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Combination shock wave therapy and core muscle training reduced analgesic dependence in chronic low back pain: A retrospective cohort analysis of multimodal rehabilitation versus pharmacotherapy alone

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Abstract: **Background**: Few studies examine combined shockwave and core training for chronic low back pain (CLBP) analgesic dependence. **Objectives**: This study compared multimodal rehabilitation (shock wave therapy plus core muscle training) with pharmacotherapy alone for analgesic dependence in CLBP patients. **Methods**: Clinical data were retrospectively collected from 187 consecutive CLBP patients admitted to Jiangbin Hospital of Guangxi Zhuang Autonomous Region between January 2024 and June 2025. After exclusion, 184 patients were enrolled and divided into a multimodal rehabilitation group (shock wave therapy, core muscle exercises and routine medications; n=94) and a monotherapy group (pharmacotherapy only; n=90). 1:1 propensity score matching (PSM) produced 86 matched cases per group. The primary endpoints were analgesic dosage and the incidence of analgesic dependence. Secondary outcomes included the Visual Analogue Scale (VAS), Oswestry Disability Index (ODI), back extensor endurance, side-bridge holding time, lumbar range of motion, Hamilton Anxiety Rating Scale (HAMA) and Hamilton Depression Rating Scale (HAMD) scores and adverse events. Multivariate logistic regression was performed to identify independent predictors of analgesic dependence in CLBP patients. **Results**: After PSM, baseline characteristics were balanced between groups (all $P > 0.05$). At 12-week follow-up, the multimodal rehabilitation group showed lower analgesic dosage and analgesic dependence rate than the medication-only group (both $P < 0.05$). Both groups showed improvements in VAS, ODI, HAMA, and HAMD scores (all $P < 0.05$), with the multimodal group showing better outcomes (all $P < 0.001$). The multimodal group also exhibited greater enhancements in Sorensen test time, side-bridge duration and lumbar range of motion (all $P < 0.001$). No significant between-group difference in adverse events was observed ($P = 0.109$). Therapeutic strategy and baseline analgesic dosage were independent predictors of analgesic dependence (all $P < 0.05$). **Conclusion**: Multimodal rehabilitation combining shock wave therapy and core muscle training is more effective in reducing analgesic dependence in CLBP patients.

Keywords: Chronic low back pain; Core muscle training; Multimodal rehabilitation; Medication dependence; Shock wave therapy

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INTRODUCTION

Chronic low back pain (CLBP) is a relatively common musculoskeletal disorder characterized by discomfort confined to the lower back, lumbosacral, and hip areas, lasting more than 12 weeks, regardless of whether it is accompanied by radiation of pain or numbness to the lower limbs (Maharty *et al.*, 2024). Its etiology is multifactorial and is typically associated with degenerative changes in spinal structure, impaired muscle function, neuromodulation disorders and various psychological effects. In addition to causing persistent physical discomfort, CLBP often restricts lumbar mobility and impairs trunk function, significantly limiting patients' daily activities, occupational performance and overall quality of life (Thiveos *et al.*, 2024, Hayden *et al.*, 2021).

The clinical goals of CLBP remain pain relief, improved function, and enhanced quality of life and are addressed through diverse treatment strategies. Common ones include medication, physical therapy, rehabilitation exercises and surgery. Among them, due to its convenience and speed, drug therapy has become the most widely used first-line treatment method. Commonly used analgesics include nonsteroidal anti-inflammatory drugs, opioid analgesics and muscle relaxants (Abd-Elsayed *et al.*, 2025). These drugs can effectively relieve pain and restore some physical functions in the short term, but long-term use carries risks, with analgesia dependence being one of the most prominent complications (Blanco-Gimenez *et al.*, 2024). Analgesia dependence refers to a condition in which the body adapts to long-term drug exposure, requiring continuous increases in dosage to achieve a comparable

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pain relief effect. Discontinuing medication may trigger withdrawal symptoms, while psychological dependence often occurs, leading patients to become overly dependent on medication rather than addressing underlying physical dysfunction (Zhou *et al.*, 2024, Nijs *et al.*, 2024). This pattern may further exacerbate functional limitations and perpetuate chronic pain. In addition, long-term use of analgesics is associated with gastrointestinal injury, liver and kidney dysfunction, cardiovascular adverse events and other systemic complications that impair long-term health. Thus, identifying strategies that reduce pain while minimizing analgesic dependency has become a clinical challenge (Cashin *et al.*, 2023).

With the rapid development of rehabilitation medicine, multimodal rehabilitation has gradually replaced monotherapy and become the preferred strategy for CLBP. Its core principle lies in integrating multiple treatment approaches while simultaneously addressing physical function, neuroregulation and psychological states (Liu *et al.*, 2023). Shock wave therapy is an innovative physical intervention that has been widely used in the management of chronic musculoskeletal pain. Applying high-energy pressure waves to the painful area can improve local blood circulation, release fibrotic adhesions, inhibit nociceptive transmission, promote tissue repair and offer advantages such as non-invasiveness, good therapeutic effects and reliable safety (Li *et al.*, 2022).

Core muscle training is another key focus of CLBP rehabilitation. The core muscles are essential for maintaining spinal posture, power transmission and protecting the spine and pelvis from overload. Most patients with chronic peritonitis exhibit core muscle dysfunction, characterized by delayed activation, inhibition, or impaired coordination (Franks *et al.*, 2023). Such defects can lead to segmental instability in the spinal cord, abnormal load distribution and postural disorders, thereby causing or exacerbating lower back pain. Core training restores the pre-activation capacity of internal spinal stabilizers by selectively activating deep stabilizing muscles and optimizing neuromuscular control (Hansford *et al.*, 2023). It can also enhance core strength and endurance, improve trunk load resistance, optimize posture control and normalize spinal stress distribution. From a biomechanical perspective, these effects can reduce pain triggers, interrupt the vicious pain cycle, provide stable mechanical support for the lumbar spine and lower the risk of pain recurrence (Li *et al.*, 2025).

