Exercise Intensity Matters in Chronic Nonspecific Low Back Pain Rehabilitation

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ABSTRACT

VERBRUGGHE, J., A. AGTEN, S. STEVENS, D. HANSEN, C. DEMOULIN, B. O. EIJNDE, F. VANDENABEELE, and A. TIMMERMANS. Exercise Intensity Matters in Chronic Nonspecific Low Back Pain Rehabilitation. *Med. Sci. Sports Exerc.*, Vol. 51, No. 12, pp. 2434–2442, 2019. **Introduction:** Exercise therapy (ET) is advocated as a treatment for chronic nonspecific low back pain (CNSLBP). However, therapy effect sizes remain low. In other chronic disorders, training at higher intensity has resulted in greater improvements on both general health related and disease specific outcomes compared to lower-intensity ET. Possibly, high-intensity training also improves effect sizes in CNSLBP. **Objective:** To compare the effects of a high-intensity ET program with a similar moderate-intensity ET program on disability, pain, function, exercise capacity, and abdominal/back muscle strength in persons with CNSLBP. **Methods:** In a randomized controlled trial, persons with CNSLBP performed a 12-wk ET program (24 sessions, 1.5 h per session, twice per week) at high-intensity training (HIT) or moderate-intensity training (MIT). Questionnaires to assess disability (Modified Oswestry Index [MODI]), pain intensity (Numeric Pain Rating Scale), and function (Patient Specific Functioning Scale), a cardiopulmonary exercise test to assess exercise capacity ($\dot{V}O_{2max}$, cycling time), and a maximum isometric muscle strength test to assess abdominal/back muscle strength (maximum muscle torque) were administered at baseline and after the training program. **Results:** Thirty-eight participants (HIT: n = 19, MIT: n = 19) were included (mean age, 44.1 yr, SD = 9.8, 12 males). Groups did not differ at baseline. Between group differences ($P < 0.01$) in favor of HIT were found for MODI, $\dot{V}O_{2max}$, and cycling time. Within group improvements ($P < 0.01$) were found in both groups on MODI (HIT:−64%, MIT: −33%), Numeric Pain Rating Scale (HIT, −56%; MIT, −39%), Patient-Specific Functioning Scale (HIT:+37%, MIT:+39%), $\dot{V}O_{2max}$ (HIT: +14, MIT:+4%), cycling time (HIT:+18%, MIT:+13%), and back muscle strength (HIT:+10%, MIT:+14%). **Conclusions:** High-intensity training proved to be a feasible, well tolerated, and effective therapy modality in CNSLBP. Moreover, it shows greater improvements on disability and exercise capacity than a similar ET performed at moderate intensity. **Key Words:** CHRONIC LOW BACK PAIN, EXERCISE THERAPY, HIGH-INTENSITY TRAINING, REHABILITATION, RANDOMIZED CONTROLLED TRIAL

Chronic low back pain is one of the most common musculoskeletal disorders affecting men and women of all age groups (1). It causes the highest amount of years lived with disability of all diseases, leads to high levels of work absenteeism, and substantially burdens healthcare systems through a variety of direct and indirect financial costs (2). Although a small percentage of persons with chronic low back pain can be diagnosed with a specific underlying disease, most are categorized as having chronic nonspecific low back pain (CNSLBP), meaning that no clear pathoanatomical cause can be attributed to the symptoms (1).

Despite the fact that exercise therapy (ET) is an important and frequently applied part of multidisciplinary treatment of CNSLBP (3), overall therapy effects remain low (4). It has been suggested that the currently applied low to moderate exercise intensities in CNSLBP rehabilitation could be below the required level and that this might attenuate therapy outcomes (4,5). In healthy persons, several modes of high-intensity training (HIT) programs have clearly shown enhanced exercise capacity, muscle strength and health-related parameters compared with training programs at moderate intensity (6). Similar to healthy persons, HIT also substantially improved these variables in chronic disorders, such as axial spondyloarthritis (7), multiple sclerosis (8), and cardiometabolic diseases (9), as well as decreasing the level of disability caused by these disorders.

