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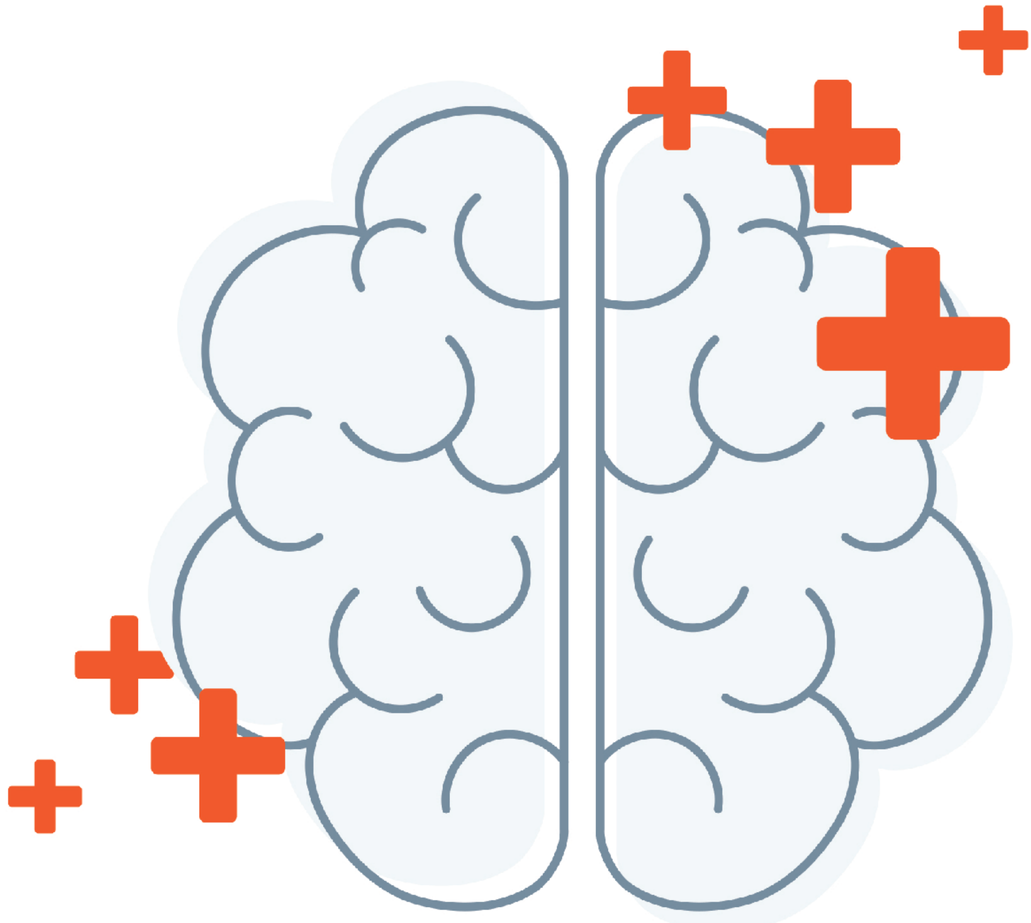

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Effect of high-intensity interval exercise on pain, disability, and autonomic balance in female patients with nonspecific chronic low back pain

Wpływ ćwiczeń interwałowych o wysokiej intensywności na ból, niepełnosprawność i równowagę autonomiczną u pacjentek z niespecyficznym przewlekłym bólem krzyża

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Abstract

Aim. To assess the impact of a 6-weeks high-intensity interval exercise (HIIE) regimen on pain, disability, as well as autonomic balance in women with nonspecific chronic low back pain (NSCLBP). Materials and methods. Sixty six females with mild to moderate NSCLBP, with ages of 18–60 years, were recruited from the physiotherapy department at King Fahd University Hospital, AlKhobar. They were assigned randomly into the control group (n = 32), which received standard regular physiotherapy, or the experimental group (n = 34), which received HIIE as well as conventional regular physiotherapy. Pre- and post-intervention (after 6 weeks) assessments included pain intensity via Numerical Rating Scale (NRS), disability via Oswestry Disability Index (ODI), as well as autonomic balance via heart rate variability (HRV) parameters & baroreceptor sensitivity (BRS) Both at rest and in reaction to an orthostatic challenge. Results. Both groups experienced significant improvements in pain and disability, with the HIIE group experiencing a higher improvement in both variables. For the HRV parameters after 6 weeks of intervention, the control group had a statistically significant reduction in high frequency (HF), and in response to the orthostatic challenge, a significantly higher rise in the normalized low frequency (LFnu) compared to the baseline. BRS showed a significant reduction and heart rate recovery was significantly faster post-intervention in the HIIE group in the 2nd and 3rd minutes, compared to the baseline values. Conclusions. HIIE can be a valuable addition to NSCLBP patients' exercise routines in practice, since adding HIIE to standard physiotherapy resulted in more reduction in pain, disability compared to conventional physiotherapy alone, with enhanced autonomic regulation after six weeks of treatment.