According to the literature, for patients with CLBP, shockwave therapy or core muscle training alone can effectively reduce pain and improve physical function. Although shock wave therapy can provide rapid pain relief, its impact on core muscle dysfunction is minimal, leading to underlying spinal instability issues that remain largely unresolved (Ahn *et al.*, 2024). In contrast, core training can enhance spinal stability and muscle performance, but pain relief tends to be slower. For patients with severe pain, this delayed response may reduce treatment adherence. Therefore, combining shock wave therapy with core muscle training is a promising direction in CLBP treatment (Alqhtani *et al.*, 2024).

Crucially, significant research gaps remain in current published studies. Firstly, most previous studies focused on a single physical intervention (extracorporeal shock wave) or a single core muscle training, and the relevant evidence mainly focused on pain severity and lumbar physical function outcomes; almost no original studies have examined analgesic dependence, a critical clinical adverse outcome of long-term analgesic administration. Secondly, prior monomodal rehabilitation schemes cannot simultaneously achieve rapid pain mitigation and spinal biomechanical reconstruction, which fail to cut off the linkage between persistent pain, long-term medication demand and drug dependence. Thirdly, no published research has clarified the clinical efficacy and independent influencing factors of this combined multimodal rehabilitation regimen on analgesic consumption and analgesic dependence among CLBP patients.

Compared with previous single-mode rehabilitation research, the present study produces substantial innovations and advancements. Clinically, this combined multimodal strategy integrates rapid neuro-mediated analgesia from shock wave therapy and long-term biomechanical improvement from core muscle training, thereby overcoming the respective limitations of the two single therapies. Methodologically, this study first treats analgesic dependence as the primary outcome rather than conventional pain and functional indicators, thereby complementing existing clinical evidence. Moreover, after propensity score matching (PSM) baseline balancing, this retrospective cohort study further explores independent risk factors of analgesic dependence, providing targeted clinical references for reducing analgesic overuse and drug dependence in CLBP population.

To address the aforementioned research gap, this study retrospectively analyzed the clinical data of patients diagnosed with CLBP and admitted to Jiangbin Hospital of Guangxi Zhuang Autonomous Region. The effects of multimodal rehabilitation, including shock wave therapy combined with core muscle training and monotherapy, on analgesia dependence were compared, and factors associated with drug dependence were identified.

MATERIALS AND METHODS

Patients and methods

Study design

This is a retrospective observational study and no causal inference is drawn in this analysis. From January 2024 to

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June 2025, clinical data were collected from 187 patients diagnosed with CLBP. After exclusion, 184 individuals were ultimately retained for formal analysis. Then, these patients were divided into two distinct groups according to the treatment strategies they received: one group received multimodal rehabilitation (n=94), including shock wave therapy, core muscle training, and medication; the other group received monotherapy (n=90), with medication alone. All participants received at least 12 weeks of treatment. To minimize confounding bias from baseline characteristics, PSM was used in a 1:1 ratio, yielding 86 matched pairs per study group (Fig. 1).

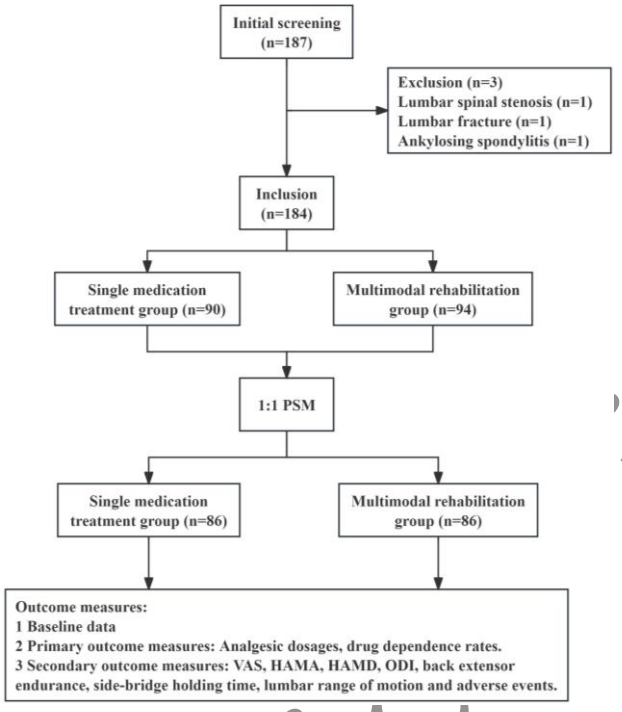


Fig. 1: Research flowchart.
Legend: 187 patients were initially screened in this study; after exclusions, 184 cases were included; after PSM, 172 cases were included in the subsequent analysis, with 86 cases in each group. Note: PSM: propensity score matching; VAS: Visual Analog Scale; HAMA: Hamilton Anxiety Rating Scale; HAMD: Hamilton Depression Rating Scale; ODI: Oswestry Disability Index.

Inclusion criteria

(1) The patient was diagnosed with chronic obstructive pulmonary hypertension according to the diagnostic criteria listed in the 2021 edition of the "Clinical Guidelines for Chronic Musculoskeletal Pain." The pain is confined to the lumbosacral area, lumbar vertebrae and buttocks, with or without radial numbness or pain and extends to the lower limbs (Tong, 2021). (2) All included cases were confirmed to have non-specific CLBP. (3) Participants experienced persistent low back pain lasting ≥12 weeks, with no significant spontaneous remission observed in the past four weeks. (4) Age ranged from 18 to 75 years (Masroor *et al.*, 2023). (5) The patient completed at least 12 weeks of standardized treatment, with clearly documented treatment plans, continuous implementation and fully traceable treatment records. (6) Complete and comprehensive medical records were available for all included subjects. (7) Patients with analgesic dependence enrolled in this study were diagnosed with analgesic dependence syndrome based on unified, internationally validated International Classification of Diseases-11th Revision (ICD-11) official diagnostic criteria for substance dependence syndrome (Harrison *et al.*, 2021). Critically, this study strictly distinguishes clinical definitions among analgesic dependence, simple prolonged medication use, pain-driven dose escalation and physiological drug tolerance. Simple prolonged analgesic administration and unilateral dose escalation caused by uncontrolled primary lumbago pain, as well as routine physiological drug tolerance induced by standardized regular analgesic medication, are explicitly excluded from the diagnostic scope of analgesic dependence. Only patients who meet complete ICD-11 diagnostic indicators of substance dependence, including typical physical and psychological drug withdrawal symptoms, compulsive medication craving and uncontrollable automatic dose-taking behavior, are uniformly defined as analgesic dependent cases in the present research.

