Postprint of a Retrospective Study Using Wearable Gait Analysis to Evaluate Comprehensive Traditional Chinese Medicine Therapy for Qi Stagnation and Blood Stasis Pattern Lumbar Disc Herniation

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Date: 2022-12-01T00:00:00+00:00

Abstract

Background: In clinical practice, Traditional Chinese Medicine (TCM) conservative treatment has demonstrated definite efficacy in patients with lumbar disc herniation (LDH), and its mechanism of action and biomechanical effects are currently hot topics of research. Objective: To analyze the gait of LDH patients with qi stagnation and blood stasis pattern before and after treatment using wearable inertial sensors, and to verify the therapeutic advantages of integrated TCM therapy through biomechanical methods. Methods: Data of inpatients diagnosed with LDH and differentiated as qi stagnation and blood stasis syndrome were retrospectively collected. Patients sequentially received integrated TCM therapy including acupuncture, tuina, Chinese patent medicine, and TCM directional drug permeation for no less than one week. Changes in gait analysis parameters, pain, and functional impairment before and after treatment were compared. Results: A total of 40 patients were included. After treatment with integrated TCM therapy, the therapeutic effect was definite, and no obvious adverse events occurred. Post-treatment, the Visual Analogue Scale (VAS) for pain, Oswestry Disability Index (ODI) for lumbar function, and Japanese Orthopaedic Association (JOA) lumbar function score were significantly decreased compared with pre-treatment values ($P<0.05$). After treatment, the spatiotemporal parameters, joint rotation angles, and symmetry index in gait analysis all showed significant changes ($P<0.05$), while changes in pelvic range of motion in all directions and flexion-extension range of motion of hip, knee, and ankle joints showed no significant difference ($P>0.05$). Conclusion: Integrated Traditional Chinese Medicine therapy can significantly improve pain and functional impairment in LDH patients with qi stagnation and blood stasis pattern,

increase dynamic stability during walking, and represents a safe and effective conservative treatment regimen.

Full Text

Preamble

Title: Retrospective Study on Evaluating Integrated Traditional Chinese Medicine Therapy for Lumbar Disc Herniation with Qi Stagnation and Blood Stasis Syndrome Using Wearable Gait Analysis

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Abstract

Background: In clinical practice, conservative treatment with traditional Chinese medicine (TCM) demonstrates clear therapeutic efficacy for patients with lumbar disc herniation (LDH), and its mechanisms of action and biomechanical effects represent current research hotspots.

Objective: This study employed wearable inertial sensors to analyze gait parameters in LDH patients with qi stagnation and blood stasis syndrome before and after treatment, verifying the advantages of integrated TCM therapy through biomechanical methods.

Methods: We retrospectively collected data from hospitalized patients diagnosed with LDH and classified with qi stagnation and blood stasis syndrome according to TCM pattern differentiation. All patients sequentially received integrated TCM therapy—including acupuncture, Tuina, Chinese patent medicine, and TCM directional drug permeation—for no less than one week. Changes in gait analysis parameters, pain levels, and functional disability were compared before and after treatment.

Results: A total of 40 patients were included. Integrated TCM therapy produced definitive therapeutic effects without significant adverse events. Post-treatment scores for the Visual Analogue Scale (VAS), Oswestry Disability Index (ODI), and Japanese Orthopaedic Association (JOA) scores significantly decreased compared with baseline ($P<0.05$). Gait analysis revealed significant

changes in spatiotemporal parameters, joint rotation angles, and symmetry indices after treatment ($P<0.05$), while pelvic range of motion in all directions and flexion-extension ROM of the hip, knee, and ankle joints showed no significant changes ($P>0.05$).

Conclusion: Integrated TCM therapy can significantly improve pain and functional disability in LDH patients with qi stagnation and blood stasis syndrome, enhancing dynamic stability during walking. This represents a safe and effective conservative treatment approach.

Keywords: Integrated traditional Chinese medicine therapy; Gait analysis; Lumbar disc herniation; Biomechanics; Inertial measurement units

Introduction

Lumbar disc herniation (LDH) is a common clinical condition characterized by pathological disc protrusion that irritates or compresses nerves, resulting in low back pain, radicular pain, unilateral or bilateral lower limb numbness and pain, and even abnormalities in bowel and bladder function [1]. Epidemiological surveys indicate that the prevalence of LDH is approximately 2-4%, with incidence slightly higher in females as age increases [2, 3]. Current treatment modalities primarily include conservative therapy, medication, minimally invasive procedures, and surgery. Most clinical guidelines recommend conservative treatment as the initial approach, with individualized treatment plans based on clinical presentation, herniation location, and degree of nerve root compression.