Keywords

chronic low back pain, Oswestry disability index, autonomic balance, heart rate variability

Streszczenie

Cel. Ocena wpływu 6-tygodniowego schematu ćwiczeń interwałowych o wysokiej intensywności (HIIE) na ból, niepełnosprawność, a także równowagę autonomiczną u kobiet z niespecyficznym przewlekłym bólem krzyża (NSCLBP). Materiał i metody. Sześćdziesiąt sześć kobiet z łagodnym do umiarkowanego niespecyficznym przewlekłym bólem krzyża, w wieku od 18 do 60 lat, rekrutowano z oddziału fizjoterapii Szpitala Uniwersyteckiego King Fahd w AlKhobar do udziału w badaniu. Kobiety zostały losowo przydzielone do grupy kontrolnej (n = 32), która była poddawana standardowej regularnej fizjoterapii lub do grupy eksperymentalnej (n = 34), która wykonywała ćwiczenia HIIE oraz była poddawana konwencjonalnej regularnej fizjoterapii. Ocena przed i po interwencji (po 6 tygodniach) obejmowała intensywność bólu za pomocą Numerycznej Skali Oceny (NRS), wskaźnik niepełnosprawności Oswestry (ODI), a także równowagę autonomiczną ocenianą na podstawie parametrów zmienności rytmu serca (HRV) i wrażliwości baroreceptorów (BRS) zarówno w spoczynku, jak i w odpowiedzi na wyzwanie ortostatyczne. Wyniki. Obie grupy doświadczyły znacznej poprawy w zakresie bólu i niepełnosprawności, przy czym grupa HIIE doświadczyła większej poprawy w zakresie obu zmiennych. W przypadku parametrów HRV po 6 tygodniach interwencji w grupie kontrolnej zaobserwowano statystycznie istotną redukcję wysokiej częstotliwości (HF), a w odpowiedzi na wyzwanie ortostatyczne znacznie większy wzrost znormalizowanej niskiej częstotliwości (LFnu) w porównaniu z wartością wyjściową. BRS wykazał znaczną redukcję, a rytm serca wrócił do normy znacznie szybciej po interwencji w grupie HIIE w 2. i 3. minucie w porównaniu z wartościami wyjściowymi. Wnioski. Ćwiczenia HIIE mogą być cennym dodatkiem do rutynowych ćwiczeń pacjentów z niespecyficznym przewlekłym bólem krzyża, ponieważ wprowadzenie HIIE do standardowej fizjoterapii spowodowało większą redukcję bólu i niepełnosprawności w porównaniu z samą konwencjonalną fizjoterapią, ze zwiększoną regulacją autonomiczną po sześciu tygodniach leczenia.

Słowa kluczowe

przewlekły ból krzyża, wskaźnik niepełnosprawności Oswestry, równowaga autonomiczna, zmienność rytmu serca

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Introduction

Chronic low back pain (CLBP) is described as "a back pain problem that has lasted for at least three months and has caused discomfort on at least half of the days in the previous six months". It is a highly prevalent condition with great socioeconomic impact. Most LBP cases have unclear pain origin and mechanism and are, therefore, classified as non-specific LBP [1]. Aberrant autonomic nervous system (ANS) regulation is hypothesized to contribute to the production and persistence of muscle chronic pain [2]. Regular exercise can avert the development of chronic pain and autonomic dysfunction [3, 4]. Conversely, pain-induced physical inactivity leads to deconditioning, which causes an imbalance in autonomic activity. Increased sympathetic tone, in turn, leads to regional ischemia that further aggravates the pain [5].

The cardiac baroreflex system responsible for blood pressure beat-to-beat control is interconnected with body analgesia systems, giving rise to links between cardiovascular parameters such as blood pressure, and baroreceptor sensitivity (BRS) with acute pain reactions [6]. These closely interlinked cardiovascular/ pain modulatory systems are modified in individuals with chronic pain [7]. Patients suffering from chronic pain were reported to have a reduction in high-frequency heart rate variability (HRV), suggestive of reduced parasympathetic activity [8]. The ANS activity in humans can be monitored by measuring HRV and BRS which, compared to the simple routine measurements of heart rate and blood pressure, provides a more accurate and sensitive way of early detecting autonomic problems [9].