Exclusion criteria

(1) Patients with identifiable etiologies of specific low back pain were excluded, such as acute lumbar disc herniation, lumbar spinal stenosis, lumbar fracture, spinal tumor, spinal infection, ankylosing spondylitis, rheumatoid arthritis and other organic spinal disorders, as verified by medical records and imaging. (2) Individuals with severe lumbar deformity, lumbar surgery within the past year, or chronic pain in other regions (e.g., cervical spondylosis, knee osteoarthritis) that exceeded low back pain in severity were excluded. (3) Patients with severe lumbar nerve root compression accompanied by notable complications, including reduced lower extremity muscle strength or defecation and urination dysfunction, were not enrolled. (4) Those with severe comorbidities were excluded, including serious cardiovascular and cerebrovascular diseases, hepatic or renal failure, coagulation disorders and malignant tumors. (5) Patients with cognitive impairment, psychiatric disorders (such as schizophrenia, severe anxiety or depression), or impaired consciousness were excluded from the study (Arcanjo *et al.*, 2022). (6) Individuals who discontinued treatment voluntarily or modified their therapeutic regimen during the intervention period were removed from the analysis.

Data extraction

Baseline information was collected from the week before the start of treatment, including demographic and clinical characteristics, pain and function assessment scores,

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psychological status scores, and baseline analgesic medication use. After 12 weeks (±3 days) of treatment, data on analgesic consumption, pain, functional outcomes, and psychological evaluation were extracted again. Adverse events recorded during the 12-week treatment period were also compiled to ensure that outcome measures accurately reflected the intervention duration and maintained full traceability. After data extraction, double-blind cross-checking and independent reviewer verification were conducted.

Treatment regimens and analgesic medication use

Multimodal rehabilitation group

(1) *Extracorporeal shock wave therapy*: All patients in this group received shock wave therapy using an extracorporeal shock wave device (model SW1000, Beijing Huayi Shengjie Medical Technology Co., Ltd., China). The treatment targets the most sensitive lumbosacral region. The treatment parameters are set to 8–12 Hz and 0.20–0.35 MPa, delivering 1500–2000 pulses per session. The course is scheduled twice a week, each lasting 15 to 20 minutes and lasts for at least 12 consecutive weeks without any recorded interruptions (Ma *et al.*, 2022).

(2) *Core muscle training*: Specific exercises included transverse abdominis activation, multifidus training, plank exercises, side-bridge holds and gluteal bridges. Training was performed three times per week, with each session lasting 30–40 minutes and intensity was gradually increased from low to moderate levels over the course of treatment (Zuo *et al.*, 2024). Strict on-site supervision was implemented throughout the intervention by professional physiotherapists. Real-time compliance monitoring and attendance checks were conducted for every training session. All enrolled patients completed the full course of training with a 100% attendance rate and no unexcused absences or early termination were observed during the 12-week period. Patients' rehabilitation compliance and treatment satisfaction were uniformly recorded at the end of the intervention. Exercise adherence was closely tracked as a key indicator, given its critical impact on rehabilitation outcomes. Notably, no standardized home-based exercise protocol was developed in this study; all core muscle training was completed in the hospital under professional supervision, and no additional home rehabilitation exercises were required for participants.

(3) *Analgesic medication*: Analgesic agents prescribed included celecoxib capsules (200 mg per capsule, Pfizer Inc., USA), ibuprofen sustained-release capsules (0.3 g per capsule, Sino-American Tianjin Smith Kline and French Laboratories Ltd., China) and eperisone hydrochloride tablets (50 mg per tablet, Eisai (China) Co., Ltd., China) (Cashin *et al.*, 2025).

The relevant medication details are listed below:

1. Drug selection criteria: Prescribing principles for celecoxib, ibuprofen and eperisone hydrochloride were clearly defined based on clinical assessment.
2. Dose adjustment protocols: Specific guidelines for dose adjustment during treatment were implemented.
3. Rescue medication: The administration of rescue analgesics for acute pain flare-ups was documented in detail.
4. Baseline analgesic exposure: The duration and intensity of analgesic use prior to intervention were recorded.
5. Opioid exclusion: All opioid-containing medications were strictly excluded in this study.

Single medication treatment group

Patients in this group received the same categories of analgesic medications as those in the multimodal rehabilitation group, with a treatment course of no less than 12 weeks. No instances of unauthorized changes in medication type, dosage, or premature discontinuation were identified in any patient's medical history. Regular follow-up and medication adherence monitoring were performed for all participants. Patients' satisfaction with pharmacotherapy was evaluated upon treatment completion. All participants fully followed the medication regimen and health education guidance throughout the study. According to a retrospective review of clinical progress notes, participants in this arm received only basic health education, such as advice to avoid prolonged sitting or standing, maintain proper posture, and refrain from excessive lumbar loading.

Outcome measures

Primary outcome measures

Analgesic dosage: Daily analgesic intake (mg/d) was calculated at baseline and at 12 weeks after treatment. Record the types of analgesics used and any dose adjustments and conduct an analysis using the average daily dose (Cashin *et al.*, 2025).

Incidence of analgesic dependence: Increase the dosage to maintain analgesic effect; withdrawal symptoms occur when discontinuing medication and patients request an increased dose or an extended duration of administration. The incidence of analgesia dependence is calculated as (number of dependent cases/total number of cases) × 100% (Elyn *et al.*, 2025).

Secondary outcome measures

Visual analogue scale (VAS): Use a VAS ruler (Model: VAS-100; Shanghai Kangge Medical Device Co., Ltd., China) to assess pain intensity. The rating ranges from 0 (no pain) to 10 (unbearable severe pain) (Li *et al.*, 2025).