Due to changing work and lifestyle patterns, the incidence of LDH continues to rise annually. Research directions both domestically and internationally have gradually shifted from mechanistic studies to explorations of human biomechanics, with gait analysis demonstrating substantial potential for intervention, rehabilitation, and exercise training in this condition [4, 5]. Walking involves the most joint activities and repetitions in daily life, and biomechanical gait analysis provides important insights into the pathogenesis, progression, and prognosis of LDH. Scientifically validated gait analysis technologies include infrared camera and force platform systems, markerless motion capture systems, and wearable inertial sensor systems. While infrared camera technology is commonly used domestically, its stringent requirements for personnel and facilities limit clinical applicability and large-scale trials. Wearable inertial sensor systems offer advantages of simple operation, low facility requirements, and accurate, rich data recording. Therefore, we conducted a retrospective analysis of 40 LDH patients who underwent gait analysis using a wearable inertial sensor system before and after treatment, aiming to explore the biomechanical changes during integrated TCM therapy and provide recommendations for optimizing conservative treatment protocols for LDH.

1.1 Study Subjects

We retrospectively collected data from 607 patients admitted to the Department of Tuina at the Affiliated Hospital of Changchun University of Chinese Medicine between June 2020 and December 2021 with an admission diagnosis of LDH. Based on diagnostic and inclusion/exclusion criteria, 40 patients were ultimately included in the retrospective analysis. This study was approved by the Medical Ethics Committee of the Affiliated Hospital of Changchun University of Chinese Medicine (Approval No.: CCZYFYLL-SQ-2020-0171).

1.1.1 Diagnostic Criteria

Western medicine diagnostic criteria followed the "Guidelines for the Diagnosis and Treatment of Lumbar Disc Herniation" [1], requiring corresponding history, symptoms, signs, and imaging findings consistent with neurological localization. TCM pattern differentiation criteria followed the "Diagnostic and Therapeutic Criteria for TCM Diseases and Patterns" [6], identifying qi stagnation and blood stasis syndrome characterized by severe low back pain radiating to the lower limbs, worsening at night, rigid lumbar region, limited flexion and rotation, tender or fixed pain sites, dark purple tongue or with ecchymosis, and wiry or choppy pulse.

1.1.2 Inclusion and Exclusion Criteria

Inclusion Criteria: (1) Met the above diagnostic and TCM pattern differentiation criteria; (2) Received sequential integrated TCM therapy for no less than one week; (3) Had not taken antidepressants or analgesic medications; (4) Visual Analogue Scale (VAS) score $ $4; (5) No restrictions on sex or ethnicity, age $ $18 years.

Exclusion Criteria: (1) Patients with severe cognitive or communication impairments or poor questionnaire completion; (2) Patients with severe osteoporosis, bone metastasis, intraspinal space-occupying lesions, bone injury, spina bifida occulta, or spondylolysis; (3) Patients lacking key clinical information or gait analysis data.

1.2 Integrated TCM Treatment Protocol

Treatment Principles: During the acute phase, the principle was to relieve spasms and pain through gentle, soothing Tuina maneuvers, with joint manipulation techniques contraindicated or used with caution to gradually alleviate pain symptoms. During the remission and recovery phases, the principle was to eliminate obstruction and unblock meridians to relieve pain, applying integrated TCM therapy to further reduce pain and improve functional disability.

1.2.1 Tuina Treatment

Performed according to the "Low Back Pain Treatment Protocol" for LDH in the Department of Tuina at the Affiliated Hospital of Changchun University of Chinese Medicine. (1) **Treatment Areas:** Focused on the lumbosacral region and buttocks, supplemented by abdominal and lower limb areas, with emphasis on the Bladder Meridian pathway. (2) **Tuina Techniques:** Included kneading, rolling, thumb pressure, and lumbar oblique pulling maneuvers. (3) **Treatment Duration:** Tuina therapy was administered once daily for approximately 30 minutes per session, followed by lumbar oblique pulling maneuvers every other day (three times per week).

1.2.2 Acupuncture Treatment

Performed according to the acupuncture treatment protocol for LDH in the above-mentioned guidelines. (1) **Point Selection Principle:** Primarily local points along the Governor Vessel, lumbar Huatuojiaji points, Bladder Meridian, Stomach Meridian, and Gallbladder Meridian, with additional neural trunk stimulation along the sciatic nerve pathway in the lower limbs. (2) **Technique:** Filiform needle insertion with even reinforcing-reducing method. (3) **Treatment Duration:** Once daily with 30-minute needle retention.

