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Research article

Interventional effect of core stability training on pain and muscle function of youth with chronic non-specific lower back pain: A randomized controlled trial

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A R T I C L E I N F O

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A B S T R A C T

Nowadays, due to lifestyle changes, the number of young people suffering from chronic non-specific low back pain (CNLBP) is gradually increasing. The recent guidelines for the treatment of low back pain emphasize that exercise therapy is the preferred treatment method for CNLBP. This study take ordinary college male students with CNLBP as objective of the study, focused into how core stability training affected the pain and muscle function of the CNLBP of youth. Herein, 60 male subjects were randomly divided into a control group and an experimental group, and conducted a randomized control trial in the Sports Rehabilitation Laboratory of Guangxi Normal University from September to October 2023. The control group received traditional waist strength training, while the experimental group received core stability training. VAS scores, pain symptoms scores and clinical efficacy grades were evaluated. Waist muscles fitness was evaluated, including back muscle strength, the prone upper body up's static holding time, 1-min modified sit-ups' pcs, the supine abdominal curling's static holding time and the supine leg raising's static holding time. Waist movement function was also evaluated using oswestry disability index (ODI) questionnaire. Surface electromyographic (EMG) signals were collected from rectus abdominis, erector spinae and multifidus. The independent sample *t*-test was used to compare groups, and the paired sample *t*-test was used for the data comparison before and post-exercise within the group. The results of the study found that CNLBP was improved in both the experimental and control groups in the post-exercise. Compared to pre-exercise, there are significant decrease in the VAS scores (95%CI: 2.51 to 6.51, $p = 0.000$), pain symptoms scores (95%CI: 2.95 to 3.55, $p = 0.000$), waist movement function's evaluation scores for ODI (95%CI: 2.23 to 4.31, $p = 0.000$), rectus abdominis' IEMG values (95%CI: 2.29 to 4.39, $p = 0.000$), erector spinae and multifidus' IEMG values (95%CI: 2.18 to 4.45, $p = 0.000$) of experimental group in the post-exercise. Compared to pre-exercise, there are significant improvement in the back muscle strength (95%CI: 12.85 to 19.49, $p = 0.000$), the prone upper body up's static holding time (95%CI: 9.67 to 19.17, $p = 0.000$), the 1-min modified sit-ups' pcs (95%CI: 8.56 to 18.12, $p = 0.000$), the supine abdominal curling's static holding time (95%CI: 6.73 to 19.14, $p = 0.000$), and the supine leg raising's static holding time (95%CI: 8.21 to 18.35, $p = 0.000$) of experimental group in the post-exercise. In the post-exercise,there are significant lower in the VAS scores (95%CI: 1.41 to 4.98, $p = 0.000$), pain

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symptoms scores (95%CI: 1.14 to 1.79, p = 0.011), waist movement function's evaluation scores for ODI (95%CI: 1.13 to 2.25, p = 0.000), rectus abdominis' IEMG values (95%CI: 2.36 to 4.47, p = 0.000), erector spinae and multifidus' IEMG values (95%CI: 2.24 to 4.23, p = 0.017) of experimental group than those of control group. In the post-exercise, there are significant higher in the recovery rate (p = 0.000), the prone upper body up's static holding time (95%CI: 4.16 to 8.32, p = 0.008), and the supine abdominal curling's static holding time (95%CI: 3.89 to 7.44, p = 0.000) of experimental group than those of control group. Therefore, it can be concluded that core stability training is significantly effective in treating CNLBP in youth, enhancing lower back muscle function. This therapeutic effect is primarily attributed to the improvement in muscle function.

1. Introduction

Low back pain (LBP) is a very common clinical condition in modern society, characterized by unilateral or bilateral pain in the lower back. Recent epidemiological surveys show that although only 25%–30 % of LBP patients seek medical treatment, LBP still ranks second in outpatient visits, only behind the common cold [1]. Based on the duration of the patient's LBP, it can be divided into three categories: acute lower back pain (continuous pain lasting up to four weeks), subacute lower back pain (continuous pain lasting four to twelve weeks), and chronic lower back pain (continuous pain lasting more than twelve weeks). Furthermore, based on changes in the histopathological structure during the onset, LBP can be classified into two types: specific lower back pain and non-specific lower back pain (NLBP), with approximately 90 % of LBP diagnoses being NLBP [2].

NLBP refers to the fact that there is no definite change in the histopathological structure and objective, and the examination also failed to find the exact cause of pain [2,3]. NLBP affects health, quality of life, and work, and causes a heavy medical burden and indirect social cost. NLBP is a complicated disease, lingering, challenging to heal, and recurrence. Although the curative effect of NLBP by conventional Chinese medicine treatment is evident in the short term, patients' recurrence rate is higher [4,5]. Oral medication treatment brings more significant side effects, but it is difficult to learn from the root and eliminate pain [6]. Therefore, actively exploring the treatment of NLBP to improve the curative effect and reduce recurrence is an important life question [7–9].