Oswestry disability index (ODI): Assess lower back dysfunction using the Chinese version of ODI, covering 10 areas: pain intensity, personal care, weightlifting, walking, sitting, standing, sleep, sexual activity, social life and travel. The score for each item ranges from 0 to 5, with a total score of 0 to 50; the higher the score, the more severe the functional limitations (Li *et al.*, 2025).

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Sorensen test (Back Extensor Endurance): The endurance of the posterior extensor muscles was measured using a standard posture assessment device (Model: ZT-100; Beijing Zetai Medical Technology Co., Ltd., China) and an electronic stopwatch (Model: ST-800; Shenzhen Jingzhen Electronics Co., Ltd., China). The patient lies on their stomach with the pelvis fixed, arms crossed over their chest, and maintains a horizontal posture until they can no longer maintain a stable horizontal position (Alqhtani *et al.*, 2024).

Side-bridge holding time: The evaluation was conducted using an electronic stopwatch (model ST-800) and a spirit level (model SP-300; Shanghai Kyoto Instrument Co., Ltd., China). The patient adopts a side bridge position, with the elbows directly below the shoulders, legs extended, and the body vertically aligned, until a noticeable sagging occurs (Alqhtani *et al.*, 2024).

Lumbar range of motion: The lumbar vertebrae were measured using a lumbar angle analyzer (Model: LY-200; Nanjing Leyou Medical Technology Co., Ltd., China), with a range of 0–180° and an accuracy of 0.1°. The patient stands with feet at shoulder width and the device is fixed at the corresponding waist position (Siglan and Colak, 2023).

Hamilton anxiety rating scale (HAMA) / Hamilton depression rating scale (HAMD) scores: Trained clinicians rated patients based on clinical manifestations and responses. HAMA scores ranged 0–56; scores ≥14 indicated anxiety. HAMD scores ranged 0–78: ≥24 marked severe depression, 17–23 moderate, 7–16 mild and <7 no depression. All ratings were recorded in medical records (Collinet *et al.*, 2023).

Incidence of adverse events: Adverse events (including gastrointestinal discomfort, skin redness, dizziness, etc.) were identified from medical records and adverse reaction reports during treatment and follow-up. Timing, type, management and outcome were documented. The incidence rate was calculated as (number of events / total patients) × 100% and cross-checked by two researchers to avoid omissions (Johnson *et al.*, 2022).

Ethical statement

The study was performed in strict accordance with the Declaration of Helsinki. The Ethics Committee of Jiangbin Hospital of Guangxi Zhuang Autonomous Region approved all procedures. Informed consent was waived for this retrospective study.

Sample size calculation

Based on a previous randomized trial, a 27.5% reduction in pain intensity was defined as the minimum clinically important improvement for CLBP treated with non-steroidal anti-inflammatory drugs (NSAIDs) (Hansford *et al.*, 2023). With a two-sided $\alpha = 0.05$ and statistical power = 0.90, the calculation indicated that a minimum of 152 participants per group was required. To offset potential case loss during PSM, Extra participants were recruited.. A total of 172 patients were initially enrolled in each group before matching, which exceeded the calculated minimum sample size. After 1:1 PSM, unmatched cases were excluded, leaving 86 patients in each group for subsequent analyses. Using the final sample size of 86 participants per group, the minimum detectable effect size was calculated. For binary outcomes such as analgesic dependence rate, the study could detect a relative reduction of approximately 27.57% in event rate. For continuous outcomes, the minimum detectable standardized effect size (Cohen's d) was 0.60, indicating the ability to identify moderate between-group differences.

Statistical analysis

All statistical analyses were performed using SPSS 26.0 (IBM Corp., Armonk, NY, USA). To reduce selection bias, 1:1 nearest-neighbor PSM was performed in this study. The propensity score model incorporated age, gender, body mass index (BMI), disease course, hypertension, diabetes, osteoarthritis, predisposing factors of low back pain and profession. A total of 184 patients were enrolled, including 90 in the single-medication group and 94 in the multimodal rehabilitation group. After matching, 86 pairs were successfully matched and 12 unmatched cases were excluded. The caliper width was set at 0.02 for nearest-neighbor matching. The standardized mean difference (SMD) was used to assess the balance of baseline characteristics between groups, and an SMD of less than 0.2 indicated acceptable balance. Normality was tested using the Kolmogorov-Smirnov test and homogeneity of variance using Levene's test. Normal data are expressed as mean ± standard deviation (SD); paired t-tests were used for intra-group comparisons and independent-samples t-tests were used for inter-group comparisons. Non-normal data are expressed as medians (interquartile ranges) [M(Q1, Q3)] and analyzed using the Wilcoxon test (within groups) and the Mann-Whitney U test (between groups). Classification data are reported in the form of n (%) and compared using the chi-square test or the Fisher exact test. Multiple logistic regression was used to identify risk factors for CLBP analgesia dependence. Variables with $P < 0.10$ in the univariate analysis were entered into the model after exclusion of multicollinearity. Effect sizes were reported as odds ratios (OR) with 95% confidence intervals (CI). A two-sided $P < 0.05$ was considered statistically significant.

