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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 Activity 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%  $HR_{max}$ , ~ 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

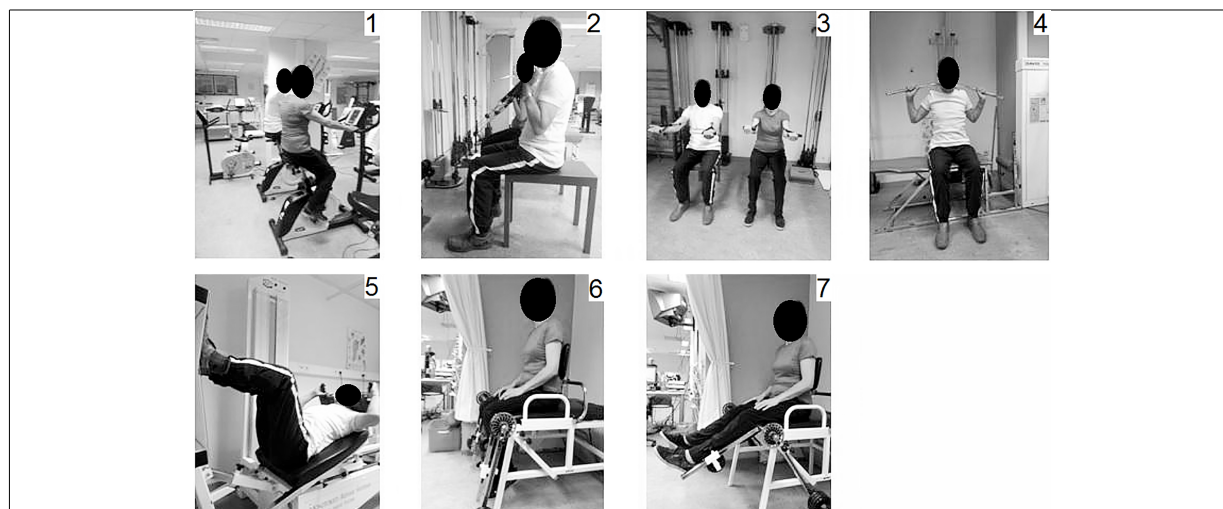


Fig. 1. Exercise program in HIT group: 1) high intensity interval cardio, 2) biceps curl, 3) chest press, 4) vertical traction, 5) leg press, 6) leg extension, 7) leg curl.

112 stabilizing of the trunk region (i.e. unstable posture  
113 corrections, plank and bridge variations [30]). Progression of the exercise therapy was determined individu-  
114 ally based on patient improvement. *HIT training* consisted of individualized sessions, supervised by the in-  
115 vestigators. HIT training consisted of HIT interval cardio training on a cycle ergometer based on a protocol  
116 by Wens et al. [20] and high load whole body resistance training. Special attention was paid to good postu-  
117 ral control of the lower back during the whole training protocol. After a five minute cycle ergometer warm  
118 up HIT interval cardiovascular training started comprising five one minute bouts at maximal effort (bicy-  
119 cle resistance was set at  $VO_{2max}$  workload), separated  
120 by one minute of rest. High intensity cycling bouts  
121 weekly increased by 10 seconds up to one minute and  
122 50 seconds in week six. Recovery time (one minute)  
123 between bouts remained stable. High load resistance  
124 training consisted of three upper body and three lower  
125 body exercises (Fig. 1). All exercises were executed  
126 without back support and with an active upright pos-  
127 ture, to stimulate core muscle activation during ex-  
128 tremity training. Before starting high load resistance  
129 training, a one repetition maximum (1RM) testing was  
130 performed for every exercise. The amount of weight  
131 used in the exercises was adjusted to 80% 1RM, as  
132 this is stated as the optimal load for muscular hyper-  
133 trophy [31]. Participants started the training program  
134 by executing each resistance exercise once. After three  
135 habituation sessions the participants progressed to do-  
136 ing each resistance exercise twice. Participants were  
137 instructed to aim at 8–12 repetitions for each exer-

144 cise. Researchers decreased the weight when the pa-  
145 tient wasn't able to perform 8 repetitions and increased  
146 the exercise weight when the patient was able to per-  
147 form 12 repetitions with correct form in two consec-  
148 utive sessions. At the end of every therapy session  
149 BORG scales to evaluate training burden were filled in  
150 and number of weeks completed ( $\geq 1$  session/week),  
151 number of sessions completed, and absence due to low  
152 back pain or therapy independent reasons were regis-  
153 tered to assess therapy adherence. Following 6 weeks  
154 of CON or HIT exercise therapy, POST measurements  
155 (with addition of assessment of the Intrinsic Motiva-  
156 tion Inventory [32]) were performed similar to PRE.