With the increasing influence of competitive sports and mass sports in society, more and more attention are paying to the impact of physical exercise on physical health. In recent years, NLBP's sports rehabilitation therapy has become a research hotspot in the fields of rehabilitation medicine and sports medicine. According to the classification of LBP, NLBP exceeding 12 weeks belongs to chronic non-specific lower back pain (CNLBP). The 11th revision of the International Classification of Diseases (ICD-11) categorizes it as chronic primary musculoskeletal pain, called chronic primary lower back pain (ME84.2). In 2017, the American Medical Association pointed out that exercise therapy has become the preferred rehabilitation therapy for CNLBP [1]. The main advantage of exercise therapy lies in its ability to restore function in patients with CNLBP. Nowadays, exercise therapy has become the mainstream treatment method for CNLBP in worldwide [10]. For example, McKenzie extension therapy can help stabilize the spine, restore trunk muscle function, and alleviate pain [11]. But, there are also doubts for McKenzie extension therapy [12]. With the proposal of the three subsystems model for lumbar spine stability, core stability training have been widely applied in CNLBP rehabilitation treatment [13,14]. Compared to other exercise therapies, core stability training can train the muscle strength of the deep and shallow core muscles of the spine, train lumbar stability, balance coordination, and neuromuscular control ability. In clinical practice, suspension and whole-body vibration are commonly used to provide core stability training for patients with CNLBP. It is now clear that suspension training and whole-body vibration can improve pain and lumbar mobility function in patients with CNLBP [15–17]. But previous studies have paid less attention to muscle function. In addition, both suspension training and whole-body vibration require professional instruments to complete, making it difficult to use on a large scale. Swiss balls can also be used for core stability training, and they are economical and easy to obtain, therefore, it is easy to promote on a large scale. Due to the relatively high requirement for physical fitness in the core stability training of Swiss balls, the core stability training of Swiss balls is particularly suitable for young male patients with CNLBP. Herein, the Swiss Ball is applied to train CNLBP male students to stabilize the core area, to explore the effect of core stability training on CNLBP and improvement of muscle function. The significance of this study is to enrich research data on CNLBP, provide economic and efficient reference methods for clinical treatment of CNLBP, thereby reducing patient pain and improving their quality of life.

2. Materials and methods

2.1. Study design

This study investigated in Guangxi, China was a randomized controlled trial that was planned in accordance with CONSORT guidelines. Using the media and advertisements, the recruitment of volunteers took place in August 2023 and was finished in September. The recruitment target is ordinary male college students suffering from CNLBP. The web-based procedure was utilized for inclusion, randomization, and data collection, and it was limited to the investigator's preliminary survey. Informed consent was obtained in writing from each participant. This experiment is being studied in a practical manner. The major goal was to explore how young individuals with persistent, NLBP responded to core stability training in terms of muscle function. The study received approval from the Ethics Committee of Guangxi Normal University with ethics application number 20230806001. Additionally, the clinical trial protocol for this study has been registered on ClinicalTrials.gov PRS with registration number NCT06308809.

Because the consultation form enables better and more thorough reporting of randomized controlled trials (RCTS), the sampling procedure is displayed in Fig. 1 that is also used to showcase the sampling process. 60 participants provided their informed consent. Using a medium effect size of 0.55 calculated with G × Power 3.1.9.7 [18], we determined a sample size of 46, with an additional 20 % dropout rate factored in, resulting in the selection of 60 participants for the study. 60 participants were randomly divided into the control group (conventional strength training group, n = 30) and the experimental group (core stability training group, n = 30) using a digital scale method. When grouping, participants were randomly assigned integer numbers starting from 1, with odd numbered participants as the control group and even numbered participants as the experimental group. The control group underwent traditional waist strength training, while the experimental group underwent core stability training. This experiment was conducted using a rigorous double-blind design to ensure the validity and reliability of the results. Specifically, the intervention administrator, who conducted the exercise interventions on the two groups of patients, was not informed of the hypotheses or the group assignments. Additionally, a separate, dedicated individual was responsible for collecting the health indicators from both groups. This individual was also unaware of the participants' group assignments, thereby preserving the integrity of the data collection process. Both roles were clearly separated to prevent any potential bias, adhering strictly to the principles of double-blinding. Exercise intervention plan was designed for this experiment by the researcher, and then the exercise intervention plan was handed over to a rehabilitation therapist. Rehabilitation therapists, without being informed, conducted corresponding exercise interventions on the experimental group and control group according to the exercise intervention plan. To control for the bias caused by covariates, based on random and blind methods, the exercise intervention time for both the experimental group and the control group in this experiment was fixed from 2 p.m. to 6 p.m., and the training was completed under the guidance of the same rehabilitation therapist; In addition, each observation indicator is tested by the same person.

2.2. Participant

Volunteers with CNLBP, a total of 60 ordinary college male students (19–23 years old) were included.

2.3. Diagnostic criteria

Diagnosis of CNLBP completed by the chief orthopedic physician of Affiliated Hospital of Guilin Medical University. The Diagnosis based on the 2022 North American Spine Society (NASS) evidence-based guidelines for CNLBP. Low back pain, muscle stiffness, pain often changes with the weather. Fixed tender points or tenderness in the waist, with or without limb pain, no intermittent claudication, straight leg elevation test negative, no signs of nerve root damage, the objective examination did not find the exact cause. CNLBP was diagnosed at the Orthopedic Clinic of Affiliated Hospital of Guilin Medical University.

2.4. Inclusion criteria

Participants eligible for this study are required to have a confirmed diagnosis of chronic non-specific lower back pain persisting for more than 12 weeks, with pain intensity measured between 2 and 7 on the Visual Analog Scale (VAS). They must not have received any formal or informal therapies in the week preceding their enrollment. Additionally, participants should be naïve to core stability