RESULTS

Baseline characteristics

After PSM, baseline data were well balanced between the two groups. In terms of age, the single medication treatment group had a mean age of (52.34 ± 5.39) years, while the multimodal rehabilitation group was

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(53.36 ± 5.38) years, with a between-group P value of 0.214, Cohen's D of 0.190 and SMD of 0.189.For gender distribution, 37 males (43.0%) and 49 females (57.0%) were included in the single medication treatment group, compared with 36 males (41.9%) and 50 females (58.1%) in the multimodal rehabilitation group; the between-group difference was not significant ($P = 0.877$), with a Phi coefficient of 0.012 and SMD of 0.024. BMI averaged (24.30 ± 1.19) kg/m² in the medication group and (24.50 ± 1.18) kg/m² in the rehabilitation group, yielding $P = 0.263$, Cohen's D = 0.171 and SMD = 0.169. Disease duration was with $P = 0.197$, Cohen's D = 0.197 and SMD = 0.198. The P-values for hypertension, diabetes and osteoarthritis were 0.856, 0.823 and 1,000, respectively. Corresponding Phi coefficients were all far below 0.1 and SMD values were minimal, suggesting no meaningful intergroup differences. The proportion of each trigger of low back pain was similar between the two arms ($P = 0.882$), with Cramer's V = 0.038 and SMD = 0.076. Occupational status was divided into sedentary office work, manual labor and other types and no significant between-group differences were observed (P = 0.931), with Cramer's V = 0.029 and SMD = 0.057. All baseline variables showed $P > 0.05$, accompanied by very small effect sizes and SMD values. These findings collectively confirm that after 1:1 PSM, baseline homogeneity between the two groups was satisfactory and intergroup comparability was adequately achieved, supporting further comparative analyses of therapeutic efficacy (Table 1).

Analgesic medication dosage

At baseline, the mean daily analgesic dosage was comparable between the two groups with no statistically significant difference. Patients in the single medication treatment group had a mean dosage of (241.03 ± 7.51) mg, whereas those in the multimodal rehabilitation group had a mean dosage of (242.76 ± 7.77) mg. Between-group comparison yielded P = 0.141 and Cohen's d = 0.225, with a 95% CI for the mean difference ranging from −4.02 to 0.58. Since the interval crossed zero, it further confirmed that baseline analgesic dosage was similar between groups. After 12 weeks of treatment, both groups showed a marked reduction in analgesic dosage compared with baseline and these changes were statistically significant (all $P < 0.05$). Intergroup comparisons showed a greater reduction in the multimodal rehabilitation group (P < 0.001), with a Cohen's d effect size of 11.408. The 95% CI for differences between groups after treatment ranged from 97.24 to 102.51, excluding zero. This result further supports that multimodal rehabilitation may be superior to monotherapy in reducing analgesic consumption (Table 2).

Incidence of analgesic dependence

After 12 weeks of treatment, the incidence of analgesic dependence in the monotherapy group decreased slightly to 18 cases (20.9%), with no significant difference compared with baseline. In contrast, the incidence in the multimodal rehabilitation group dropped markedly to 6 cases (7.0%), showing a statistically significant intra-group reduction relative to pre-treatment values (all $P < 0.05$). Between-group comparison after treatment showed $P = 0.201$ and a Phi coefficient of 0.008. Combined with intra-group changes, these findings suggest that single medication therapy only slightly alleviates analgesic dependence, whereas the multimodal rehabilitation program consisting of shock wave therapy combined with core muscle training is associated with a reduced risk of analgesic dependence in patients with CLBP, yielding superior effects compared with conventional medication alone (Table 3).

VAS, HAMA, HAMD and ODI

Baseline values of VAS pain score, HAMA anxiety score, HAMD depression score and ODI disability index were comparable between the two groups with no significant intergroup differences. The single medication treatment group had a VAS score of (6.76 ± 0.85) versus (6.77 ± 0.84) in the multimodal rehabilitation group ($P = 0.928$, Cohen's D = 0.014, 95%CI for mean difference: −0.27 to 0.24). HAMA scores were (13.28 ± 2.08) and (13.33 ± 2.00), respectively ($P = 0.881$, Cohen's D = 0.023, 95%CI: −0.67 to 0.57). HAMD scores were (12.28 ± 2.08) and (12.33 ± 2.00), respectively ($P = 0.881$, Cohen's D = 0.023, 95%CI: −0.66 to 0.57). ODI scores were (33.97 ± 3.33) and (34.01 ± 3.26), respectively ($P = 0.926$, Cohen's D = 0.014, 95%CI: −1.04 to 0.94). All 95% CIs at baseline crossed zero, with negligible effect sizes, further confirming satisfactory baseline balance. Following 12 weeks of treatment, all four outcomes decreased significantly in both groups relative to baseline (all $P < 0.05$). Improvements were significantly more pronounced in the multimodal rehabilitation group, with highly significant between-group differences (all $P < 0.001$). VAS score declined to (4.36 ± 0.48) in the medication group and (1.84 ± 0.72) in the rehabilitation group (Cohen's D = 4.127, 95%CI: 2.34 to 2.71). HAMA scores fell to (8.65 ± 2.10) and (3.59 ± 1.86), respectively (Cohen's D = 2.547, 95%CI: 4.46 to 5.66). HAMD scores decreased to (7.65 ± 2.10) and (2.60 ± 1.81), respectively (Cohen's D = 2.573, 95%CI: 4.46 to 5.64). ODI index dropped to (23.03 ± 2.49) and (10.99 ± 2.40), respectively (Cohen's D = 4.918, 95%CI: 11.31 to 12.78). None of the post-treatment 95% CIs included zero, accompanied by large Cohen's D effect sizes. These results demonstrate that multimodal rehabilitation is superior to single medication therapy in relieving low back pain, alleviating anxiety and depression and reducing lumbar functional disability (Table 4).

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Table 1: Baseline clinical data [mean±SD, n (%)].

Indicators	After PSM				
	Single medication treatment group (n=86)	Multimodal rehabilitation group (n=86)	*P*	Effect size	SMD
Age (years, mean±SD)	52.34±5.39	53.36±5.38	0.214	Cohen's D=0.190	0.189
Gender (n %)	-	-	0.877	Phi=0.012	0.024
Male	37 (43.0)	36 (41.9)	-	-	-
Female	49 (57.0)	50 (58.1)	-	-	-
BMI (kg/m^2, mean±SD)	24.30±1.19	24.50±1.18	0.263	Cohen's D=0.171	0.169
Course of disease (months, mean±SD)	17.66±4.36	18.52±4.35	0.197	Cohen's D=0.197	0.198
Hypertension (n %)	19 (22.1)	20 (23.3)	0.856	Phi=0.014	0.028
Diabetes (n %)	11 (12.8)	12 (14.0)	0.823	Phi=0.017	0.034
Osteoarthritis (n %)	15 (17.4)	15 (17.4)	1.000	Phi<0.001	0.000
Predisposing factors of low back pain (n %)	-	-	0.882	Cramer's V=0.038	0.076
Strain and trauma	51 (59.3)	50 (58.1)	-	-	-
Degeneration and cold exposure	27 (31.4)	26 (30.2)	-	-	-
No obvious predisposing cause	8 (9.3)	10 (11.6)	-	-	-
Profession (n %)	-	-	0.931	Cramer's V=0.029	0.057
Sedentary office work	43 (50.0)	42 (48.8)	-	-	-
Manual labor	26 (30.2)	25 (29.1)	-	-	-
Others	17 (19.8)	19 (22.1)	-	-	-

Note: BMI: Body Mass Index; PSM: Propensity Score Matching; SMD: Standardized Mean Difference.