### 2.3. Measurements

#### 2.3.1. Feasibility measures

158 *Motivation for rehabilitation and satisfaction with*  
159 *rehabilitation* was assessed by the Motivation Visual  
160 Analog Scale (MVAS) and Satisfaction Visual Analog  
161 Scale (SVAS). These nominal scales consist of a line  
162 indicating eleven successive scores (0–10), whereby  
163 zero means 'no motivation/satisfaction' and ten means  
164 'very high motivation/satisfaction'.  
165

166 *Intrinsic motivation* was assessed by the Intrinsic  
167 motivation inventory (IMI) [32]. This is a nominal 35  
168 item questionnaire that assesses the multidimensional  
169 subjective experience while performing a certain ac-  
170 tivity yielding six subscales (interest/enjoyment, per-  
171 ceived competence, effort, value/usefulness, felt pres-  
172 sure and tension, and perceived choice), with the possi-  
173 bility of independent scoring for each scale and a gen-

174 eral scoring. A higher score correlates to higher intrinsic  
175 motivation (total range 35–245).

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

### 183 2.3.2. Exercise capacity and body composition 184 measures

185 *Exercise capacity.* Exercise capacity was evaluated  
186 by a continuous graded maximal cycle test (70 rpm)  
187 to volitional fatigue on an electronically braked cycle  
188 ergometer (eBike Basic, General Electric GmbH, Bitz,  
189 Germany) to evaluate maximal workload ( $W_{\max}$ ), and  
190 time to exhaustion (TTE). Participants started at a low  
191 workload that gradually increases after each completed  
192 minute ( $\sigma$ : 30 W + 15 W/min,  $\varphi$ : 20 W + 10 W/min).  
193 Maximal oxygen uptake ( $VO_{2\max}$ ), expiratory volume  
194 (VE), and respiratory exchange ratio (RER) and heart  
195 rate were determined through breath-by-breath gas ex-  
196 change analysis [33] (Jaeger Oxycon<sup>®</sup>, Erich Jaeger  
197 GmbH, Germany) and heartrate monitoring (Polar<sup>®</sup>,  
198 Finland).

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

### 207 2.3.3. Condition related measures

208 *Pain intensity* was assessed by the Numeric Pain  
209 Rating Scale (NPRS) [28]. This is a nominal scale in-  
210 dicating the amount of pain at a certain moment. It  
211 consists of a line indicating eleven successive scores  
212 (0–10), whereby zero means ‘no pain’ and ten means  
213 ‘worst pain imaginable’.

214 *Functional disability.* The Roland Morris Disabil-  
215 ity Questionnaire (RMDQ) [35] is an ordinal 24 item  
216 questionnaire for evaluating the disability level of a  
217 person with low back pain with regards to activities of  
218 daily living. A higher score (range 0–24) correlates to  
219 a higher level of disability.

220 *Subjective activity level* was assessed by the Phys-  
221 ical Activities Scale for Individuals with Physical  
222 Disabilities (PASIPD) [2,36]. This is a nominal 12

223 item questionnaire that gives information about leisure,  
224 household and work related physical activity over the  
225 preceding 7 days. Respondents are asked to report the  
226 number of days and average hours in a day spent en-  
227 gaging in activities. The metabolic equivalent (MET) \*  
228 hours/week can be calculated. Scores range from zero  
229 (no activity) to over 100 METh/week (very high).