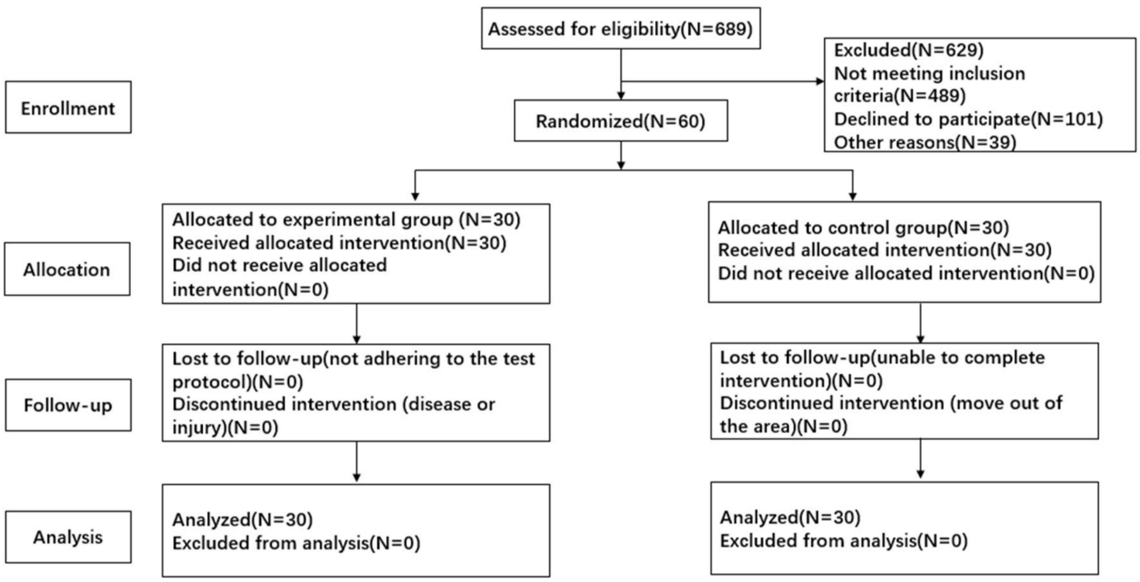

Fig. 1. CONSORT flow chart.

exercises and have engaged irregularly in physical fitness exercises prior to the study. All participants are required to commit to adhering to the exercise therapy regimen and complete the entire course of treatment. During the intervention period, participants were prohibited from engaging in any other physical exercises to ensure the purity of the study's results.

2.5. Exclusion criteria

Does not meet the above diagnostic criteria, diagnosed lumbar disc herniation, spinal stenosis, fracture, vertebral dislocation or spinal cord injury, people with low back pain caused by infectious diseases, those who have received lumbar spine surgery.

2.6. Intervention program

This experiment was conducted in the Sports Rehabilitation Laboratory of Guangxi Normal University from September to October 2023. The exercise rehabilitation training for both experimental and control groups lasted for 8 weeks, conducted in different indoor facilities within the same province to avoid interference from external environmental factors. Each workout consists of three parts: warm-up activities, formal training, and tidying up activities. There are three training sessions a week, which are completed between 18:00 and 22:00 on Monday, Wednesday, and Friday, respectively. The total time for each training is 50~55 min, among which the warm-up activity takes 5 min, including the dynamic traction activation training of the shoulder, waist, abdomen, hip, and other muscle groups; formal training takes 40–45 min. The experimental group underwent core stability training on a Swiss ball (see Table 1 for training arrangements), while the control group engaged in conventional waist strength training (see Table 2 for training arrangements). The finishing activities, which lasted 5 min, included static stretching and relaxation movements targeting the shoulders, waist, abdomen, hips, and other muscle groups.

Core stability training actions and their essentials: (1) Double bridge exercise: Lie on your back, place your calves on the Swiss ball, this is the initial posture; move up to the shoulders, hips, knees, and ankles in a straight line; return to the initial posture after static maintenance. (2) Single bridge exercise: Lie on your back with your calves on the Swiss ball. This is the initial posture; move the hips upwards until the shoulder, hip, knee, and ankle connect approximately in a straight line, and the lower limbs of the rear side leave the Swiss ball suspended; return to the initial posture after maintaining the static state. Alternate bilateral lower limbs. (3) Knee flexion and double bridge exercise: Lie on your back, place your calves on the Swiss ball, this is the initial posture; move the hips upwards until the line of shoulders, hips, knees, and ankles is approximately a straight line, and then flex your knees by 90°, double Step on the ball; return to the initial posture after static holding. (4) Knee bend and single bridge exercise: Lie on your back and place your calves on the Swiss ball. This is the initial posture; move the hips upwards until the shoulders, hips, knees, and ankles are approximately in a straight line, and then move the lower limbs away from the Swiss. The ball is suspended, the other knee joint is flexed to 90°, and the ball is stepped on with one foot. After static maintenance, it returns to the original posture. This is a complete action. Alternate bilateral lower limbs. (5) Anti-bridge movement: lying on your back with your shoulders and back on the Swiss ball, this is the initial posture; the hips move upward until the knee joints are at 90° simultaneously so that the connection between the shoulders, hips, and knees is approximately a straight line; static return to the original posture after holding. (6) Reverse bridge one-leg straightening exercise: lying on your back, placing your shoulders and back on the Swiss ball, this is the initial posture; moving the hips upwards until the knee joints are at 90° at the same time, making the connection between the shoulders, hips, and knees approximately a straight line, straighten one lower limb hanging in the air; return to the initial posture after static holding. This is a complete action—alternate bilateral lower limbs.

Routine waste strength training actions and essentials: (1) Improved sit-ups: Lie on your back, place your hands next to your ears, flex your knees at 90°, and fix your feet together on the mat. This is the initial posture; the waist and abdomen muscles contract to make the upper body sit upright and then lie down slowly. Return to the original position. (2) Russian swivel: Sitting position, with legs close together and knees bent at 90°, feet on the mat, lower back straight, upper back slightly arched back, this is the initial posture; waist and abdominal muscle contraction make the upper body and head Turn the head to one side, visually, both hands touch the ground on the same side at the same time, and slowly return to the original posture. Completing the left and right one at a time is a complete action. (3) Core V-shaped abdomen: Sit backward, hold both sides of the mat behind you with both hands to fix the body so that the angle between the back and the horizontal plane is about 45°, and the lower limbs are brought together at an angle of about 140° between the upper and lower legs. The calf is parallel to the horizontal plane; this is the initial posture; the waist and abdomen muscles contract as much as possible to bring the knees closer to the chest, while the upper body leans forward to maintain the balance of the body and slowly return to the initial posture. (4) Supine upper body hanging in the air: Lie on your back, hold your hands behind your head, and fix your lower limbs in slightly flexed hips and knees. This is the initial posture; contract the abdominal muscles as much as possible to raise the upper body by 45°, and then return to the initial pose. (5) Lie down on both sides: Lie down on your stomach, hold your hands behind your head, and straighten your body. This is the initial posture; contract your back muscles as much as possible to

Table 1
Statistics of clinical efficacy grades of the two groups in the post-exercise ($\bar{x} \pm s$).