As persons with CNSLBP can show physical deconditioning (10), training at a higher intensity could improve therapy outcomes. High-intensity cardiorespiratory training (i.e., training near 100% of the maximum HR (11)) has already been applied in CNSLBP and showed improved maximal oxygen intake as well as decreased pain intensity and disability compared to a control

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group receiving passive modalities (12,13). However, continuous workload protocols were used, while in healthy persons evidence recommends the use of interval protocols (6). Although maximal oxygen intake improvements are comparable to continuous workload protocols (14), interval protocols provide a more time-efficient training (15) and elicit greater enjoyment which could support the low therapy adherence in musculoskeletal rehabilitation (16). Also, high-intensity strength training might help through improving muscle strength and increasing functional abilities (17), as deconditioning of the trunk (e.g., in m. multifidus (18)) and extremity muscles (e.g., hip extensors (19)) has been reported in CNSLBP (20). So far, various modes of strength training have been applied in CNSLBP rehabilitation, including full body resistance training and specific core muscle training (i.e., training of superficial and deep core muscles with the intention to normalize core muscle function, maintain segmental stability, and provide improved support to the spine). However, most strength training programs did not use high-intensity protocols and only showed moderate effects compared to control groups receiving no active therapy (5). High intensity in resistance training is generally defined as a percentage of more than 70% to 80% of the one repetition maximum (1RM) (21). In core muscle training a muscle activation of more than 60% of the maximal voluntary muscle contraction (MVC) (evaluated through electromyography analysis) is considered as very high (22). Although some high-intensity strength exercise protocols produced positive effects on muscle strength, quality of life, and pain intensity in persons with CNSLBP (23,24), convincing evidence is scarce. Moreover, vague descriptions of training protocols complicate the understanding of which training intensity optimizes the effectiveness.

Interestingly, a combination of high-intensity cardiorespiratory and high-intensity strength training further improves outcomes in healthy persons (25). In this respect, it is important to notice that a recent clinical pilot trial reported good feasibility, safety, and well tolerance of a high-intensity cardiorespiratory interval training coupled with general resistance training protocol in persons with CNSLBP (26). However, currently, no studies have evaluated the effectiveness of a combined HIT protocol in persons with CNSLBP. Therefore, the objective of this study was to compare the effectiveness of a high-intensity exercise program consisting of a combined cardiorespiratory, general full body resistance, and core muscle training protocol to a similar training protocol performed at moderate intensity on disability, pain, function, exercise capacity, and abdominal/back muscle strength, in persons with CNSLBP.

METHODS

Trial Design

The present randomized controlled trial is part of a larger project that evaluates the effects of training intensity and training mode in CNSLBP rehabilitation through a prospectively registered, five-arm, randomized controlled trial. This manuscript only describes phase 1, which evaluates the difference between two training programs with an identical training content but contrasting training intensities. In the larger project, a total of 147 persons with CNSLBP were screened for eligibility between October 2016 and March 2019. Of these, 41 did not meet the inclusion criteria, and six were not able to start the therapy program due to conflicting job schedules or commuting problems and were not further included. As such, 100 persons were included. Finally, 38 participants were randomized in one of the two groups evaluated in this analysis. A comprehensive research design flowchart is displayed in Figure 1. This project was approved by the Medical Ethics Committee of Jessa Hospital (Hasselt, Belgium) under protocol name 14.87/REVA14.12 and registered at clinicaltrials.gov as NCT02786316.

Participants and Recruitment

Persons with CNSLBP were regionally (Limburg, Belgium) recruited through local advertisements. To be eligible, persons had to speak Dutch, be 25 to 60 years old, have CNSLBP (i.e., pain localized below the costal margin and above the inferior gluteal folds with or without referred leg pain of a nociceptive mechanical nature, not attributable to a recognizable, known specific pathology, for example, infection, tumor, osteoporosis, fracture, structural deformity, inflammatory disorder, radicular syndrome, or cauda equina syndrome for a period of at least 12 wk (1)). Persons were excluded when they had a history of spinal fusion, had a musculoskeletal disorder aside from CNSLBP that could affect the correct execution of the therapy program, had comorbidities (e.g., paresis and/or sensory disturbances by neurological causes, diabetes mellitus, rheumatoid arthritis), were pregnant, had ongoing compensation claims and/or a work disability >6 months, had followed an ET program for low back pain in the past 3 months, or were not able to attend regular therapy appointments.

Interested persons received a patient information letter and were invited for an intake session by one of the researchers. During the intake session, the information letter was reviewed, study inclusion and exclusion criteria were evaluated, the informed consent was signed, and a study-specific screening form concerning red flags for low back pain rehabilitation was filled out.