230 *Objective activity level* was evaluated by using three  
231 accelerometers (Actigraph GT3X+) worn at the left  
232 and right wrist, and at the hip. This allowed for differ-  
233 entiation of meaningful upper limb activities (move-  
234 ment of upper extremities without hip involvement)  
235 and walking activities (simultaneous upper extremity  
236 and hip movement), as it was hypothesized that this  
237 can provide more sensitive data to evaluate and dif-  
238 ferentiate changes in activity level. Assessment con-  
239 sisted of continuous recording over three consecutive  
240 days [37], including minimally two weekdays. Only  
241 daytime activity (waking hours) was recorded. Patients  
242 were instructed to take off the accelerometers during  
243 the nightly sleeping hours. Sample frequency of the  
244 GT3X+ was 30 Hz, epoch time was 1 second. Specific  
245 characteristics of the Actigraph GT3X+ algorithm are  
246 presented elsewhere [38]. Total activity time (in sec-  
247 onds), total activity power (in Activity counts [39]),  
248 and total time active (in % of three days) were calcu-  
249 lated from raw accelerometer data (MathWorks Matlab  
250 coding) for upper and lower extremity activity analy-  
251 sis.

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

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

## 267 2.4. Statistical analysis

268 To analyse data, nonparametric statistics (JMP Pro  
269 12.0, SAS Institute Inc, Cary, USA) were used. Be-  
270 tween group differences at baseline were analysed us-  
271 ing 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 <sup>†</sup>
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). <sup>†</sup>*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 participants 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 ( $W_{max}$ : +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

	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) <sup>†</sup>	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) <sup>†</sup>	-
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<sub>2max</sub> cardio training + moderate intensity stabilization exercises) or high intensity exercise therapy (HIT, > 80% 1RM resistance training + 100% VO<sub>2max</sub> interval cardio training). Δ: median difference. \**p* < 0.05 compared to PRE. <sup>†</sup>*p* < 0.05 compared to CON.

	CON (n = 8)			HIT (n = 10)		
	PRE	POST	Δ	PRE	POST	Δ
W <sub>Max</sub> (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 <sub>2max</sub> (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) <sup>†</sup>	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<sub>max</sub>), time to exhaustion (TTE), maximal oxygen uptake (VO<sub>2max</sub>) and lean mass, before (PRE) and after (POST) 6 weeks of conventional exercise therapy (CON, 50–60% VO<sub>2max</sub> cardio training + moderate intensity stabilization exercises) or high intensity exercise therapy (HIT, HIT, > 80% 1RM resistance training + 100% VO<sub>2max</sub> interval cardio training). Abbreviations: BW: body weight. Δ: median difference. \**p* < 0.05 compared to PRE. <sup>†</sup>*p* < 0.05 compared to CON.

	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<sub>2max</sub> cardio training + moderate intensity stabilization exercises) or high intensity exercise therapy (HIT, HIT, > 80% 1RM resistance training + 100% VO<sub>2max</sub> interval cardio training). Δ: median difference. \**p* < 0.05 compared to PRE. <sup>†</sup>*p* < 0.05 compared to CON.

352 the high intensity training (HIT) group. Apparently,  
353 even though participants in HIT were urged to train  
354 at intensities that they perceived as relatively to very  
355 demanding (average Borg Intensity Score of 13/20)  
356 and which to them could be experienced as a bur-

den, 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 en-  
gage in high intensity interval training and that this  
elicits higher enjoyment than high intensity continu-

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	PRE			POST			$\Delta$		
	L	R	H	L	R	H	L	R	H
CON ( <i>n</i> = 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)	$11.1 \times 10^6$	$13.7 \times 10^6$	$2.8 \times 10^6$	$10.4 \times 10^6$	$11.1 \times 10^6$	$2.5 \times 10^6$	$3.7 \times 10^5$	$5.2 \times 10^5$	$0.78 \times 10^5$
Total time active (%)	27.5	28.5	17.4	27.2	27.1	13.7	0.20	0.35	-0.51
HIT ( <i>n</i> = 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)	$10.2 \times 10^6$	$11.4 \times 10^6$	$2.5 \times 10^6$	$11.7 \times 10^6$	$12.1 \times 10^6$	$32.8 \times 10^6$	$12.5 \times 10^5$	$7.4 \times 10^5$	$2.9 \times 10^5$
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. † $p < 0.05$  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]. Con-

trary 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  $\pm 15$  minutes in comparison with the CON cardio program that lasted  $\pm 45$  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 hy-