Table 2: Comparison of analgesic dosages [mean±SD].

Indicators		Single medication treatment group (n=86)	Multimodal rehabilitation group (n=86)	*P*	Effect size (Cohen's D)	*95%CI of the difference*
Analgesic dosages (mg)	*Before treatment*	241.03±7.51	242.76±7.77	0.141	0.225	-4.02,0.58
	After treatment	212.95±5.31*	113.08±11.18*	<0.001	11.408	97.24,102.51

Note: **P*<0.05 vs. Before Treatment; 95%CI: 95% Confidence Interval.

Table 3: Comparison of drug dependence rates [n (%)].

Indicators	Single medication treatment group (n=86)	Multimodal rehabilitation group (n=86)	*P*	Effect size (Phi)
Before treatment	21 (24.4)	22 (25.6)	0.860	0.013
After treatment	18 (20.9)	6 (7.0)*	0.201	0.008

Note: **P*<0.05 vs. Before Treatment.

Table 4: Comparison of VAS, HAMA, HAMD and ODI [mean±SD].

Indicators		Single medication treatment group (n=86)	Multimodal rehabilitation group (n=86)	*P*	Effect size (Cohen's D)	*95%CI of the difference*
VAS (scores)	*Before treatment*	6.76±0.85	6.77±0.84	0.928	0.014	-0.27,0.24
	After treatment	4.36±0.48*	1.84±0.72*	<0.001	4.127	2.34,2.71
HAMA (scores)	*Before treatment*	13.28±2.08	13.33±2.00	0.881	0.023	-0.67,0.57
	After treatment	8.65±2.10*	3.59±1.86*	<0.001	2.547	4.46,5.66
HAMD (scores)	*Before treatment*	12.28±2.08	12.33±2.00	0.881	0.023	-0.66,0.57
	After treatment	7.65±2.10*	2.60±1.81*	<0.001	2.573	4.46,5.64
ODI (scores)	*Before treatment*	33.97±3.33	34.01±3.26	0.926	0.014	-1.04,0.94
	After treatment	23.03±2.49*	10.99±2.40*	<0.001	4.918	11.31,12.78

Note: **P*<0.05 vs. Before Treatment; VAS: Visual Analogue Scale; HAMA: Hamilton Anxiety Rating Scale; HAMD: Hamilton Depression Rating Scale; ODI: Oswestry Disability Index.

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Table 5: Comparison of back extensor endurance, side-bridge holding time and lumbar range of motion [mean±SD].

Indicators		Single medication treatment group (n=86)	Multimodal rehabilitation group (n=86)	*P*	Effect size (Cohen's D)	*95%CI of the difference*
Back extensor endurance (s)	*Before treatment*	44.48±3.76	44.50±3.70	0.967	0.006	-1.15,1.10
	After treatment	46.77±3.48*	82.15±4.28*	<0.001	9.075	-36.56,-34.21
Side-bridge holding time (s)	*Before treatment*	37.53±3.72	37.50±3.70	0.951	0.009	-1.08,1.15
	After treatment	38.93±3.44*	72.15±4.28*	<0.001	8.552	-34.39,-32.05
Lumbar range of motion (°)	*Before treatment*	31.49±3.75	31.50±3.70	0.984	0.003	-1.13,1.11
	After treatment	33.93±3.42*	56.15±4.28*	<0.001	5.737	-23.39,-21.05

Note: **P*<0.05 vs. Before treatment.

Table 6: Comparison of adverse events [n (%)].

Indicators	Single medication treatment group (n=86)	Multimodal rehabilitation group (n=86)	*P*	Effect size (Phi)
Gastrointestinal discomfort (nausea, abdominal distension)	8 (9.3)	3 (3.5)	0.119	0.119
Local soft tissue soreness and distending pain / mild tenderness	1 (1.2)	5 (5.8)	0.096	0.127
Dizziness and mild headache	4 (4.7)	1 (1.2)	0.173	0.104
Transient rebound soreness in the waist	5 (5.8)	2 (2.3)	0.247	0.088
Total	18 (20.9)	11 (12.8)	0.154	0.109

Back extensor endurance, side-bridge holding time and lumbar range of motion

After 12 weeks of treatment, the back extensor endurance, side-bridge holding time and lumbar range of motion showed only slight improvement compared to baseline in the monotherapy group (all $P < 0.05$), whereas a significant increase was observed in the multimodal rehabilitation group, with highly significant differences between groups (all $P < 0.001$). The 95% CIs after treatment did not include zero, and all Cohen's d Effect sizes were relatively large. These findings suggest that a multimodal rehabilitation program combining shock wave therapy and core muscle training is associated with enhanced back extensor endurance, lateral core stability, and lumbar range of motion in patients with chronic abdominal muscle expansion syndrome and may be more effective than monotherapy (Table 5).