Exercise therapy is an effective strategy to treat CLBP [10]. Though there are no clear recommendations for a particular type of exercise for managing CLBP, some studies are in favor of intense exercise [11], especially, high-intensity aerobic exercise, with positive results [12]. High-intensity interval exercise (HIIE) is characterized by short bursts of high-intensity exercise interspersed with rest intervals. [13]. According to which HIIE protocol is applied, different benefits could be gained (e.g., increased blood flow, improved metabolic function, vs. regenerating creatine phosphate) [13].

There are hardly any studies in Saudi Arabia addressing the effects of HIIE on patients suffering from nonspecific CLBP, especially from the autonomic aspect. Therefore, this study explored the effects of six-week training with HIIE on pain, disability, and autonomic regulation in patients with nonspecific CLBP.

Materials and methods

Design and study settings

This study was designed as a randomized controlled trial. The practical aspect lasted from 17th August 2018 to 6th January 2019 and was conducted in the Physiology department at Imam Abdulrahman Bin-Faisal University while the patients' recruitment was carried out at the physiotherapy department of King Fahd University hospital.

Ethical approval and patients' consent

The human-use research adhered to all relevant national rules and institutional standards, as well as the concepts of the Helsinki Declaration, and approved by Bin-Faisal University's Research Ethics Committee (IRB-PGS-2018-01-076). Each participant was informed of the study's nature, purpose, and advantages, as well as their freedom to refuse or withdraw at any time and the confidentiality of any data gathered. Then, before beginning the trial, informed consent was obtained from all participants.

Participants

To avoid a type II error, a preliminary power analysis [power (1−α error P) = 0.95, α = 0.05, effect size = 0.32, with a two-tails for a comparison of 2 independent groups] determined a sample size for each group in this study. This effect size was calculated accordingly after a pilot study on 12 participants (6 in each group) considering HRV at a lying position as a primary outcome. A sample size of 32 participants per group was necessary. To account for dropouts and missing data, the sample size was expanded to 40 per group.

Consequently, a convenient sample of 80 female with nonspecific CLBP was recruited from the physiotherapy department at King Fahad University Hospital. All CLBP patients had mild to moderate lumbar pain with no evidence of specific origin that lasted > 3 months. Their ages ranged from 18 to 60 years, and their BMI ranged from 18.5 to 34.9 kg/m^2.

Secondary LBP, osteoporosis, osteoarthritis, sciatica, generalized neuromuscular problem, deformities, fractures, walking with assistive devices, any diagnosed disorder that is likely to interfere with exercising on a bicycle ergometer or the subject's safety (e.g., cardiac, or respiratory diseases), any disease with a history of autonomic problems (e.g., diabetes), pregnancy, and lactation were all exclusion criteria. Patients receiving medications that could interfere with heart rate variability (HRV) variables (e.g., beta blockers and calcium antagonists) were also excluded.

Randomization

Following eligibility screening, participants were randomly assigned to two equal groups: control and experimental, each with forty participants, using a computer-based randomization software, and no dropouts occurred following randomization, Figure 1.

Interventions

The CLBP patients of the control group received a 45-minute standard physiotherapy program consisting of heat therapy and interferential electrical current, twice per week for 6 weeks. For the study group, patients received a supervised exercise program of HIIE for 20 minutes, two sessions per week, for six weeks using a computerized controlled ergometer bicycle, in addition to the standard physiotherapy program as the control.

Each patient in both groups was comfortably placed in a prone lying position, with a cushion below the abdominal area and forefoot zone. The hot pack was wrapped with a towel and applied to the lumber region for approximately 15 minutes. After the removal of the hot pack, the lumber area was dried from excessive water with a paper towel [14]. For applying the interferential current, in the prone lying position, four cutaneous electrode pads (8 × 6 cm) (Phyaction 787, Uniphy, Eindhoven,