1.2.3 Oral Chinese Patent Medicine

Yaotuitongning Capsule (hospital preparation of the Affiliated Hospital of Changchun University of Chinese Medicine, Approval No.: Ji Yao Zhi Zi Z20170064), composed of processed Rehmannia root, processed Drynaria rhizome, processed Cibotium rhizome, Spatholobus stem, calcined Dragon bone, calcined Oyster shell, processed Frankincense, Coix seed, Lycopodium, Achyranthes root, and processed Corydalis rhizome. Functions: unblocking meridians, dispelling stasis, and relieving pain. Dosage: 6 capsules orally, three times daily.

1.2.4 TCM Directional Drug Permeation

Using a hospital-prepared purified formulation (hospital preparation of the Affiliated Hospital of Changchun University of Chinese Medicine, composed of purified extracts of Drynaria rhizome, Cibotium rhizome, Tougucao, Pollen Typhae, Impatiens seed, Frankincense, Myrrh, and Kudzu root as a paste for activating blood, dispelling stasis, moving qi, and relieving pain). The paste was applied to the affected area, covered with medical gauze, and irradiated with a microwave therapy device once daily for 15 minutes per session.

1.3 Observation Indices

Gait analysis parameters and low back pain-related scale scores were collected by two physicians working together. (1) **Gait Analysis Parameter Collec-**

tion: Using Movit G1 wearable inertial sensors (Captiks Srl, Italy) and Captiks Motion Studio (Movit System - Gait Analysis) software. Patients wore tight-fitting clothing with seven inertial sensors attached via Velcro to the pelvis (at L5 level), bilateral mid-femur lateral aspects, bilateral tibia lateral aspects (slightly above the ankle), and bilateral dorsal foot surfaces. After adequate adaptation to the environment and equipment, patients walked naturally in a straight line for 10 meters, repeated three times to obtain complete gait data (see Figure 1 [Figure 1: see original paper]).

Figure 1 Wearing of inertial measurement units. Note: (a) Placement of wearable inertial sensors; (b) Gait analysis testing.

(2) **Low Back Pain-Related Scale Scores:** VAS score; Japanese Orthopaedic Association (JOA) score; Oswestry Disability Index (ODI) score.

(3) **Efficacy Criteria (Treatment-Related Indices):** Visual Analogue Scale (VAS) was used to assess improvement degree before and after treatment. According to the "Clinical Disease Diagnostic Criteria for Cure and Improvement," changes in pre- and post-treatment scores were recorded and categorized into four levels: cured (score improvement $ $90%), markedly effective (90% > improvement $ $75%), effective (75% > improvement $ $50%), and ineffective (improvement <50%). Total effective rate (%) = (cured cases + markedly effective cases + effective cases) / total cases × 100%.

1.4 Statistical Analysis

SPSS 26.0 statistical software was used for analysis. The Shapiro-Wilk test verified data normality. Measurement data were described as (±s). Paired t-tests were applied to analyze differences in treatment efficacy before and after intervention. P<0.05 indicated statistically significant differences.

2.1 Baseline Data (see Table 1)

Table 1 General data analysis of patients with lumbar disc herniation (±s, n=40)

Parameter	Value
Age (years)	52.85$±15.17\|\|$Height(cm)$\|170.19±9.71\|\|$Weight(kg)$|73.95±
Affected side (cases): Left/Right/Bilateral	18/22/8

2.2 Analysis of Score Changes Before and After Treatment

Pain and functional disability scores showed significant changes before and after treatment (P<0.05). According to clinical efficacy criteria, 35 cases were effective or markedly effective after integrated TCM therapy, with 5 cases ineffective,

yielding a total effective rate of 87.5%. Detailed score comparisons are shown in Table 2 .

Table 2 Comparison of JOA, ODI, and VAS scores before and after treatment (±s, n=40)

Scale	Before Treatment	After Treatment	P-value
JOA score	11.68$±2.52\|24.55±2.71\| < <0.001 0.001\|\|$ODIscore$\|53.78±6.33\|17.77±7.69\| < 0.001\|\|$VASscore$|7.40±1.25|2.30±$1.09[a]		

Note: [a]P<0.05 compared with before treatment.

2.3 Analysis of Gait Changes Before and After Treatment

Spatiotemporal parameters in gait analysis showed significant changes after treatment (P<0.05), including increased step frequency, walking speed, step length, gait cycle duration, stance phase percentage, and impact forces on the tibia and foot, with decreased swing phase percentage. Details are shown in Table 3 .