Incidence of adverse events

All adverse events in both groups were mild and transient, with no serious adverse events, treatment interruptions, or life-threatening responses observed, indicating good overall safety. In the monotherapy group, 8 patients (9.3%) experienced gastrointestinal discomfort, 4 patients (4.7%) experienced dizziness and headache, 5 patients (5.8%) experienced transient low back pain, and only 1 patient (1.2%) experienced mild local soft-tissue pain and tenderness. In the multimodal rehabilitation group, adverse events were dominated by local soft-tissue soreness and tenderness, affecting 5 patients (5.8%). The incidence of gastrointestinal discomfort, dizziness and headache, and transient lumbar soreness was relatively low: 3 patients (3.5%), 1 patient (1.2%), and 2 patients (2.3%), respectively. Between-group comparisons for each individual adverse event showed no statistically significant differences, with all *P* values > 0.05 and low Phi coefficients. For gastrointestinal discomfort, $P = 0.119$ and Phi = 0.119; for local soft tissue soreness and tenderness, $P = 0.096$ and Phi = 0.127; for dizziness and headache, $P = 0.173$ and Phi = 0.104; and for transient lumbar soreness, $P = 0.247$ and Phi = 0.088. Regarding total adverse events, 18 cases (20.9%) were reported in the single medication treatment group and 11 cases (12.8%) in the multimodal rehabilitation group, with a between-group P value of 0.154 and a Phi coefficient of 0.109, indicating no statistically significant difference (Table 6).

Multivariate logistic regression analysis for risk factors of analgesic dependence in patients with CLBP

Table 7 presents the results of multivariate logistic regression analysis exploring independent correlates of analgesic dependence among patients with CLBP. In this fully adjusted model, daily analgesic dosage (β=0.387, OR=1.473, 95%CI: 1.191–1.820, P<0.001) and treatment regimen (multimodal rehabilitation versus medication alone; β=3.964, OR=52.680, 95%CI: 14.369–193.142, P<0.001) were identified as statistically significant correlates of analgesic dependence. By contrast, age, gender, BMI, disease course, comorbid hypertension and diabetes, combined osteoarthritis, predisposing factors of low back pain, occupation, baseline VAS pain score, HAMA, HAMD, ODI, back extensor endurance, side-bridge holding time and lumbar range of motion showed no statistically significant association with analgesic dependence (all P>0.05).

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Table 7: Multivariate logistic regression analysis of influencing factors for analgesic drug dependence in patients with CLBP.

Indicators	β	OR	95%CI for OR	*P*
Age	0.006	1.006	0.783,1.293	0.963
Gender	1.793	6.008	0.635,56.802	0.118
BMI	-0.281	0.755	0.183,3.108	0.697
Course of disease	0.077	1.080	0.971,1.201	0.156
Hypertension	-0.402	0.669	0.077,5.842	0.716
Diabetes	-0.172	0.842	0.033,21.671	0.917
Osteoarthritis	-1.226	0.294	0.008,10.900	0.506
Predisposing factors of low back pain	0.869	2.385	0.449,12.682	0.308
Profession	-0.728	0.483	0.155,1.506	0.210
VAS	0.059	1.061	0.172,6.549	0.949
HAMA	-0.787	0.455	0.110,1.890	0.279
HAMD	-0.787	1.061	0.172,6.549	0.279
ODI	0.745	2.107	0.243,18.241	0.499
Back extensor endurance	0.899	2.457	0.166,36.398	0.513
Side-bridge holding time	-1.833	0.160	0.004,6.036	0.322
Lumbar range of motion	0.013	1.013	0.422,2.431	0.977
Analgesic dosages	0.387	1.473	1.191,1.820	<0.001
Treatment protocol	3.964	52.680	14.369,193.142	<0.001

Notably, as acknowledged in the study limitations, this regression model did not incorporate several clinically critical potential confounders, including prior duration of analgesic medication use, detailed socioeconomic status indicators, granular stratification of pain chronicity severity and more comprehensive baseline psychological characteristic variables. Accordingly, the observed associations should be interpreted with caution rather than regarded as definitively causal risk factors for analgesic dependence.

DISCUSSION

In this retrospective cohort analysis, the association between a multimodal rehabilitation program combining shock wave therapy and core muscle training and analgesic dependence in patients with CLBP was explored. After PSM adjustment, baseline characteristics were well balanced and comparable between the two groups. Following 12 weeks of intervention, lower analgesic consumption and a lower proportion of patients presenting with analgesic dependence were observed in the multimodal rehabilitation group relative to the medication-only group. Multivariate logistic regression analysis indicated that treatment modality and baseline analgesic dosage were independently associated with analgesic dependence in this cohort. For secondary outcomes, both groups exhibited within-group improvements in pain intensity and functional disability from baseline. Nevertheless, relative improvements in the VAS score, ODI index, anxiety and depression scales, as well as physical functional indicators, including back extensor endurance, side bridge holding time, and lumbar range of motion, were numerically greater in the multimodal rehabilitation group. Numerically larger declines in HAMA and HAMD scores were also noted among patients receiving combined rehabilitation. Several plausible explanatory pathways may account for these observed mood differences. Structured regular physical activity is commonly associated with mood regulation and mitigation of negative emotional states in chronic pain populations. Moreover, progressive pain relief and physical functional gains may correlate with improved patient self-efficacy over time. In addition, targeted core stabilization training and functional rehabilitation might coincide with reductions in kinesiophobia and activity-related fear-avoidance behaviors, which could partially accompany the alleviation of anxiety and depressive symptoms in this sample. No statistically significant intergroup difference in the overall incidence of adverse events was identified.

Several potential psychological and contextual biases should also be acknowledged in this retrospective cohort study. First, the placebo effect cannot be fully ruled out: patients receiving regular physical intervention may obtain subjective pain relief associated with psychological suggestion. Second, treatment expectation bias existed in both groups and participants might report favorable self-reported outcomes due to positive treatment expectations. Furthermore, patients in the multimodal rehabilitation group acquired more frequent therapist communication and one-on-one professional supervision during shock wave therapy and core muscle training, which was correlated with extra psychological comfort and improved treatment compliance. Meanwhile, increased clinical medical attention among rehabilitation participants may cause

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attention bias, which could affect patient-reported pain intensity, emotional state and analgesic medication behaviors. Notably, given the inherent limitations of retrospective observational design, these unmeasured confounding biases, rather than single intervention effect, may partially account for the observed inter-group outcome differences. Overinterpretation of definite pathological mechanisms, reduction of long-term analgesic dependence, and generalized rehabilitation optimization should be avoided in the present study.