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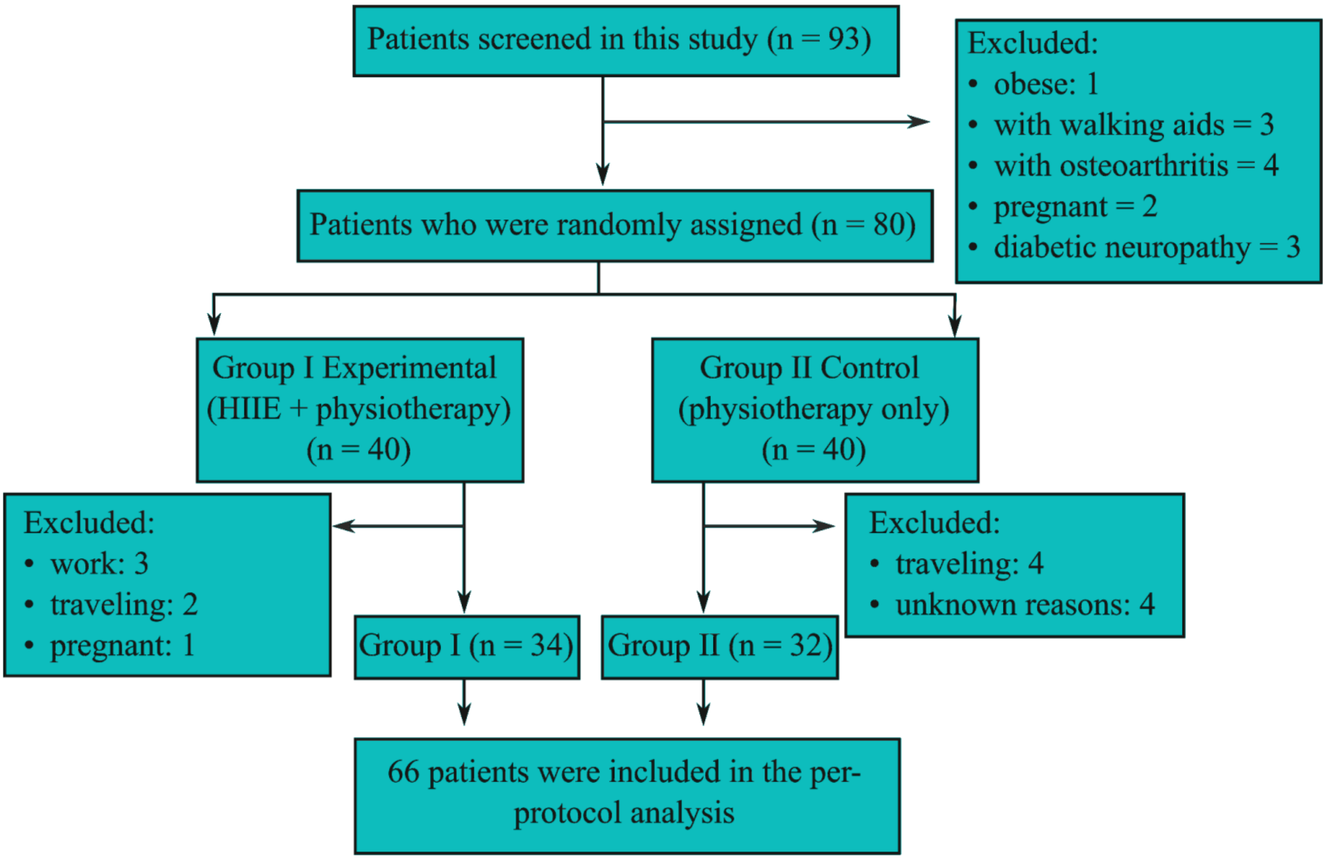

Figure 1. Study design flow chart

NL) gel and fixation tape were placed to the aching lower back. We used a carrier frequency of 4000 Hz, with an amplitude of 20 Hz for 30 minutes, and adjusted the intensity based on patient response. Once the electrodes were taken out, the gel was wiped off the lumber with a paper towel. Electrodes were rinsed under running water and dried using paper towels after each use [15].

For the HIIE, after instructing the patients to evacuate the bladder and report any symptoms to stop the exercise, the predicted HRmax was calculated according to the formula: heart rate maximum (220-age). Then, a Graded Maximal Exercise test (GME) was done for prescribing exercise intensity using a Polar belt and ECG setup [16]. After determining the suitable intensity, training was performed on a computerized controlled ergometer bicycle. Each session of HIIE consisted of warm-up (3 minutes of cycling with an intensity of 10 watts), interval exercise (10 repetitions of 60-second bursts at 80% of the HRmax interspersed by 60 seconds of recovery), and cool down (5 minutes at a power of 20 watts). The HR was continuously displayed to maintain the exercise intensity level.

Assessment of outcomes

The descriptive data for every patient including age, BMI, baseline heart rate, and blood pressure were taken and recorded. All variables were assessed for each patient at baseline and after six weeks of treatment. The pain intensity was assessed through a numerical rating scale, the LBP-causing disability, through the Oswestry disability index (ODI), the HRV by ECG recording, and BRS by Finometer Each patient was instructed to indicate her level of pain by making a mark somewhere along the line [1]. For identifying disability levels using ODI, the scores of each section were summated, divided by 50 which is the total score and multiplied by 100 to provide a percentage of disability. A percentage of 0-20% indicated minimal disability, 21–40% indicated moderate disability, 41-60% indicated severe disability, 61–80% indicated crippling back pain and 81–100% indicated bedbound [17].