Table 3 Comparison of spatiotemporal gait parameters before and after treatment (±s, n=40)

Parameter	Before Treatment	After Treatment	P-value
Step frequency (steps/min)	103.31$±9.33\|107.54±7.08\|<0.001 0.001\|\|$Walkingspeed(m/s)$\|0.96±0.19\|1.03±0.14\| < 0.001\|\|$Steplength(m)$\|1.05±0.14\|1.15±0.14\| < 0.001\|\|$Gaitcycle(s)$\|1.13±0.11\|1.19±0.12\| < 0.001\|\|$Stancephase(±2.29|61.14±3.56| < 0.001||$Swingphase(±2.29\|38.86±3.56\| < 0.001\|\|$Tibialimpactforce(g)$\|2.88±0.28\|2.98±0.28\| < 0.001\|\|$Plantarimpactforce(g)$|3.16±0.16|3.23±$0.18[a]		

Note: [a]P<0.05 compared with before treatment.

Post-treatment analysis revealed increased pelvic obliquity but decreased pelvic tilt and rotation, though ROM changes were not significant. Hip adduction/abduction and rotation ROM showed significant changes (P<0.05), while flexion/extension ROM showed no significant change. Knee varus/valgus and rotation ROM demonstrated significant changes (P<0.05), while flexion/extension ROM did not. Ankle rotation ROM showed significant change (P<0.05), while varus/valgus and flexion/extension ROM showed no significant changes. Details are shown in Table 4 .

Table 4 Comparison of joint ROM before and after treatment (±s, n=40)

Joint ROM (°)	Before Treatment	After Treatment	P-value
Hip adduction/abduction	2.89$±1.22|3.00±1.17|0.396||*Hipflexion/extension*|3.83±1.73|3.60±1.26|0.969||*Hiprotat*		
	0.001||*Kneevarus/valgus*|9.60±2.77|7.87±2.64| <		
	0.001||*Kneeflexion/extension*|29.83±6.31|28.43±4.49|0.969||*Kneerotation*|11.15±4.09|8		
	0.001||*Anklevarus/valgus*|9.82±3.68|7.63±3.41| <		
	0.001||*Ankleflexion/extension*|44.24±4.51|45.28±7.90|0.969||*Anklerotation*|12.56±4.43|9		

Note: [a]P<0.05 compared with before treatment.

Post-treatment angular symmetry indices increased for all joints, with statistical significance (P<0.05) except for pelvic rotation and knee flexion/extension symmetry indices. Knee varus/valgus symmetry index was excluded from analysis due to missing data. Details are shown in Table 5 .

Table 5 Comparison of angular symmetry indices before and after treatment (±s, n=40)

Symmetry Index (%)	Before Treatment	After Treatment	P-value
Hip adduction/abduction	84.75$±17.11|92.65±7.26|<0.001		
	0.001||*Hipflexion/extension*|69.31±19.15|80.07±16.36| <		
	0.001||*Hiprotation*|89.86±14.01|93.22±7.29| <		
	0.001||*Kneevarus/valgus*|87.16±12.74|87.05±9.58|0.969||*Kneeflexion/extension*|97		
	0.001||*Anklevarus/valgus*|97.84±3.94|98.49±1.70| <		
	0.001||*Ankleflexion/extension*|62.58±24.37|84.52±11.92| <		
	0.001||*Anklerotation*|79.55±21.80|91.27±9.34| <		
	0.001||*Pelvicrotation*|86.88±13.24|95.65±$2.84[a]		

Note: [a]P<0.05 compared with before treatment.

2.4 Adverse Reactions and Follow-up

None of the 40 LDH patients experienced adverse reactions or toxic side effects during hospital treatment, demonstrating good treatment compliance and cooperation. However, during follow-up, 5 patients experienced symptom recurrence or required readmission (12.5%). In the broader cohort of 607 patients, 53 cases experienced recurrence or readmission (8.7%).

Discussion

As research on LDH has progressed, its etiology has been found to involve not only disc degeneration, trauma, and congenital deformities, but also occupational factors, biomechanics, genetics, pregnancy, obesity, and hyperlipi-

demia [7-9]. Modern medical treatment primarily involves non-steroidal anti-inflammatory drugs, opioid analgesics, and surgery. While medications can relieve low back pain and improve some functional status, their effectiveness for neuropathic pain is limited, and issues of side effects and dependence have significantly contributed to the global disease burden [10, 11]. Surgery remains the optimal choice for patients with ineffective conservative treatment, recurrent worsening symptoms, or obvious nerve compression, with minimally invasive lumbar discectomy currently offering the best safety, efficacy, and prognosis, though problems such as revision surgery, dural tears, and nerve root injury persist [12]. Conservative treatment is the preferred approach for patients without obvious neurological symptoms or those refusing surgery.