Randomization and Blinding

Participants were randomly assigned into an experimental group performing HIT or a control group performing moderate-intensity training (MIT) as it would be performed predominantly in usual care (5,27). To ensure concealment of allocation, a research assistant not involved in the study picked a sealed, opaque, sequentially numbered envelope containing the allocated group for each participant. Given the nature of the ET, it was not possible to blind participants and caregivers for group assignment. To limit performance bias of the participants, the study was described to the participants as "a comparison between different modes of ET

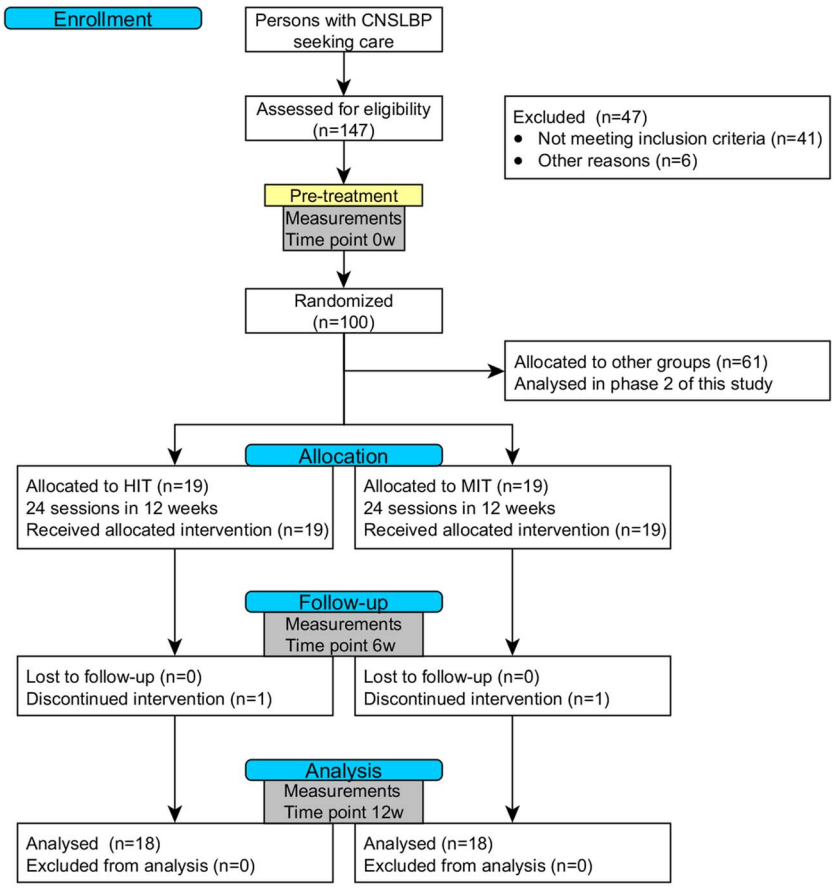

FIGURE 1—CONSORT flowchart of the research design.

treatments," and participants were informed that equal progression could be expected in each group.

Interventions

Participants of both groups were enrolled in a 12-wk ET program consisting of 24 individual therapy sessions (2×1.5 h·wk^{-1}) organized at REVAL (Hasselt University, Diepenbeek, Belgium), under the supervision of a physiotherapist who was a member of the research team. A manual with protocols, exercises and progression definitions was provided to the caregivers to assure standardized follow-up of all participants (see Appendix, Supplemental Digital Content, core strength exercises with their estimated activation intensities, http://links.lww.com/MSS/B669). Sessions missed by the participants because of adverse events (e.g., acute increase of low back pain, acute musculoskeletal issues due to exercises) were registered.

Experimental group ("HIT"). This group performed a protocol consisting of cardiorespiratory training, general resistance training and core muscle training, all at high intensity.

Cardiorespiratory training consisted of an interval training protocol on a cycle ergometer. After a 5-min warm-up interval training started, consisting of five 1-min bouts (110 repetitions per minute at 100% $\dot{V}O_{2max}$ workload), separated by 1 min of active rest (75 repetitions per minute at 50% $\dot{V}O_{2max}$ workload). Cycling bouts increased every two sessions by 10 s, up to 1 min 50 s after 12 sessions. Recovery time (1 min) between bouts remained stable. This protocol was repeated from session 13 to 24 with an updated workload, extracted from a complementary cardiopulmonary exercise test.

General resistance training consisted of three upper body (vertical traction, chest press, arm curl) and three lower body exercises (leg curl, leg press, leg extension) executed on fitness equipment (Fig. 2). On the first training session, exercises were explained and demonstrated by the physiotherapist. Then, exercises were repeated by the participant while movement corrections were made by the physiotherapist. On the second training session, 1RM testing was performed for every exercise. During the following sessions, one set of a maximum of 12 repetitions was performed at 80% of 1RM for each exercise. Researchers progressively increased the workload by using a 5% progression scale when the participant was able to perform more than 10 repetitions on two consecutive training sessions (28).