Group	Recovered n (%)	Significant effect n (%)	Effective n (%)	Invalid n (%)	The total effective n (%)
Control	6 (20)	14 (46.67)	10 (33.33)	0 (0)	30 (100)
Experimental	20 (66.67▲)	9 (30)	1 (3.33)	0 (0)	30 (100)

Note: ▲ $p < 0.05$ compared with the control group.

Table 2
Comparison of related indexes of lumbar muscle fitness between the two groups ($\bar{x} \pm s$).

Index	Phase	Statistics[1]	Group		Statistics[2]	
			Control	Experimental	t_2	p_2
Back muscle strength/lb	Pre-exercise		66.92 ± 8.67	65.5 ± 14.62	1.172	0.254
	Post-exercise		83.23 ± 10.86	86.54 ± 11.23	−1.601	0.161
		t_1	−6.413	−8.725		
		p_1	0.000	0.000		
Prone upper body up/s	Pre-exercise		18.20 ± 11.48	19.05 ± 9.09	−1.293	0.153
	Post-exercise		55.74 ± 13.95	64.63 ± 15.06	−2.503	0.008
		t_1	−8.733	−13.851		
		p_1	0.000	0.000		
One-minute modified sit-up/pcs	Pre-exercise		26.47 ± 7.75	25.42 ± 10.79	1.596	0.079
	Post-exercise		49.79 ± 9.68	51.53 ± 6.95	−1.954	0.056
		t_1	−8.929	−9.531		
		p_1	0.000	0.000		
Supine abdominal curling/s	Pre-exercise		19.07 ± 11.34	19.95 ± 8.59	−1.482	0.103
	Post-exercise		51.00 ± 19.70	62.84 ± 13.04	−3.604	0.000
		t_1	−6.366	−11.321		
		p_1	0.000	0.000		
Supine leg lifting/s	Pre-exercise		35.68 ± 18.78	33.11 ± 16.41	1.389	0.175
	Post-exercise		71.74 ± 16.79	73.47 ± 19.53	−1.162	0.169
		$\boldsymbol{t_1}$	−6.942	−7.869		
		$\boldsymbol{p_1}$	0.000	0.000		

Note: 1 is the statistical value of self-comparison pre and post the group; 2 is the statistical value of the simultaneous comparison between groups.

lift the upper body and legs so that the angle between the shoulder and hip connection, hip and ankle connection, and the horizontal plane is at least more than 20°, slowly return to the initial posture. (6) Prone upper body hanging in the air: Lying flat, holding your hands behind your head, straighten your body, this is the initial posture; during exercise, the back muscles contract as much as possible to raise the upper body so that the angle between the shoulder and hip line and the horizontal plane is at least greater than 30°. After maintaining the static state, return to the initial posture.

3. Measure

3.1. Evaluation of pain intensity score

Visual analog scale (VAS) was used to score subjects' pain intensity with NSLBP [19,20]. Choose a ruler with a length of 10 cm, and face the tester with the ruler with a complete digital scale from 0 to 10. The larger the scale, the more pain, the 0 end means "no pain', and the ten ends mean "pain unbearable during an attack'. The subject's ruler only has scale displays on both ends. The issue began to imagine the pain state of his back pain at the time of the onset. The tester recorded the corresponding scale value, the final score of the tester's pain intensity score. Then, minimal clinically important difference (MCID) is used to determine the clinical efficacy of the intervention, with a 2 point reduction in VAS, defined as MCID [21].

3.2. Evaluation of pain symptom score

Refer to the evaluation criteria for the functional classification of chronic soft tissue injury in the "State Administration of Traditional Chinese Medicine' [22]. And "Guiding Principles for Clinical Research of New Chinese Medicines' [23]. It is mainly divided into three items: pain, tenderness, and functional activity. The sum of the three scores is the final pain symptom score. The scoring method for the pain part is: 0 points for no pain; 1 threshold for mild pain; stop, the pain can be tolerated for two topics; often attacks, unbearable pain, lasting more than 3 points. The scoring method for tenderness is 0 points for no sympathy, one matter for pain during heavy pressure, 2 points for pain during moderate pressure, and 3 points for mild anxiety. The functional activity part is scored for the waist to move freely and can engage in various activities 0 points; the core is slightly restricted and can be involved in everyday activities for 1 point; the waist activities are limited, but you can take care of yourself for 2 points; you cannot do general labor, waist movement is restricted, which affects self-care by 3 points.

3.3. Evaluation of clinical efficacy grades

Recovery: The symptoms of lower back pain have basically disappeared, and the lower back can move freely, reduction of pain symptom scores≥ 80 %. Significant effect: The symptoms of lower back pain have significantly improved, and lower back movement is basically normal. The patient can participate in normal activities and work, 60 % ≤ reduction of pain symptom scores <80 %. Effective: The symptoms of lower back pain have been alleviated, lower back activity has improved, ability to participate in activities or work has improved, 40 % ≤ reduction of pain symptom scores <60 %. Invalid: The symptoms of lower back pain have slightly relieved or are ineffective, reduction of pain symptom scores <40 %. Total effective rate = (recovery + significantly effect + effective) number of cases/total number of cases × 100 %.