In TCM, LDH falls under the category of "lumbar-leg pain," primarily caused by traumatic injury, qi stagnation and blood stasis, or liver-kidney deficiency, with treatment focusing on activating blood, dispelling stasis, and relaxing muscles to unblock meridians. Integrated TCM therapy represents an individualized, stage-based conservative treatment approach combining internal herbal medicine with external techniques such as acupuncture and Tuina under TCM theoretical guidance. For qi stagnation and blood stasis syndrome, external acupuncture and Tuina treatments focus on Bladder Meridian points in the lumbar and leg regions, supplemented by Huatuojiaji points and Stomach and Gallbladder Meridian points to relax muscles and unblock meridians. Internal and external herbal formulas use Drynaria rhizome, Cibotium rhizome, Achyranthes root, Spatholobus stem, Frankincense, and Myrrh as principal ingredients to dispel stasis, move qi, and relieve pain. While numerous clinical practices and expert consensus statements have confirmed the effectiveness of TCM therapies, their mechanisms of action have been explained only in terms of promoting inflammation resolution and disc herniation reduction [13-15], with insufficient evidence-based medical evidence and limited biomechanical research.

Numerous domestic and international studies have analyzed human movement and biomechanics using wearable inertial sensors or other technologies [16-18], providing objective data evaluation for clinical trials. This retrospective study employed a novel gait analysis method—the wearable inertial sensor system—which features low equipment and software requirements, simple operation, good patient acceptance, and reliable results [19-21]. This approach not only demonstrates the effectiveness of TCM therapy from a biomechanical perspective but also offers new possibilities and approaches for biomechanical research on conservative treatment of this condition. Our results show that integrated TCM therapy significantly reduced pain and functional disability in LDH patients, with efficacy and safety non-inferior to rehabilitation exercise or pharmacological treatment. Gait analysis revealed positive effects on gait and joint movement improvements, promoting body movement stability and symmetry, particularly evident in enhanced stability of hip, knee, and ankle movements. These improvements may be related to the therapy' s ability to reduce muscle tension, inhibit radicular pain, enhance dynamic stability of lumbar segmental muscles, promote neural regulation, and correct movement alignment [22-24], while demonstrat-

ing advantages in low adverse reactions and improved quality of life, providing evidence-based support for TCM treatment of LDH. Previous studies reported recurrence rates of 15-25% for LDH conservative treatment [25, 26], while this retrospective study showed a recurrence rate of approximately 10%, lower than other treatment methods. However, due to the large time span of collected cases and non-uniform follow-up duration, these recurrence rates should be considered reference values only. Additionally, among the 40 included LDH patients, BMI measurements showed 15 cases (37.5%) were overweight (24≤BMI<28) and 10 cases (25%) were obese (BMI$ $28), with an overweight rate of 62.5% and obesity rate of 25%, consistent with latest epidemiological findings [27, 28], suggesting that high BMI should be a key focus for prevention and treatment in mild LDH patients.

This retrospective study represents initial research using wearable inertial sensor systems to analyze integrated TCM therapy for LDH and has several limitations. First, due to methodological constraints, the lack of a control group prevents comparison with other conservative therapies or healthy controls. Gait analysis research in this disease remains an evolving field, with current studies demonstrating good validity and reliability of wearable inertial sensors for spatiotemporal parameters, though improvements in study design are needed for spatiotemporal variability and joint kinematics to provide standardized protocols and application techniques. Although studies analyzing healthy individuals' gait parameters exist, the lack of strict experimental protocols, different processing techniques, and large variations among subjects prevent unified analytical standards [21, 29]. Second, the large time span of collected cases prevented uniform follow-up timing, lacking an objective prognostic indicator. Third, while this study demonstrates the efficacy and advantages of TCM in LDH treatment, the complex nature of integrated TCM therapy makes quality control challenging, with insufficient detailed interpretation of gait analysis data and incomplete clinical guidance. Future studies should not only improve evidence-based medical quality but also refine and optimize TCM intervention protocols to enrich evidence-based support for TCM treatment of LDH.

Author Contributions

YAO Junjie conceived the research idea, collected and organized data, and wrote the manuscript; WANG Yufeng organized data, provided statistical design input, and assisted with editing and revision; LI Jiahui and LIU Chang collected data; PANG Tingting performed statistical analysis; SHANG Qiangqiang managed the project, provided conceptual guidance, and supervised and reviewed the article.

Conflict of Interest

The authors declare no conflict of interest.

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Note: Figure translations are in progress. See original paper for figures.