Using the ECG, identifying cardiac cycle was done through the R wave of each QRS complex. The R-R intervals were used to measure the frequency domain parameters of HRV (HF, LF, LF/HF ratio). For measuring BRS using Finometer Pro (FMS, Netherlands), the peaks of the pressure waves were detected, and the peak-to-peak interval was calculated and recorded from the finger cuff. To analyze resting hemodynamic recording, the cardiac BRS (in milliseconds per millimeter of mercury) was measured by the spontaneous baroreflex (SBR) method [18].

Statistical analysis

Data were entered in Microsoft excel and all data analysis was performed using SPSS for windows version 20.0 (SPSS Inc., Chicago, IL). Prior to final analysis, data were screened for normality assumption, homogeneity of variance, and presence of extreme scores, as a pre-requisite for parametric calculations of the analysis of difference. The homogeneity of variance test and test of normality were done using Shapiro-Wilk test. Based on the results, the non-parametric Wilcoxon Signed Rank and Mann-Whitney U tests were used for pain, disability normali-

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zed low frequency (LFnu), and BRS within and between groups comparisons, respectively. Continuous independent variables (high frequency (HF), normalized HF (HFnu), LF, LF/HF Ratio, and heart rate recovery (HRR) parameters) were examined by t-test and analysis of variance. For normally distributed data, MANOVA was applied to see the differences within and between the groups. P-value of less than 0.05 was considered significant in all statistical analyses.

Results

Sixty six CLBP female were assigned to either the control group (standard physiotherapy program) or the study group (HIIE added to the standard physiotherapy program). Analysis has shown no significant differences between groups for baseline data except for age. The HIIE group's mean age was significantly lower (P = 0.000) (Table 1).

Table 1. Descriptive statistics of patients in both groups

Variables	HIIE group (N = 34) Mean (SD)	Control hgroup (N = 32) Mean (SD)	P value
Age [years]	29.14(8.95)	39.24(13.51)	0.000*
Height [cm]	161.4(10.55)	159.82(9.32)	0.411
Weight [kg]	70.01(12.65)	74.03(11.46)	0.143
BMI [kg/m²]	27.52(4.73)	28.80(5.04)	0.201
Heart rate (bpm)	80.92(13.38)	81.26(12.61)	0.561
SBP (mm Hg)	120.79(16.30)	121.82(15.48)	0.954
DBP (mm Hg)	70.21(11.78)	73.44(9.87)	0.054

Data were expressed as mean (SD), N = Number of subjects, BMI = Body Mass Index, SBP: systolic blood pressure, DBP: diastolic blood pressure
**: significant p-value ≤ 0.05*

Pain intensity and disability

Within groups, there was a significant reduction ($p < 0.05$) in both pain intensity and disability in both groups. Mann-Whitney U tests showed insignificant differences ($p > 0.05$) between both groups at baseline in both pain intensity and ODI. However, there was a significant decrease ($p < 0.05$) after six weeks of treatment for HIIE group in comparison to control group in both variables (Table 2).

Table 2. Comparison between both groups in pain, and disability

Variables and measuring times	HIIE group (N = 34) Median (IQR)	Control hgroup (N = 32) Median (IQR)	P value between groups
Pain Intensity (0-10 NRS)			
Baseline	4 (3)	5 (2)	0.272
6 Weeks	0 (2)	2.5 (4)	0.000*
P value within groups	0.0005*	0.0005*	
ODI (0-100)			
Baseline	13.5 (10.5)	20 (18.5)	0.050
6 Weeks	6 (8)	12.5 (14)	0.002*
P value within groups	0.0001*	0.0001*	

IQR: Interquartile range, NRS=Numerical Rating Scale, ODI= Oswestry Disability Index, HVR: heart rate variability,
**: significant p-value ≤ 0.05.*

HRV parameters in Standing Position

Concerning LF, HF, HFnu, and LF/HF Ratio, multiple pairwise comparison tests (Post hoc tests) of two-way MANOVA showed insignificant differences ($p > 0.05$) within groups for all these dependent variables except for HF and HFnu. There was a significant reduction ($p < 0.05$) in HF and HFnu for control group after six weeks of treatment compared to baseline. Between groups, there were no significant differences ($P > 0.05$) in the mean values of all variables at baseline and after six weeks of treatment. For LFnu parameter, tests revealed no significant differences ($p > 0.05$) within or between groups ($p > 0.05$), comparing baseline results to six weeks of treatment (Table 3).