The lower risk of analgesic dependence is associated with synergistic effects of the multimodal rehabilitation regimen. Shock wave therapy produces analgesic effects primarily by inhibiting central sensitization. Previous studies have confirmed that shock wave intervention can downregulate neurotrophic factors in dorsal root ganglia and spinal dorsal horn and suppress the activity of pain-related molecules, thereby inhibiting the transmission of peripheral nociceptive signals to the central nervous system (Wang *et al.*, 2022, Huang *et al.*, 2025). Core muscle training alleviates chronic pain by improving lumbar biomechanics, enhancing spinal stability, and relieving soft-tissue spasm. Relevant studies indicate that standardized core stability training can regulate pain-related neurohumoral levels and relieve persistent pain discomfort in patients with CLBP, without affecting cortisol metabolism (Wu *et al.*, 2023, He, 2022). The stable pain control achieved by rehabilitation further reduces the demand for long-term medication. In this study, all patients were treated with celecoxib, ibuprofen and eperisone, which do not cause physical addiction. However, long-term use for chronic pain commonly leads to drug tolerance, psychological dependence and compulsive medication behavior. Shock wave therapy provides rapid pain relief and improves patients' compliance with training; core muscle training improves lumbar function and maintains long-term curative effects (Majidi *et al.*, 2024, Dagistan *et al.*, 2025). The combined intervention significantly cuts down the total dosage and duration of medication and effectively relieves medication-related behavioral dependence and drug tolerance. This study did not detect biomarkers, including brain-derived neurotrophic factor (BDNF), endorphins, and substance P, nor did it conduct neuroimaging studies. Accordingly, the relevant mechanistic elaborations are presented as research hypotheses rather than as conclusive interpretations.

A systematic review and meta-analysis previously reported that extracorporeal shock wave therapy may significantly reduce pain intensity and functional disability in patients with CLBP in the short term (Yue et al., 2021), findings that align with the improvements in pain and functional outcomes observed in the multimodal rehabilitation group. That review also noted no serious adverse events related to shock wave treatment, consistent with the safety profile seen in the present study. Regarding core stability training, a meta-analysis including 23 studies and 1132 patients demonstrated that 8–12 weeks of such training produces strong effects on pain relief and functional improvement (Dimitrijevic *et al.*, 2025). The 12-week observation period matches the optimal treatment duration suggested by that research. The same study also reported that core stability training may be superior to general spinal stabilization exercises for pain relief, supporting the choice of core muscle training as a key component of the intervention. Nonetheless, some studies suggest that physical therapy alone may have limited efficacy in reducing opioid use. One investigation examining early physical therapy on opioid burden in CLBP found that only 3.3% of patients in the physical therapy and functional training group required opioids, compared with 60% continuing opioid use in the medication group; yet no significant difference was observed between groups in the reduction of subjective pain scores (Martin *et al.*, 2020). Differences may arise from variations in study design, patient characteristics and intervention protocols. The study employed an integrated multimodal strategy rather than isolated physical therapy.

This work has novel aspects. This study may be the first to systematically evaluate the effect of shock wave therapy combined with core muscle training on analgesia dependence for chronic abdominal pain, filling an important research gap in this field. Most previous studies have focused on shock waves or core training itself, with insufficient exploration of their synergistic effects. The study employs a multimodal rehabilitation framework that combines physical therapy with exercise-based rehabilitation, reflecting an innovative shift in chronic pain management from a single model to a multimodal strategy. Analgesic reliance was selected as the primary endpoint, rather than pain-relief effectiveness alone, representing an innovative shift in perspective.

Limitations and future directions

This study also has limitations. In a retrospective cohort study, residual confounding from unmeasured variables may persist despite PSM controlling for known confounders. The matched sample size of 86 patients per group may be insufficient to detect intergroup differences in certain secondary outcomes or may lead to unstable effect-size estimates. For a chronic disease that typically lasts for many years, a 12-week follow-up period is relatively short. Long-term data are lacking, so it cannot be assessed whether the protective effect against analgesic dependence will persist over time or whether delayed dependence may develop. From a mechanistic perspective, biomarkers of central sensitization and endogenous opioid system activity were not directly measured in this observational study. Interpretations of potential

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mechanisms are largely based on inferences from published literature instead of direct evidence from the study population. Future research should include large-sample, multicenter randomized controlled trials to validate these findings, alongside long-term follow-up to evaluate sustained outcomes. This study did not perform analyses of clinical significance and minimal clinically important difference (MCID) for the VAS and ODI. Future prospective randomized trials should adopt the MCID to distinguish trivial minor numerical fluctuations from symptomatic and functional improvements perceptible to patients and with genuine clinical therapeutic value. This regression model did not incorporate several clinically critical potential confounders, including prior duration of analgesic medication use, detailed socioeconomic status indicators, granular stratification of pain chronicity severity and more comprehensive baseline psychological characteristic variables. Accordingly, the observed associations should be interpreted with caution rather than regarded as definitively causal risk factors for analgesic dependence.

CONCLUSION

For CLBP patients, a multimodal rehabilitation regimen combining shock wave therapy and core muscle training may be more effective in reducing the risk of analgesic dependence than medication alone. Given the retrospective design and limited observation period, these findings should be interpreted with caution. High-quality randomized controlled trials and long-term follow-up are needed to further confirm these results.

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Author's contributions
Huiyu Zhang and Feifei Zhou: Edited and refined the manuscript with a focus on critical intellectual contributions and provided substantial intellectual input during the drafting and revision of the manuscript; Feifei Zhou and Shaoping Lin: Participated in collecting, assessing and interpreting the data, and made significant contributions to data interpretation and manuscript preparation. All authors have read and approved the final manuscript.

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Data availability statement
The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethical approval
This study was approved by the Ethics Committee of Jiangbin Hospital of Guangxi Zhuang Autonomous Region (ZYYSY2025-09). This study was performed in adherence with the STROBE guidelines. See supplementary file for the STROBE checklist.

Conflict of interest
The authors declare no conflict of interest.

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