Core muscle training consisted of six static core exercises [glute bridge, resistance band glute clam, lying diagonal back extension, adapted knee plank, adapted knee side plank, elastic band shoulder retraction with hip hinge (Fig. 3), and related progressions (see Appendix, Supplemental Digital Content, core strength exercises with their estimated activation intensities, http://links.lww.com/MSS/B669)]. Exercises were chosen in

FIGURE 2—General resistance exercises. 1: vertical traction; 2: leg curl; 3: chest press; 4: leg press; 5: arm curl; 6: leg extension.

function of their ability to load the core muscles at an intensity of >60% of the MVC (22). On the first session, patients were educated on isolated activation of specific core muscles [m. transversus abdominis, m. multifidus, m. gluteus (see Appendix, Supplemental Digital Content, core strength exercises with their estimated activation intensities, http://links.lww.com/MSS/B669)], to minimize other compensatory muscle work during the exercises. On the second session, the physiotherapist explained and demonstrated the exercises. The participant then repeated the exercises while movement corrections were made by the physiotherapist. During the following sessions, participants performed one set of 10 repetitions of a 10-s static hold. Participants were encouraged to hold the last repetition as long as possible. Exercise difficulty was increased when the participant could execute the exercise with a stable posture for the indicated time on two consecutive training sessions. This was done by increasing the time of the static hold up to 12 s and progressing to more demanding postures through the use of increased body weight bearing (e.g., plank instead of knee plank), using elastic resistance bands (e.g., resistance band glute clam exercise), or adding additional weights (e.g., weight supported superman exercise).

Control group ("MIT"). This group performed a protocol consisting of cardiorespiratory training at a continuous load, general resistance training and core muscle training, all at moderate intensity.

Cardiorespiratory training consisted of a continuous training protocol on a cycle ergometer. After a 5-min warm-up,

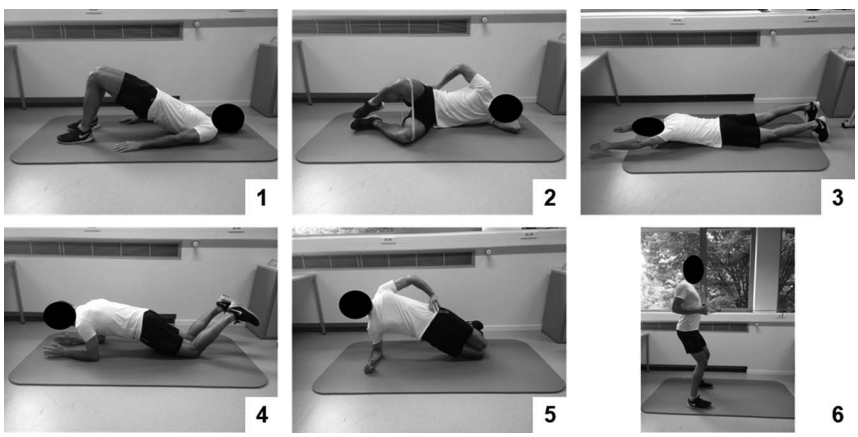

FIGURE 3—Core muscle exercises. 1: glute bridge; 2: glute clam; 3: lying diagonal back extension; 4: adapted knee plank; 5: adapted knee side plank; 6: elastic band shoulder retraction with hip hinge.

participants started with 14 min of cycling (90 repetitions per minute at 60%$\dot{V}O_{2max}$ workload). Duration increased every two sessions with 1 min 40 s up to 22 min 40 s. This protocol was repeated from sessions 13 to 24 with an updated workload, extracted from a complementary cardiopulmonary exercise test.

General resistance training was identical to the protocol described in "HIT" with the exception of the exercise intensity. From session 3, one set of 15 repetitions was performed at 60% of 1RM.

Core training was identical to the protocol described in "HIT" with the exception of the exercise intensity. Participants performed one set of 10 repetitions of a 10-s static hold. Exercises were made more difficult when they were executed with a stable core posture for the indicated time by increasing the time of the static hold each 6 sessions.

Testing Procedure and Outcomes

Demographic and clinical characteristics were collected at baseline (sex, age (yr), weight (kg) and height (cm) to calculate BMI, time of onset of CNSLBP, the 17-item Tampa Scale for Kinesiophobia to evaluate fear of movement, and the Physical Activity Scale for Individuals with Physical Disabilities to evaluate physical activity.

Primary and secondary outcome measures were collected at baseline ("PRE") and at the end of the training program ("POST"). An interim evaluation ("MID") was executed after 12 sessions (only used when an intention to treat analysis was performed). The primary outcome was disability. Secondary outcome measures were pain intensity, function, exercise capacity, and muscle strength. All measurement tools were tested on psychometric properties in previous research.

Disability was measured by the Modified Oswestry Disability Index (MODI) (29). The MODI evaluates disability experienced by people in their daily activities due to chronic low back pain. It consists of 10 items scored on a five-point scale. The total score is expressed in percentage and displays a degree of functional limitation.