HRV parameters in response to orthostatic challenge (from lying to standing)

Within groups, there was a statistically significant increase in LFnu post-treatment in the control group when compared to baseline ($p = 0.034$), while on comparing both groups, Statistically, there was a difference between the groups, but it was not significant ($P = 0.053$) (Table3).

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Table 3. Comparison of HRV parameters in standing & in response to orthostatic stress between both groups

Variables and measuring times	HIIE group (N = 34) Mean (SD)	Control hgroup (N = 32) Mean (SD)	P value between groups
HRV parameters in standing			
High frequency (ms²)			
Baseline	2.58 (0.51)	2.79 (0.65)	0.171
6 Weeks	2.62 (0.55)	2.51 (0.45)	0.409
P-Value within groups	0.762	0.027*	
Normalized high frequency			
Baseline	1.43 (0.23)	1.54 (0.2)	0.057
6 Weeks	1.42 (0.26)	1.43 (0.23)	0.824
P-Value within groups	0.777	0.047*	
Low frequency (ms²)			
Baseline	2.96 (0.42)	2.98 (0.53)	0.92
6 Weeks	2.99 (0.36)	2.86 (0.3)	0.165
P-Value within groups	0.782	0.174	
Normalized low frequency			
Baseline	1.87 (0.17)	1.78 (0.25)	0.053
6 Weeks	1.84 (0.17)	1.86 (0.196)	0.697
P-Value within groups	0.806	0.102	
Low-frequency to high-frequency ratio			
Baseline	0.35 (0.4)	0.18 (0.36)	0.098
6 Weeks	0.36 (0.42)	0.36 (0.37)	0.944
P-Value within groups	0.853	0.06	
	Delta change	Delta change	
HRV in response to orthostatic stress			
Normalized high frequency			
Baseline	12.16 (20.73)[a]	5.58 (20.07)	0.170
6 Weeks	11.37 (19.38)	17.94 (16.45)	0.158
P-Value within groups	0.610	0.074	
Normalized low frequency			
Baseline	−12.41 (24.32)[b]	−7.40 (20.65)	0.346
6 Weeks	−11.37 (24.27)	−22.46 (19.15)	0.053
P-Value within groups	0.617	0.034*	
Low-frequency to high-frequency ratio			
Baseline	−2.02 (2.95)	−1.09 (2.57)	0.156
6 Weeks	−2.27 (3.74)	−2.89 (4.51)	0.552
P-Value within groups	0.279	0.126	

SD: standard deviation, ms: millisecond, ms²: millisecond square, a: a positive value represents a reduction in the value in standing position compared to lying down, b: the negative sign represents an increase in the value during standing compared to the lying down position,
**: significant p ≤ 0.05*

HRR parameters after exercise at different periods
Our findings indicate a statistically significant increase within groups ($p < 0.05$) of mean values for relative HRR at the 2nd minute (%HRR2) and the 3rd minute (%HRR3) for the HIIE group after six weeks post-exercise as compared to baseline. While there were statistically insignificant differences ($p > 0.05$) in other dependent variables (maximal heart rate (HRmax), HRR at 1st, 2nd & 3rd minutes, and relative HRR at the 1st minute (%HRR1) in both groups. No statistically significant differences were found between groups ($p > 0.05$) mean difference in any of the dependent variables at both measuring periods (baseline and post-intervention) (Table 4).

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BRS values in supine and standing

Within groups, there was a significant reduction of BRS in HIIE group after receiving treatment for a period of six weeks in comparison to baseline. On comparing both groups, no significant differences were found (p > 0.05) in the mean BRS values at baseline or after six weeks of treatment (Table 4).

Table 4. Comparison of HRR and BRS parameters between both groups across different measuring times

Variables	HIIE group (N = 34) Mean (SD)	Control hgroup (N = 32) Mean (SD)	P value between groups
HRR parameters			
HRmax			
Baseline	149 (17)	139 (21)	0.056
6 Weeks	146 (17)	137 (19)	0.057
P-Value within groups	0.271	0.572	
HRR1			
Baseline	25 (10)	25 (14)	0.707
6 Weeks	28 (12)	27 (13)	0.707
P-Value within groups	0.209	0.412	
HRR2			
Baseline	38 (13)	36 (15)	0.181
6 Weeks	43 (11)	39 (14)	0.125
P-Value within groups	0.062	0.442	
HRR3			
Baseline	43 (12)	40 (15)	0.184
6 Weeks	48 (12)	43 (15)	0.130
P-Value within groups	0.136	0.468	
%HRR1			
Baseline	16.6 (7.1)	17.9 (9)	0.689
6 Weeks	19.3 (8.7)	20.2 (9.3)	0.630
P-Value within groups	0.144	0.215	
%HRR2			
Baseline	25.9 (8.8)	25.8 (9.4)	0.524
6 Weeks	29.5 (7.0)	28.1 (10.2)	0.540
P-Value within groups	0.035*	0.205	
%HHR3			
Baseline	29.3 (7.4)	29 (9.8)	0.511
6 Weeks	33 (8.0)	31.2 (9.5)	0.518
P-Value within groups	0.034*	0.276	
BRS parameters			
BRS msec/mmHg (supine)			
Baseline	0.95 (0.25)	0.91 (0.31)	0.65
6 Weeks	0.84 (0.32)	0.81 (0.31)	0.649
P-Value within groups	0.049*	0.079	
BRS ms/mmHg (standing)			
Baseline	0.84 (0.22)	0.72 (0.24)	0.065
6 Weeks	0.68 (0.29)	0.68 (0.27)	0.985
P-Value within groups	0.002*	0.459	