436 pertrophy, specific high load resistance exercises with  
437 an active trunk posture were used in the present study.  
438 This type of exercising has never been executed at  
439 high intensity in low back pain. The authors hypothe-  
440 size that these exercises simultaneously challenged the  
441 extremities and trunk muscles, stimulating enhanced  
442 neuromuscular firing in both regions. However, Lean  
443 mass did not increase over time in HIT nor CON and  
444 no differences were seen between groups. It was hy-  
445 pothesized that a Borg score of 15 to 16 rightly corre-  
446 sponded with a high intensity training protocol (80%  
447 of 1RM). Nevertheless, defining the effective intensity  
448 of each active muscle group during the exercises was  
449 outside the scope of this study. Because the protocol  
450 consisted of exercises that where set up to train both  
451 the trunk and extremities at the same time, lacking of  
452 muscular strength in one of these areas could be seen  
453 as a limiting factor for the other area. Also, partici-  
454 pants needed a sufficient amount of motor control in  
455 the trunk region to keep the correct posture during the  
456 high load exercises. Using exercises that only train one  
457 of these areas could provide more knowledge on the  
458 added value of extremity or core muscle strength train-  
459 ing at high intensity. In this pilot study no specific as-  
460 sessment of muscular strength was executed. Future re-  
461 search should try to incorporate standardized strength  
462 testing such as isometric or isokinetic strength mea-  
463 surement to investigate the isolated muscular effects  
464 of this training, preferably on both back and extrem-  
465 ity muscles. Furthermore, the specific contribution of  
466 the cardio training on the one side and of the resistance  
467 training protocol on the other side can be further in-  
468 vestigated. In addition, it would be interesting to look  
469 at microscopic structural changes in low back muscle  
470 characteristics when following a HIT program to de-  
471 termine whether the use rehabilitation protocols show  
472 an actual effect at muscle fibre level. However, none  
473 of these methodologies were within the scope of the  
474 present study.

#### 475 4.1. Limitations

476 Although positive trends in outcomes were noted,  
477 some limitations should be taken into account. Firstly,  
478 data of two drop outs in CON were not available for  
479 data analysis. This meant loss of data in CON which  
480 may have affected outcomes. Secondly, the lack of  
481 patient randomization could have created a selection  
482 bias. However, motivation at the start of the study did  
483 not differ between groups which lead the authors to  
484 conclude that this factor had limited effects on study

485 results. Thirdly, as the influence of supervision dur-  
486 ing rehabilitation can affect therapy outcomes [59],  
487 the same amount of supervision was given in each  
488 group, thus minimizing supervision and performance  
489 bias. Furthermore, each patient in HIT received su-  
490 pervision from a variety of researchers to mimic the  
491 method used in CON at the Jessa Hospital (training  
492 without a preassigned therapist). However, it is still  
493 possible that the non-blinding of researchers in this  
494 study (who helped during rehabilitation) had an effect  
495 on HIT results, and therefore on the contrast between  
496 HIT and CON. Fourthly, as no analysis was made to  
497 objectively evaluate the amount of core muscle activity  
498 (e.g. m. transversus abdominus, m. multifidus) during  
499 the exercises, this study cannot state with certainty that  
500 this muscle group was loaded at a high intensity. Future  
501 research should evaluate muscle activation (e.g. EMG  
502 analysis) of trunk muscles for each exercise to ensure  
503 correct display of exercise intensity. Fifthly, because  
504 patients in CON followed a personalized exercise pro-  
505 gram, exercise variety and training volume differed  
506 slightly across individuals. However, the total duration  
507 of every program was comparable between groups and  
508 intensity and content of every session were comparable  
509 within groups. Lastly, the difference in therapy adher-  
510 ence between HIT and CON, could have affected ex-  
511 ercise capacity at POST because of differences in total  
512 training volume.

#### 513 5. Conclusion

514 Under the conditions of the present study, a reha-  
515 bilitation program consisting of a short term high in-  
516 tensity interval cardio training and high load resistance  
517 trainings seems feasible in NSCLBP and may improve  
518 physical activity in daily life, exercise capacity and dis-  
519 ability, when compared to conventional exercise ther-  
520 apy. Large scale studies are warranted to corroborate  
521 these results.

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**Conflict of interest**

None to report.

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