Pain intensity was measured by the Numeric Pain Rating Score (NPRS) (30). The NPRS indicates the amount of pain intensity in adult pain patients. Participants evaluated their average pain intensity in the previous 6-wk period by choosing a number of the 0 to 10 scale (0 means no pain and 10 means worst pain imaginable). An improvement of two units or more is accepted as clinically relevant (31).

Function was measured by the Patient-Specific Functioning Scale (PSFS). The PSFS evaluates individual-specific functioning (32). Participants wrote down three to five activities that were compromised because of a physical disability. These activities are rated on a 0 to 10 numeric rating scale (0 means unable to perform, and 10 means able to perform at preinjury level). A mean percentage is calculated.

Exercise capacity was evaluated by a maximal cardiopulmonary exercise test on an electronically braked cycle ergometer (eBike Basic, General Electric GmbH). Participants started at a low workload (75 repetitions per minute) that gradually increased each minute (♂: 30 W + 15 W·min^{-1}, ♀: 20 W + 10 W·min^{-1}). Maximal oxygen uptake ($\dot{V}O_{2max}$) and maximal workload through cycling time (min.) were evaluated through breath-by-breath gas exchange analysis (Cortex MetaMax 3B) blood lactate measurements, and HR monitoring (Polar). A minimum RER threshold of 1.10 or a post exercise venous lactic acid concentration of 8 to 10 mmol·L^{-1} were used to evaluate proper validity of the maximum effort (33).

Muscle strength was measured by a maximal isometric muscle strength test of the trunk flexors and extensors using an isokinetic dynamometer (system 3; Biodex, Enraf-Nonius) (34). Participants were seated with a 90° hip angle and fixated at thighs and shoulders. Seat height was adjusted to bring the axis of the dynamometer in line with the anterior iliac spine of the pelvis of the participant. A standardized warm-up consisting of 15 active back flexion/extension movements with minimal resistance was performed. A specific protocol of alternating maximum isometric back flexion and back extension was used to record peak torque during three maximal isometric force measurements of alternating back flexion and back extension ("isolated lumbar protocol" (33)). Thirty-second rests were given between each force measurement. Peak torque is expressed in newton-meters (N·m) and normalized to bodyweight (N·m·kg^{-1}).

Data Analysis

JMP Pro (12.0, SAS Institute Inc., Cary, USA) was used for data analysis. A sample size calculation was performed to detect differences in disability measured by the MODI between the groups at POST. Based on observed therapy effects from a previously published feasibility study (26) and suggested minimal important change cut off values (35), n = 14 was needed in each group to detect a between group difference of 10 points out of 100 (80% power, SD = 12.0, alpha = 0.05). A 20% loss to follow-up in rehabilitation was expected, resulting in a total needed amount of n = 34 (n = 17 per group). A *post hoc* sample size analysis was performed to confirm specific power for each evaluated outcome measure. Descriptive statistics were used to display baseline group characteristics. Normality and homoscedasticity of each primary outcome were checked by fitting a general linear model of the PRE-POST deltas and plotting the residuals to look for equal variance, symmetry and identify possible outliers. A general linear model was used to evaluate differences in the deltas of each outcome measure between the HIT and MIT group. Cohen's d was calculated to evaluate the magnitude of the effect size. An alfa level of 0.05 was used for all tests of significance. No imputation of data was performed, under the assumption that data was missing at random. For drop outs, an intention to treat analysis was followed, using a last observation carried forward approach if a MID measurement was performed. If no MID measurement was performed (drop-out before 12 sessions of therapy), this participant was seen as missing data and was not used for further analysis. To check for selective

TABLE 1. Demographic and clinical characteristics of participants at baseline (n = 38).

Variables	HIT (n = 19)	MIT (n = 19)	P
Sex (m/f)	6/13	6/13	1.000
Age (yr)	44.3 (8.8)	44.0 (11.0)	0.769
Symptom duration (yr)	11.8 (8.4)	10.3 (7.1)	0.268
BMI ($kg \cdot m^{-2}$)	25.6 (4.0)	25.9 (3.6)	0.609
PASIPD, 0-199	16.5 (10.6)	14.9 (11.7)	0.637
TSK, 17-68	32.0 (6.0)	34.7 (7.2)	0.218

Categorical variables are expressed as number, continuous variables are expressed as mean (SD). m/f, male/female; PASIPD, The Physical Activity Scale for Individuals with Physical Disabilities; TSK, Tampa Scale for Kinesiophobia.

drop-out, differences between participants completing the trial and drop-outs were examined (independent t-tests, Mann–Whitney U tests, χ^2 tests).