*SD: standard deviation, HRmax = maximal heart rate, HRR1: heart rate recovery at 1st min post-exercise, HRR2: heart rate recovery at 2nd min, HRR3: heart rate recovery at 3rd min, %HRR1 = relative heart rate recovery at 1st min, %HRR2: relative heart rate recovery at 2nd min, %HRR3: relative heart rate recovery at 3rd min, *: significant p ≤0.05*

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Discussion

The purpose of this research was to determine whether or not female patients with nonspecific CLBP would benefit from the addition of HIIE to a conventional physiotherapy program consisting of heat and interferential current in terms of pain, disability, and autonomic function. Pain and disability decreased more in the HIIE group than in the control group. Also, after 6 weeks of therapy, the HIIE group had considerably better autonomic regulation, as seen by improved response to orthostatic stress and a quicker HR recovery compared to the control group.The study utilized that type of intervention (HIIE) for the study group as it represents an acceptable exercise type with optimal adaptations and great tolerability because of recovery produced by its intermittent nature. It is considered safe for both young and old aged people as well as persons with certain diseases or disabilities, with no significant adverse effects [19].

The improvement in pain and functional level within the control group could be supported by Rajfur et al. [20], who concluded that selected electrotherapeutic modalities were successful in relieving pain and improving functional disability of patients with CLBP. More significant pain intensity reduction shown in HIIE group could be attributed to controlling the inflammatory markers that are responsible for inflammation and pain sensation in LBP patients [21]. This finding and that regarding the superior improvement of functional disability in the HIIE group were confirmed by Chatzitheodorou et al. [22], who found that 12 weeks of high-intensity exercise resulted in more pain relief and greater improvement in functional ability than passive interventions (electrotherapy).

Similarly, Murtezani et al [12] observed a significant improvement in pain and disability with high-intensity aerobic exercise in CLBP patients whereas the passive group did not show any significant improvement. On the contrary, Verbrugghe et al. [23] reported a non-significant difference in pain level or disability of CLBP patients between the high-intensity group and conventional physical therapy group after 6 weeks of treatment. However, none of these investigators used HIIE; the mode of exercise was high-intensity aerobic exercise which was not easy to maintain for longer periods at a sufficiently high level of heart rate or oxygen consumption.

As for HRV parameters, HF was significantly reduced post-treatment only in the control group. HF is thought to represent vagal activity and reduced vagal activity indicates a trend toward reduced autonomic regulation [8]. In other words, the HIIE group had better autonomic regulation compared to control group. Regular physical exercise is known to increase parasympathetic activity and/or reduce sympathetic activity thereby leading to an increase in HF and a reduction in LF components of HRV power [24].

In response to orthostatic challenge, the rise in LFnu was significantly lower in HIIE group compared to control group post-intervention. This was associated with a lower LF/HF ratio with HIIE compared to control. As the person assumes an upright posture there is increased sympathetic activity, manifested as an increase in LFnu and LF/HF ratio and sympathovagal balance would be tilted in favor of sympathetic dominance [25]. Increased sympathetic activity and/or decreased parasympathetic activity was observed in the control group in response to the orthostatic challenge, indicating an exaggerated response in this group. This was an indication that autonomic balance was better in the HIIE group at 6 weeks post-treatment.

The same findings were observed by Heydari et al. [26] found a significant improvement in HRV parameters (LF and HF) after 12 weeks of HIIE in young-aged males. Additionally, Fronchetti et al. [27] reported a greater HRV threshold after 3 weeks of HIIE. These changes might be related to delayed parasympathetic withdrawal throughout incremental exercise. In contrast, some studies [28, 29] reported a minor improvement, while others [30] did not find any alteration following training for five weeks to five months [28–30]. The lack of improvement could be attributed to inadequate training intensities, meaning that exercises were stopped before reaching supramaximal intensities [31]. Moreover, Hottenrott et al. [32] reported that exercise programs of short durations (less than three months) were not sufficient to induce vagal modulation changes in healthy and unhealthy people. Therefore, the short duration of the present study (6 weeks) could contribute to the non-significant changes in most of the parameters found in HRV measures.

