 (48.8;75.0)	67.5 (57.5;75.0)	0 (−5;16.3)

Values are reported as median (interquartile range) and represent Roland-Morris Disability Questionnaire (RMDQ), Numeric Pain Rating Scale (NPRS), Physical Activity Scale for Individuals with Physical Disabilities (PASIPD), and Tampa Scale of Kinesiophobia (TSK) before (PRE) and after (POST) 6 weeks of conventional exercise therapy (CON, 50–60% VO_{2max} cardio training + moderate intensity stabilization exercises) or high intensity exercise therapy (HIT, HIT, > 80% 1RM resistance training + 100% VO_{2max} interval cardio training). Δ: median difference. $^{*}p < 0.05$ compared to PRE. $^{\dagger}p < 0.05$ compared to CON.

the high intensity training (HIT) group. Apparently, even though participants in HIT were urged to train at intensities that they perceived as relatively to very demanding (average Borg Intensity Score of 13/20) and which to them could be experienced as a burden, this did not affect the motivation to rehabilitate. These results support the outcomes of Thum et al. [44] and Jung et al. [45] stating that patients prefer to engage in high intensity interval training and that this elicits higher enjoyment than high intensity continu-

Table 5
Objectively measured activity level

	PRE			POST			Δ		
	L	R	H	L	R	H	L	R	H
CON ($n = 10$)									
Total activity time (h)	19.7	20.5	12.5	20.9	21.4	11.2	0.14	0.25	−0.37
Total activity power (Ac)	11.1×10^6	13.7×10^6	2.8×10^6	10.4×10^6	11.1×10^6	2.5×10^6	3.7×10^5	5.2×10^5	0.78×10^5
Total time active (%)	27.5	28.5	17.4	27.2	27.1	13.7	0.20	0.35	−0.51
HIT (n =8)									
Total activity time (h)	20.7	21.6	10.8	20.6	21.0	11.2	0.18	0.01	0.69
Total activity power (Ac)	10.2×10^6	11.4×10^6	2.5×10^6	11.7×10^6	12.1×10^6	32.8×10^6	12.5×10^5	7.4×10^5	2.9×10^5
Total time active (%)	28.7	30.0	15.0	28.9	30.8	14.2	−0.25	0.01	0.96

Values are reported as median and represent accelerometer data before (PRE) and after (POST) 6 weeks of conventional exercise therapy (CON, 50–60% VO_{2max} cardio training + moderate intensity stabilization exercises) or high intensity exercise therapy (HIT, HIT, > 80% 1RM resistance training + 100% VO_{2max} interval cardio training). Abbreviations: L: left wrist; R: right; wrist H: hip; h: hours; Ac: Activity counts. $^*p < 0.05$ compared to PRE. $^\dagger p < 0.05$ compared to HIT.

ous exercise or moderate intensity continuous exercise. Secondly, therapy adherence was higher in HIT. This is in line with other literature stating that patients adhere better to therapy when motivational interventions are carried out [42,46] while non-adherence in its turn has been noted to negatively influence therapy effectiveness [47]. HIT may also have induced more self-confidence in performing (heavy) daily activities, consequently improving self-efficacy which has been linked to motivation [48] and adherence [49]. Thirdly, therapy satisfaction remained high in HIT after completing the program and no study related drop outs or adverse events were registered. The combination of these results lead the authors to conclude that this HIT program was feasible for the rehabilitation of persons with NSCLBP.