RESULTS

Participants. A total of 38 participants were included (HIT: n = 19, MIT: n = 19). More women (69%) were included. Mean age was 44.1 yr (SD = 9.8) and mean pain onset was 11.7 yr (SD = 7.7). Study groups had similar demographic and clinical characteristics and outcome measures at baseline ($P > 0.05$), except for trunk extensors strength which was higher in the HIT group. Nonetheless, all treatment effects were adjusted for baseline estimates. An overview of patient characteristics at baseline is displayed in Table 1.

Treatment adherence, drop outs, and adverse events. Treatment adherence was very high. Mean session attendance was 23.4 (SD = 1.3) of 24 sessions and did not differ between groups. Three participants dropped out (HIT: n = 1, MIT: n = 2) due to long term sickness not related to CNSLBP (n = 1), practical issues that prevented correct fulfillment of the training protocol (n = 1), and acute musculoskeletal pain not related to the protocol or CNSLBP (n = 1). One of the three drop outs (from the MIT group) performed a MID measurement and was included in the final analysis as last observation carried forward. No differences in baseline characteristics were found between the participants who dropped out and the other participants. None of the participants reported any adverse events.

Training outcomes. An overview of the results is presented in Table 2.

MODI improved with a 14.6% reduction (64% relative difference) in the HIT group and a 6.2% reduction (33% relative difference) in the MIT group. A 8.6% difference between groups ($P > 0.01$) in favor of HIT, with sufficient power ($1 - ß = 0.83$) was found.

NPRS improved with a 3.2-point reduction (56% difference) in the HIT group and a 2.2-point reduction (39% difference) in the MIT group. The 1.0-point difference between groups was non-significant ($P = 0.08$).

The PSFS improved with a 26% increase in both groups, which corresponded to a 37% relative difference in the HIT group and a 39% relative difference in the MIT group. No difference between groups ($P = 0.97$) was found.

$\dot{V}O_{2max}$ increased with 4.9 $mL \cdot kg^{-1} \cdot min^{-1}$ (14% relative difference) in the HIT group and 1.8 $mL \cdot kg^{-1} \cdot min^{-1}$ (4% relative difference) in the MIT group. A difference of 3.1 $mL \cdot kg^{-1} \cdot min^{-1}$ between groups ($P > 0.01$) in favor of HIT, with sufficient power ($1 - ß = 0.82$) was found. Cycling time increased with 2.7 min (18% relative difference) in the HIT group and 1.7 min (13% relative difference) in the MIT group. A 1.0-point difference between groups ($P > 0.01$) in favor of HIT, with borderline insufficient power ($1 - ß = 0.79$) was found.

Regarding muscle strength, abdominal strength did not improve in either group (HIT: $P = 0.34$; MIT: $P = 0.31$), while back strength improved with 0.39 $N \cdot m \cdot kg^{-1}$ (10% relative difference) in the HIT group and a 0.33 $N \cdot m \cdot kg^{-1}$ (13% relative difference) in the MIT group. No difference between groups ($P = 0.88$) was found.

DISCUSSION

This randomized controlled trial demonstrated the beneficial effect of a HIT exercise program on disability, pain intensity, function, exercise capacity and isometric back strength, in

TABLE 2. Results of the outcome measures collected from participants at PRE and POST together with between group differences and *post hoc* power calculations.

	HIT (n = 18)			MIT (n = 18)			Interaction				
Outcome Measures	PRE	POST	Delta	PRE	POST	delta	DOD	Power	CI (95%)	Cohen's d	CI (95%)
Primary											
Disability											
MODI, %	22.8 (9.4)	7.8 (5.6)	−14.6 (8.0)*	18.8 (9.2)	11.8 (10.2)	−6.2 (8.0)*	−8.6**	0.83	[−13.8 to −3.2]	1.05	[0.06 to 2.04]
Pain intensity											
NPRS, 0–10	5.7 (1.3)	2.5 (1.2)	−3.2 (1.5)*	5.6 (1.7)	3.4 (1.7)	−2.2 (2.0)*	−1.0	0.28	[−2.2 to 0.1]	0.57	[−0.38 to 1.51]
Secondary											
Function											
PSFS, %	44 (17)	70 (15)	26 (20)*	40 (15)	66 (20)	26 (19)*	0.01	0.05	[−13 to 13]	0	–
Exercise capacity											
$\dot{V}O_{2max}$, $mL \cdot kg^{-1} \cdot min^{-1}$	31.2 (9.3)	36.1 (8.0)	4.4 (3.5)*	28.8 (8.0)	30.6 (6.7)	1.2 (2.2)*	3.1**	0.82	[−5.1 to −1.2]	1.10	[0.10 to 2.09]
Cycling time, min	14.3 (3.8)	17.0 (3.5)	2.5 (1.0)*	12.4 (2.1)	14.1 (2.2)	1.6 (0.9)*	1.0**	0.79	[0.3 to 1.6]	0.95	[−0.03 to 1.92]
Relative muscle strength											
Abdominal, $N \cdot m \cdot kg^{-1}$	1.40 (0.29)	1.45 (0.28)	0.04 (0.18)	1.21 (0.35)	1.23 (0.32)	0.02 (0.10)	0.02	0.05	[−0.25 to 0.29]	0.14	[−0.79 to 1.06]
Back, $N \cdot m \cdot kg^{-1}$	3.10 (0.84)	3.49 (0.73)	0.31 (0.45)*	2.41 (0.62)	2.74 (0.71)	0.33 (0.35)*	0.02	0.05	[−0.11 to 0.08]	0.05	[−0.97 to 0.87]