Inconsistencies across HRV studies could be due to variable participants' age and physical activity level; poor reporting, removal and/or correction procedures; use of different frequency bandwidths and normalization methods for spectral measuring of LF and HF; width difference in HRV measures between subjects of the same study; and failure of studies to identify the normal and abnormal values.

Post-treatment, The HIIE group had a much quicker heart rate recovery, evidenced by significantly higher%HRR2 and%HRR3, with no significant difference between both groups. Generally, the initial 30–60 seconds of HHR after exercise cessation are dominated by the reactivation of parasympathetic nervous system, whereas the subsequent recovery is the result of parasympathetic activity and sympathetic withdrawal [33]. A faster recovery points towards better autonomic regulation in the sense of faster activation of parasympathetic system coupled with inactivation of sympathetic system [34].

Villelabeitia-Jaureguizar et al. [35] examined the effect of HIIE for 8 weeks on HRR in subjects having coronary heart disease and found a significant increase in HRR at 1st and 2nd minute after training cessation. Also, Stöggl and Björklund [36] evaluated the effect of different training intensities on acute HRR in athletes participating in endurance sports and found that the HIIE group had improvement in acute HRR after 9 weeks of training. Kannankeril et al. [37] have attributed the significant reduction in early HRR following exercise at high intensity to sympathetic withdrawal accompanied by an increased parasympathetic activation.

Conversely, Currie et al. [38] reported that 12 weeks of HIIE in coronary artery disease patients resulted in non-significant changes in HRR in the first two minutes after training cessation. They explained the lack of improvement by the optimum medical management in addition to the normative pre-training status of their sample [38]. The differences among studies re-

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garding HRR after exercise cessation could be related to the variation in the method used for obtaining HRR (passive or active), the definite recovery minute assessed, and the difference in dichotomous cut points identifying normal and abnormal HRR values [16, 35].

The response of BRS in the HIIE to orthostatic challenge was the expected one, i.e., a reduction in BRS value on assuming the standing posture, as standing leads to increased sympathetic activity, manifested as a reduction in the BRS [39]. The BRS measurement in response to HIIE could indicate the alterations in cardiovascular health, in addition to the time efficiency advantages of HIIE [40]. The reduction in BRS observed in the study could probably be because of the reading method of the BRS values, which was the momentary reading at a particular time not averaged.

The study results were inconsistent with Heydari et al. [26] and Pichot et al. [41], who found a significant increase in BRS following HIIE training in young males (for 12 weeks) and old males (for 14 weeks), respectively. Furthermore, the findings of the present investigation contradicted with Cassidy et al. [42], who reported that 12 weeks of unsupervised HIIE caused non-significant changes in BRS in type 2 diabetic patients. The lack of progress in that trial, however, may have had something to do with the fact that the exercise wasn't supervised [42].

The discrepancy in BRS results between the current study and the previous studies could be related to the difference in subjects' age and level of physical activity as both aging and low physical activity level can induce structural and functional alterations of the arteries through decreasing elastin and increasing collagen, resulting in arterial dispensability reduction and arterial stiffness increase [43]. Also, BMI, level of central adiposity and incorporation of low caloric diet could affect BRS results [43]. It is possible that a minimum period of chronic pain persistence is required to affect pain circuits integrating with autonomic centers to exhibit any appreciable effect [6]. Pinna et al. [9] have also cautioned that when BRS measures are utilised to detect therapy effects in individual patients, it is important to keep in mind the significant within-subject variability seen in the measurements of spontaneous BRS.

Study limitations

In the present study, we relied on the HRmax which shows a good correlation with oxygen consumption. Yet, the gold standard for assessing maximal ability/physical fitness is maximal oxygen consumption, but it was not possible because of logistic problems. Evaluation of the long-term influence of HIIE on pain, disability, and autonomic function (balance) could not be done. Also, the BRS patients' recorded values were momentary while to confirm the findings, the average BRS values should have been considered.

Conclusions

Based on the findings, it was determined that HIIE intervention combined with standard physiotherapy for 6 weeks resulted in significantly significant improvement in pain, disability, reactivity to orthostatic stress, as well as HR recovery in female patients suffering from mild to moderate NSCLBP compared to conventional physiotherapy alone. Patients with chronic low back pain (CLBP) may benefit from adding HIIE to their existing treatments.

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