3.4. Evaluation of waist muscles fitness

Back muscle fitness test: (1) Back muscle strength: Use the German MicroFET2 handheld muscle strength tester to test. During the trial, the subject takes the prone position, with the legs together and completely relaxed. This is the initial test position; the tester places the handheld muscle strength tester on the first to the third thoracic spine in the middle of the subject's back. Use the maximum strength to raise the upper body to form a confrontation with the tester, maintain it for 8 s, and then return to the initial movement. Repeat five times and take the maximum value. (2) The prone upper body up's static holding time (abbreviated as prone upper body up): Raise the upper body in the horizontal position and record the holding time to evaluate the subject's back muscles' static strength and strength endurance. During the test, the issue took the horizontal position, brought his legs together, moved his hip joints to the front edge of the massage table, placed his hands behind his head, put his legs together, and forced his upper body to stand at an angle of 45° to the horizontal—record-keeping time.

Lumbar muscle fitness test: (1) One-minute modified sit-ups' pcs: Assess the dynamic strength and strength endurance of the subjects' abdominal muscles. The test subject lies on the massage table with his arms crossed on his chest, the calves are retracted, the legs are bent, and the feet are placed on the massage table with the knee joints at 90°, which is the initial posture; during exercise, lift the upper body forcefully From the shoulder joint, hip joint line and the massage table at an angle of 90°, and then return to the original posture is a complete action. Record the maximum number completed in 1 min (2) The supine abdominal curling's static holding time (abbreviated as supine abdominal curling) and the supine leg raising's static holding time (abbreviated as supine leg raising): Assess the static strength and strength endurance of the abdominal muscles of the subjects. Supine abdominal curling: The issue takes the supine position, crosses his hands on his chest, puts his legs together, and relaxes completely. After the start, straighten up the upper body to 45° to the horizontal plane and hold it statically. Supine leg raising: The subject takes a supine position, crosses his hands on his chest, brings his legs together, and relaxes completely. After the start, raise his legs to 45° to the horizontal and hold them statically. Record the hold time.

3.5. Evaluation of waist movement function

The oswestry disability index (ODI) questionnaire was used to quickly assess patients' waist movement function with CNLBP. The scale is composed of 10 common daily life problems. Each question has six options. Choose the first option to get 0 points, and choose the last chance to get 5 points. The scoring method is the actual score/50 (the highest possible Score) × 100 % if all ten questions are selected. If a problem is not answered, the scoring method is the actual score/45 (highest possible Score) × 100 %.

3.6. Collection of surface EMG signal of lumbar muscles and test of its index

DASYLab 12.0 surface electromyography (EMG) test system is used to measure the changes of the subjects' psoas surface electrical signals and perform integrated (IEMG) comparison. Erector spinae, rectus abdominis and multifidus are selected as the test muscles, and their corresponding body surface test locations are pretreated (remove hairs and wipe the skin with 75 % medical alcohol). EMG test method of core muscle group (e.g. erector spinae and multifidus muscle) is as follows: Place the surface electrode sheet is placed 2 cm away from the midpoint of the bilateral iliac crest line, the second surface electrode sheet is placed 2 cm directly above the first surface electrode sheet, and the reference electrode is placed 2 cm inside the middle of the line between the two electrode sheets (on the spinous process). The subject took the prone position, with his legs close together. During the testing, the subject's hands behind his head, as far as possible to straighten up the upper body (the angle with the horizontal plane is not less than 45°) and keep it statically for 8 s, repeating three times and each time a lot of intervals in 3 min. Surface EMG test method of rectus abdominis is as follows: The first surface electrode sheet is placed 3 cm above the umbilicus and 2 cm away from the side, the second surface electrode sheet is placed 2 cm directly above the first surface electrode sheet, and the reference electrode is placed 2 cm inside the midpoint of the connection between the two electrode sheets (midline of the abdomen). The subject takes a supine position, crosses his hands on his chest, puts his legs together, and tries to straighten his upper body (with an angle of not less than 45° from the horizontal plane) and keeps statically for 8 s, repeating three times and each time interval not less than 3 min. The average left and right IEMG values are calculated by taking the EMG with the maximum EMG amplitude.

3.7. Statistical analysis

The index count chi-square test (χ two trial) is measured by using SPSS for windows 24.0 statistical analysis software and mathematical statistics, and the measurement indicators are "mean ± standard deviation' ($x \pm s$). For intergroup comparisons, perform the homogeneity of variance test after passing the normal distribution test. If the homogeneous of variance, perform the independent sample *t*-test. If the heterogeneity of variance, perform Welch's *t*-test. And the paired sample *t*-test was used for the data comparison pre-exercise and post-exercise within the group, taking $p < 0.05$ as the standard of significant difference.

4. Results

4.1. Baseline data comparison

Throughout the entire experiment, the 60 subjects had all good compliance and no adverse events occurred. After the experiment, the dropout rate between the experimental group and the control group was 0 %. Following exercise therapy, the control group comprised 30 patients with a mean age of 21.7 ± 0.92 years, a height and body mass index (BMI) of 20.7 ± 4.2 kg/m^2, and a disease duration of 32.9 ± 4.5 weeks. The experimental group also consisted of 30 patients, with a mean age of 21.5 ± 0.83 years, a BMI of 20.5 ± 3.5 kg/m^2, and a disease duration of 32.2 ± 4.7 weeks. No statistically significant differences were observed in age, BMI, or disease duration between the two groups (95%CI: 0.74 to 1.59, p = 0.779; 95%CI: 1.02 to 2.29, p = 0.834; 95%CI: 0.97 to 1.45, p = 0.815), indicating that the baseline characteristics of the subjects were balanced and comparable.

4.2. Comparison of clinical related efficacy indicators

Regarding the comparison of VAS score, the control group's VAS score was 4.00 ± 0.88 and the experimental group's VAS score was 3.74 ± 1.15 in the pre-exercise, demonstrating that there was no significant difference between the two groups (95%CI: 0.41 to 1.13, p = 0.159). In the post-exercise, the control group's VAS score was 2.11 ± 1.52 and the experimental group's VAS score was 1.11 ± 0.81, showing that the VAS score of the control group and the experimental group were significantly decrease from their pre-experiment levels (95%CI: 1.60 to 5.17, p = 0.000; 95%CI: 2.51 to 6.51, p = 0.000). In the post-exercise, the VAS score of experimental group was significantly lower than that of the control group (95%CI: 1.41 to 4.98, p = 0.000). In the post-exercise, the control group's MICD score was 19 (63.33 %) and the experimental group's MICD was 28 (93.33 %), showing that the MICD of experimental group was significantly higher than that of the control group (p = 0.000).