Values in HIT and MIT are reported as mean (standard deviation) and represent results of the Numeric Pain Rating Scale (NPRS), MODI. PSFS, a cardiopulmonary exercise capacity test, and a maximum isometric muscle strength test of the abdominals and back, before (PRE) and after (POST) 24 sessions of HIT (100%$\dot{V}O_{2max}$ interval cardio training + >80% 1RM general resistance training + >60% MVC core strength training) or MIT (50%–60% $\dot{V}O_{2max}$ cardio training +60% 1RM general resistance training +20% to 40% MVC core strength training). Delta displays the post-pre difference.
DOD: difference of deltas in HIT compared with MIT; CI: 95% confidence interval. *$P < 0.05$ compared with PRE. **$P < 0.05$ HIT compared with MIT.

persons with CNSLBP. When compared to a similar ET program executed at moderate intensity, greater improvements were found in disability and exercise capacity after training at high intensity. These improvements had a large effect size (Cohen's *d* of >0.8 (36)) and exceeded clinically relevant cutoff values (MODI = 8–10/100 (29), $\dot{V}O_{2max}$ = 3–3.5 METs (37)), underlining the clinical importance of the treatment effects. In addition, no adverse events were reported regarding the use of the HIT protocol, corroborating the safety and feasibility of this therapy modality (26). The results of this study are important, as they show the direct value of using HIT in rehabilitation management to increase the effectiveness of ET in CNSLBP.

Comparisons with other studies. The relevance of ET in CNSLBP rehabilitation has been stated extensively in previous research (4,5). However, training protocols are often not described in detail, complicating the evaluation of specific modalities such as exercise intensity (5,38). Nevertheless, research involving specific HIT protocols has been conducted. For instance, two studies showed that continuous workload aerobic HIT protocols produce positive effects of the same order of magnitude as the current study on pain and disability in persons with CNSLBP (12,13). However, as these studies only compared HIT with a control group receiving passive therapy modalities, results depicted could have been due solely to the active component of the ET generally. Aside from evaluating the therapy effects of the HIT program as a whole, no statements could be made concerning the specific impact of the high training intensity and its added value compared to an identical ET program performed at moderate intensity. When an aerobic HIT deep water running protocol was added as a supplementary therapy on top of a multimodal program consisting of exercise, manual therapy and education, it failed to show added beneficial effects on pain or disability in comparison to the multimodal program alone (39). However, participants in this study also received ET apart from the HIT deep water running. Moreover, as protocol characteristics such as volume and intensity were unclearly described, the magnitude and possible added effect of this HIT was hard to evaluate.

Surprisingly, no previous studies have been executed evaluating aerobic training in CNSLBP by means of interval training while in healthy persons and other pathological samples most aerobic HIT protocols consist of this training mode and unambiguous positive results have been noted on exercise capacity (6). In the current study, improvements on exercise capacity by performing HIT interval training were confirmed in persons with CNSLBP, as similar positive effects were displayed as in HIT interval protocols in healthy persons (14).

Concerning strength training, solely the difference between high and low-intensity isolated erector spinae training has been evaluated in CNSLBP in previous research. Conflicting results were found as one study produced greater positive results on pain, disability and physical impairments such as extensor muscle endurance and low back mobility in HIT (40), while another study using the same modality found no significant differences between intensities (41). It should be noted that isolated erector spinae strengthening is a very specific training modality of which still uncertainty exists concerning its added value in CNSLBP rehabilitation on other outcomes than back muscle strength (42). Furthermore, high-intensity definitions in both studies were lower than common guidelines (21). As such, these protocols were possibly producing insufficient stimulus to elicit strength gains (17). Therefore, a combination of general resistance and core muscle training and a higher cut off percentage to define HIT strength training was used in the current study. However, differences in back strength improvement between HIT and MIT were not found. Besides, neither group showed improvements in abdominal strength. As both groups showed within group improvements of disability and pain intensity, it remains unclear whether the present strength improvements are sufficient or even necessary during CNSLBP rehabilitation.