The second aim of this study was to investigate the magnitude of the effects of a HIT program on exercise capacity and disease related outcomes in comparison to a conventional exercise therapy program in persons with NSCLBP. It was hypothesized that HIT improves exercise capacity more than conventional exercise therapy. Consequently, improvements in exercise capacity can affect the disabling character of chronic low back pain [50,51]. Aerobic training at high intensity has been studied in persons with low back pain and has shown to reduce pain, and decrease physical disability and psychological distress [27,52]. However, the intervention differed from the current study as it did not use an *interval* cardio protocol. Interval cardio training showed promising results in improving cardiovascular function in other pathological populations [17,53] and can be used very time-efficiently [54], thus possibly decreasing therapy duration. Average VO_{2max} of the included participants was lower than seen in healthy persons of a comparable age and gender [55] which matches statements from previous research [12]. Contrary to our expectations though, after 6 weeks of training no improvement of maximal oxygen uptake was seen in either CON or HIT. Nonetheless, maximal resistance, time to exhaustion and lean mass did improve in HIT, whereas they did not in CON. Because the high intensity interval cardio protocol only had a duration of ± 15 minutes in comparison with the CON cardio program that lasted ± 45 minutes, it can be stated that the results of high intensity interval cardio are at least comparable with conventional cardio training while being much more time-efficient. When looking at the disease related outcomes, disability decreased and subjective activity level increased in HIT, while these stayed stable in CON. In other studies using accelerometry to measure objective active movement, no changes in activity levels were found and it is argued whether accelerometry is a sensitive enough measure to capture changes over time [56]. This study used an adapted protocol with a combination of three accelerometers, to increase sensitivity and make a differentiation between isolated arm (meaningful upper limb activities) and simultaneous arm and hip movement (walking activities). However, a difference in activity level between groups could not be confirmed by the results of the objective activity levels, as no differences were seen in either outcome. More differentiation in exercise capacity and disease related outcomes may be expected in a 12 week protocol. Moreover, pain intensity and kinesiophobia already showed a clear trend towards positive effects. Secondly, it was hypothesized that HIT improves muscle strength and body composition. Positive results on muscle strength in persons with low back pain have been shown previously by using high intensity isolated erector spinae training [25,57] or generalized resistance training [58]. Aside from increases in muscle strength, training in these studies also led to improvements on pain and disability. To target muscle hypertrophy, specific high load resistance exercises with an active trunk posture were used in the present study. This type of exercising has never been executed at high intensity in low back pain. The authors hypothesize that these exercises simultaneously challenged the extremities and trunk muscles, stimulating enhanced neuromuscular firing in both regions. However, Lean mass did not increase over time in HIT nor CON and no differences were seen between groups. It was hypothesized that a Borg score of 15 to 16 rightly corresponded with a high intensity training protocol (80% of 1RM). Nevertheless, defining the effective intensity of each active muscle group during the exercises was outside the scope of this study. Because the protocol consisted of exercises that where set up to train both the trunk and extremities at the same time, lacking of muscular strength in one of these areas could be seen as a limiting factor for the other area. Also, participants needed a sufficient amount of motor control in the trunk region to keep the correct posture during the high load exercises. Using exercises that only train one of these areas could provide more knowledge on the added value of extremity or core muscle strength training at high intensity. In this pilot study no specific assessment of muscular strength was executed. Future research should try to incorporate standardized strength testing such as isometric or isokinetic strength measurement to investigate the isolated muscular effects of this training, preferably on both back and extremity muscles. Furthermore, the specific contribution of the cardio training on the one side and of the resistance training protocol on the other side can be further investigated. In addition, it would be interesting to look at microscopic structural changes in low back muscle characteristics when following a HIT program to determine whether the use rehabilitation protocols show an actual effect at muscle fibre level. However, none of these methodologies were within the scope of the present study.

4.1. Limitations

Although positive trends in outcomes were noted, some limitations should be taken into account. Firstly, data of two drop outs in CON were not available for data analysis. This meant loss of data in CON which may have affected outcomes. Secondly, the lack of patient randomization could have created a selection bias. However, motivation at the start of the study did not differ between groups which lead the authors to conclude that this factor had limited effects on study results. Thirdly, as the influence of supervision during rehabilitation can affect therapy outcomes [59], the same amount of supervision was given in each group, thus minimizing supervision and performance bias. Furthermore, each patient in HIT received supervision from a variety of researchers to mimic the method used in CON at the Jessa Hospital (training without a preassigned therapist). However, it is still possible that the non-blinding of researchers in this study (who helped during rehabilitation) had an effect on HIT results, and therefore on the contrast between HIT and CON. Fourthly, as no analysis was made to objectively evaluate the amount of core muscle activity (e.g. m. transversus abdominus, m. multifidus) during the exercises, this study cannot state with certainty that this muscle group was loaded at a high intensity. Future research should evaluate muscle activation (e.g. EMG analysis) of trunk muscles for each exercise to ensure correct display of exercise intensity. Fifthly, because patients in CON followed a personalized exercise program, exercise variety and training volume differed slightly across individuals. However, the total duration of every program was comparable between groups and intensity and content of every session were comparable within groups. Lastly, the difference in therapy adherence between HIT and CON, could have affected exercise capacity at POST because of differences in total training volume.

5. Conclusion

Under the conditions of the present study, a rehabilitation program consisting of a short term high intensity interval cardio training and high load resistance trainings seems feasible in NSCLBP and may improve physical activity in daily life, exercise capacity and disability, when compared to conventional exercise therapy. Large scale studies are warranted to corroborate these results.

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Conflict of interest

None to report.

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