For the comparison of pain symptom score, the control group's pain symptom scores were 4.46 ± 1.17 and the experimental group's were 4.53 ± 0.96 in the pre-exercise, indicating that there was no significant difference between the two groups (95%CI: 0.87 to 0.95, p = 0.748). In the post-exercise, the control group's pain symptom score was 1.63 ± 1.89 and the experimental group pain symptom score were 1.26 ± 1.10, suggesting that the control group's and the experimental group's were significantly decrease from their pre-experiment levels (95%CI: 2.71 to 3.17, p = 0.000; 95%CI: 2.95 to 3.55, p = 0.000). In the post-exercise, the experimental group's was significantly lower than the control group's (95%CI: 1.14 to 1.79, p = 0.011).

In the comparison of clinical efficacy level (Table 1), the two groups' total effective rate was 100 % in the post-exercise. It's worth noting that the experimental group's recovery rate was significantly higher than that of the control group, with a significant difference (p = 0.000).

4.3. Comparison of waist muscles fitness indicators

Table 2 shows that there is no significant difference in back muscle strength between the two groups in the pre-exercise (95%CI: 0.94 to 3.71). The control group's and the experimental group's back muscle strength in the post-exercise were significantly higher than those in the pre-exercise (95%CI: 17.19 to 23.31; 95%CI: 12.85 to 19.49). In the post-exercise, the experimental group's back muscle strength is slightly higher than that of the control group (95%CI: 1.04 to 3.83). As shown in Table 2, the two groups had no significant difference in the prone upper body up's static holding time (95%CI: 1.23 to 2.97), 1-min modified sit-ups' pcs (95%CI: 1.12 to 3.15), the supine abdominal curling's static holding time (95%CI: 1.04 to 2.12), and the supine leg lifting's static holding time (95% CI: 0.86 to 1.96) in the pre-exercise. In the post-exercise, the prone upper body up's static holding time, the 1-min modified sit-ups' pcs, the supine abdominal curling's static holding time, and the supine leg lifting's static holding time of control group, were significant better than that in the pre-exercise (95%CI: 11.34 to 18.23; 95%CI: 7.98 to 19.24; 95%CI: 4.86 to 18.27; 95%CI: 7.75 to 17.23). In the post-exercise, the prone upper body up's static holding time, the 1-min modified sit-ups' pcs, the supine abdominal curling's static holding time, and the supine leg lifting's static holding time of experimental group, were significant better than that in the experimental groups (95%CI: 9.67 to 19.17; 95%CI: 8.56 to 18.12; 95%CI: 6.73 to 19.14; 95%CI: 8.21 to 18.35). In the post-exercise, the 1-min modified sit-up's pcs, the supine leg lifting's static holding time of experimental group were slightly higher than those of control group (95%CI: 1.21 to 4.21; 95%CI: 0.84 to 3.73). In the post-exercise, the prone upper body up's static holding time and the supine abdominal curling's static holding time of experimental group were significantly longer than those of control group (95%CI: 4.16 to 8.32; 95%CI: 3.89 to 7.44).

Table 3
Comparison of the waist movement function's evaluation scores between the two groups ($\bar{x} \pm s$).

Phase	Statistics[1]	Group		Statistics[2]	
		Control	Experimental	t_2	p_2
Pre-exercise		7.89 ± 3.11	7.26 ± 2.63	1.612	0.108
Post-exercise		3.32 ± 2.56	1.47 ± 0.90	19.747	0.000
	t_1	7.537	5.505		
	p_1	0.000	0.000		

Note: 1 is the statistical value of self-comparison pre and post the group; 2 is the statistical value of the simultaneous comparison between groups.

5. Comparison of waist movement function's evaluation scores for ODI

As shown in Table 3, there was no significant difference in the waist movement function's evaluation scores for ODI between the two groups in the pre-exercise (95%CI: 1.67 to 2.16). In the post-exercise, the waist movement function's evaluation scores of the control group and the experimental group were both lower than those in the pre-exercise, with significant differences (95%CI: 3.12 to 5.43; 95%CI: 2.23 to 4.31). Furthermore, the evaluation scores of the experiment group was significantly lower than that of the control group in the post-exercise (95%CI: 1.13 to 2.25).

5.1. Comparison of EMG amplitude

The surface EMG of the lumbar rectus abdominis of the two experiments in pre- and post-exercise is shown in Fig. 2A–D, and the surface EMG of the erector spinae and multifidus muscles of the waist is shown in Fig. 2E–H. The EMG amplitudes of rectus abdominis, erector spinae and multifidus of the two groups were roughly the same in the pre-exercise. While the EMG amplitude of the rectus abdominis, erector spinae, and multifidus muscles of the two groups in the post-exercise was reduced compared to the pre-exercise levels of the respective groups. The experimental group's post-exercise level seemed to be lower than the post-experiment level of the control group.

5.2. Comparison of EMG indicators

As shown in Table 4, there were no significant difference in the rectus abdominis' integrated electromyography (IEMG) values (95%CI: 0.74 to 1.94), erector spinae and multifidus' IEMG values (95%CI: 0.99 to 2.38) between the two groups in the pre-exercise. Post-exercise, the rectus abdominis' IEMG values, erector spinae and multifidus' IEMG values of experimental group were lower than those of control group, there are significant difference (95%CI: 2.36 to 4.47; 95%CI: 2.24 to 4.23). Post-exercise, the rectus abdominis' IEMG values, erector spinae and multifidus' IEMG values of experimental group were significantly lower than in the pre-exercise (95% CI: 2.29 to 4.39; 95%CI: 2.18 to 4.45). However, the rectus abdominis' IEMG values, erector spinae and multifidus' IEMG values of control group in the post-exercise were not significantly different than those in the pre-exercise (95%CI: 1.12 to 1.94; 95%CI: 1.25 to 2.13).