Recently a new HIT modality named high-intensity functional training has also been examined (43). This new HIT modality claims to be a mix of aerobic and strength training (i.e., a more multimodal way of training instead of the other unimodal protocols) through repeated whole body movement exercises (43). Although this training modality has shown positive results on aerobic capacity and muscle strength in healthy persons, it has not been evaluated whether it can improve any disorder-related outcomes. To our knowledge, the current study was the first to compare a combined HIT program consisting of both cardiorespiratory and strength training with another ET of which the sole differentiating parameter was the training intensity in this population.

Possible explanations and future research. Both previous research and the current study showed benefits of training at higher intensity, however the exact reasons for the noted improvements of this modality in CNSLBP still remain unclear. While aerobic protocols focused on impacting aerobic fitness, metabolic health, and cardiovascular health, strength protocols focused on increasing muscle strength. In CNSLBP, therapy programs implementing either of these training modalities have noted comparable improvements on disability and pain. As training at moderate intensities provided lower effect sizes, solely the physiological effect of the increased intensity could have caused the increased effectiveness. Indeed, intensity has been stated to be decisive for the physiological response to the therapy (44). However, more knowledge is also needed on the long-term effects of high-intensity training, as it is not known if positive effects of high-intensity training remain after cessation of the training intervention.

Strengths and limitations. A principal strength of this study is the display of clear definitions concerning exercise intensity for each training modality, which has been found to be a limiting factor in other studies when comparing ET programs among each other. Currently, methodological quality has been limited and definitions of the concept of high-intensity training in rehabilitation have varied greatly (5,17). Further strengths include the use of standardized treatment protocols, high adherence rates, and low dropout. Also, as the training protocols were executed by physiotherapists, similar effects can be expected when these protocols are used in clinical practice.

This study also has some limitations. Firstly, no control group was included that performed no training. As such, the natural course of function over time of the studied population could not be estimated. Nevertheless, as persons with CNSLBP with a mean onset over >10 yr were included, the authors assumed a stable clinical presentation of the symptoms. Furthermore, as the main aim of this study was to evaluate the impact of differences in exercise intensity, the authors advocate the higher need for the comparative exercise group. Second, while objective intensity levels for both the cardiorespiratory interval and the general resistance training could be clearly defined (through $\dot{V}O_{2max}$ and 1RM testing), intensity of the core muscle training had to be estimated through %MVC of exercises found in previous research. These %MVC were mostly only estimated on healthy persons and variability in muscle activation between individuals have been noted to be existent (45). Therefore, intensity could have deviated from the defined percentage. However, within the program, exercises were consistently evaluated and progressed if substandard intensity was suspected (by evaluation of the amount of repetitions performed). Third, as the participants of this study were recruited for an ET study, expectations and beliefs toward this therapy method could have deviated from the average persons with CNSLBP (i.e., selection bias toward persons who are willing to engage in active treatment approaches). However, participants were blinded for all study outcomes until finalization of the study protocol, to limit behavior based on progression of study outcomes (i.e., motivation bias). Fourth, no blinding of therapists or outcome assessors was performed. To limit influence of the outcome assessors (i.e., observer bias), assessment instruments were stripped of data displays while assessments were executed and a strict standardized testing methodology was used. Fifth, more women (69%) than men were included (i.e., sex bias). This was due to a high recruitment of nurses, a profession which is known to be a risk factor for CNSLBP and predominantly performed by women in Belgium (46). Subanalysis was not robust enough to evaluate sex-specific issues, but sex differences have not been found to impact other ET studies. Sixth, only a between group power analysis for the primary outcome measure (i.e., disability) was performed in advance. *Post hoc* sample size calculation showed insufficient power in some other outcome measures. Despite this, the authors argue that a larger sample size would not have changed the results, as in most power was too low to produce clinically relevant results. Lastly, this study did not report a long term follow up. Possibly, the greater improvements compared with moderate intensity have a higher wash-out effect.

CONCLUSIONS

A HIT exercise program consisting of cardiorespiratory interval, general resistance, and core muscle training is a safe, feasible, and effective ET modality to improve disability, pain intensity, function, exercise capacity, and back strength in persons with CNSLBP. When this program was compared to a similar MIT exercise program, greater improvements were found on reducing disability and increasing exercise capacity. These results show the potential of HIT for increasing therapy effectiveness in persons with CNSLBP. Future research needs to shed more light on the retention of the treatment effects.

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