6. Discussion

6.1. Effect of core stability training on CNLBP

When the internal balance of the lumbar spine is out of balance, the strength of a specific set of muscles that maintain the balance of the peripheral spine is reduced, the biomechanical structure of the lumbar spine is unbalanced, and the reflex causes continuous

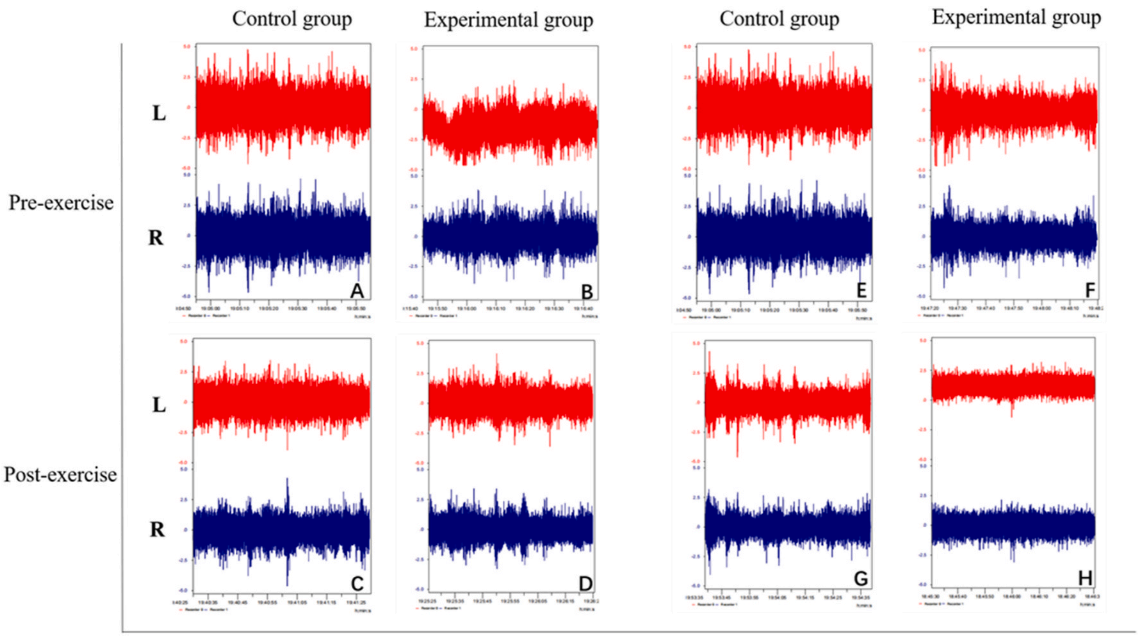

Fig. 2. EMG of trunk flexor and extensor muscle of the control groups and the experimental groups. Note: (A–D) rectus abdominis, (*E*–H) erector spinae and multifidus. L left, R right.

Table 4
Comparison of IEMG of waist muscles between the two groups (μV s, ¯x ± s).

Index	Phase	Statistics[1]	Group		Statistics[2]	
			Control	Experimental	t_2	p_2
Rectus abdominis	Pre-exercise		894.3 ± 140.23	860.9 ± 90.23	1.427	0.115
	Post-exercise		821.2 ± 100.51	623.5 ± 61.83	8.631	0.000
		t_1	1.708	8.601		
		p_1	0.096	0.000		
Erector spinae and multifidus	Pre-exercise		921.5 ± 100.19	936.4 ± 98.05	1.696	0.087
	Post-exercise		866.1 ± 99.51	698.4 ± 72.5	−2.154	0.017
		t_1	1.639	5.992		
		p_1	0.110	0.000		

Note: 1 is the statistical value pre and post within the group; 2 is the statistical value of the simultaneous comparison between groups.

spasms, pain, local congestion and edema of the back muscles, increased fibrin exudation, and soft tissue adhesion, resulting in local pain [7]. The core area muscles can be divided into the deep core muscles and the superficial core muscles. The deep core muscles play an essential role in controlling the stability of the lumbar spine. Responsible for maintaining the neutral position of the lumbar spine [24]. It is the first line of defense to keep the lumbar spine's stability; shallow core and muscles responsible for controlling the direction of movement of the lumbar spine so that the body in motion. To maintain the strength of the lumbar spine, the second line of defense. The stability and protection of the lumbar spine require the joint improvement of the muscle fitness of the waist's deep muscles and the muscle fitness of the superficial muscles. After sports rehabilitation training, the VAS scores and pain symptom scores of chronic non-specific waist passers of core stability training group and the conventional strength training group were lower than those in the pre-experiment. The experimental group's is lower compared between groups. In addition, the MCID of the core stability training group was significantly higher than that of the conventional strength training group. It shows that both core stability training and traditional strength training can effectively improve the symptoms of low back pain. However, regular exercise in the core area is significantly better than conventional strength training. This is consistent with relevant scholars' research findings at home and abroad [25,26]. Sports rehabilitation training can promote blood circulation, improve soft tissue nutrition, promote inflammation absorption, improve spasm, promote the healing of damaged soft tissue in the waist, and thus reduce pain. Core stability training is superior to conventional strength training in improving lumbar stability and neuromuscular control [27]. Therefore, the core stability training has a better effect on muscle cramps and low back pain, and improve the treatment effectiveness for CNLBP. This study also used the ODI questionnaire to assess waist movement function [28], and the results found that the improvement of waist movement function in the core stability training group was more significant than that in the conventional strength training group, which is consistent with the results of Norris [29]. The above research shows that compared with traditional training of strength, core stability training can better affect CNLBP. This study suggests that this difference in therapeutic efficacy may be related to the superiority of core stability training in improving patient muscle function, and for the first time, an audit study was conducted and subsequent analysis was conducted.

6.2. Effect of core stability training on the muscle function of CNLBP

In this study, the 1-min modified sit-up's performance indirectly reflects the subjects' abdominal muscle dynamic strength and dynamic strength endurance. The supine abdominal curling's static holding time and the supine leg lifting's static holding time are chosen to indirectly measure the static stability of the abdominal muscles and the static strength endurance, and the prone upper body up's static holding time is chosen to reflect the static strength and static strength endurance of the back muscles, while the hand-held muscle strength tester is used to directly measure the back muscle strength. From the prone upper body up's static holding time, the 1-min modified sit-up's pcs, the supine abdominal curling's static holding time, and the supine leg lifting's static holding time, those of both groups in the pre-exercise were better than those in the pre-exercise. In addition, the prone upper body up's static holding time, the supine abdominal curling's static holding time and the supine leg lifting's static holding time of the experimental group were significantly longer than those of the control group. Scholar Bronfort recruited 301 patients with CNLBP, divided into two groups to receive either conventional strength training and core stability training. After 12 weeks of exercise rehabilitation training, the static strength endurance of abdominal muscle, static strength endurance of lower back muscle, dynamic strength endurance of abdominal muscle and dynamic strength endurance of lower back muscle in the core stability training group were significantly improved compared with the conventional strength training group [30,31]. The above research shows that the core stability training can improve CNLBP muscle function better than conventional strength training.

The IEMG is the sum of the area under the curve per unit time from the measured electrical signal in the surface electromyogram after rectification and filtering. According to the change of the site under the curve, the muscle electrical signal's strength can be reflected, which is one of the essential reference indicators reflecting the strength of muscle tolerance [32,33]. When body motion is generated, muscle contraction occurs discharge phenomenon. The more significant the IEMG values of a specific part of the muscle when the subject completed the prescribed movement, the more motor units need to be recruited to complete the movement. The more full the discharge of the powers, the more tired the muscles of the corresponding parts, the worse the muscle fitness. On the contrary, the smaller the IEMG values, explain that it needs to recruit fewer motor units to complete this action. The muscles of the corresponding part are less prone to fatigue, the stronger its muscle fitness. Compared to pre-exercise rehabilitation training, CNLBP subjects whose the IEMG values under completed lumbar fixation of erector spinae, rectus abdominis and multifidus of core stability training group decreased significantly in the post-exercise rehabilitation training, but those of the conventional strength training group did not change significantly. This also further confirms that the core stability training can better improve CNLBP muscle fitness than conventional strength training [34]. One side, this is due to the better improvement effect of core stability training on the overall lumbar muscle strength of CNLBP patients. Therefore, it is not necessary to mobilize a large number of motor units to complete the same movement, and the external manifestation is a decrease in IEMG values. On the other hand, this may also be related to the improvement effect of core stability training on neuromuscular control ability. Improving neuromuscular control ability leads to energy savings in the lower back muscles when completing the same movement, resulting in reduced mobilization of motor units and a decrease in IEMG values.

Comparative of the therapeutic effects on CNLBP and muscle function of core stability training and conventional strength training.

This study was conducted to investigate the correlation between the therapeutic effect on CNLBP and the improvement of muscle function by core stability training. The experimental group used Swiss balls for core stability training, while the control group was given conventional dynamic strength training with bare hands. It found that the therapeutic effect on CNLBP of core stability training in the experimental group is better than that of conventional strength training in the control group. In addition, core stability training is better than conventional strength training in improving muscle function of CNLBP. There is a positive correlation between the therapeutic effect of CNLBP and the improvement of muscle function. Waist conventional power strength training focused on the waist superficial muscle [35,36]. Core stability training can not only exercise the superficial muscles of the waist, more significantly, it can exercise the waist-deep muscles (local stability muscles) and nerve-muscle control. Therefore, core stability training can effectively stimulate the superficial and deep muscles of the entire core area [37]. Therefore, it can better improve the strength and endurance of the whole core muscle group and maintain the stability of the lumbar spine, better improve the spasm of the affected muscles and promote blood circulation, improve the nutrition of soft tissues, promote inflammation absorption, and promote the healing of damaged soft tissues, to better reduce pain and enhance waist movement function obstacle [7]. Due to limitations in previous research, many rehabilitation therapist have chosen less core stability training for CNLBP, the discovery in this study that the intervention effect of core stability training on CNLBP is superior to conventional strength training will undoubtedly provide rehabilitation therapists with better rehabilitation treatment effects, which is beneficial for improving the rehabilitation treatment effect of CNLBP and encouraging patients to actively accept exercise therapy.

This study only conducted intervention studies on young men with chronic non-specific low back pain, and there is still a lack of systematic comparative research on the intervention effects among different populations; In the future, comprehensive clinical research should be conducted on patients of different genders and age groups. In addition, this study only explored the possible mechanism of the therapeutic effect of core stability training on chronic non-specific low back pain from the perspective of muscle adaptation; In the future, more exploration may be needed from the perspectives of brain nerves, and biochemistry.

7. Conclusion

Core stability training is significantly effective in treating chronic non-specific lower back pain in youth, enhancing lower back muscle function. This therapeutic effect is primarily attributed to the improvement in muscle function.

Declaration of conflicts interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Data availability statement

All data were included in article/supp. Material/referenced in article.

CRediT authorship contribution statement

Simao Xu: Writing – original draft, Investigation, Data curation. **Rui Wang:** Writing – original draft, Methodology, Data curation. **Shuzhen Ma:** Writing – review & editing, Investigation, Conceptualization. **Benxiang He:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e32818.

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