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Effects of a Tailored Exercise Intervention on Pain, Muscle Strength, Functional Performance and Disability in Patients with Piriformis Syndrome: A Pilot Study

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ABSTRACT:

Background: Piriformis syndrome is a common neuromuscular condition characterized by buttock pain, sciatic nerve irritation, reduced muscle strength, impaired functional mobility, and disability. Although physiotherapy remains the cornerstone of conservative management, evidence regarding individualized exercise interventions is limited. This study evaluated the effectiveness of a tailored exercise intervention on pain, muscle strength, functional performance, and disability in patients with piriformis syndrome.

Methodology: A prospective, parallel-group, pilot randomized controlled trial was conducted over four weeks involving 100 patients with clinically diagnosed piriformis syndrome. Participants were randomly allocated into Group A (Tailored Exercise Intervention; n=50) and Group B (Conventional Physiotherapy; n=50). Primary outcome was pain intensity assessed using the Visual Analog Scale (VAS). Secondary outcomes included hip muscle strength measured using a handheld dynamometer, functional performance assessed by the Lower Extremity Functional Scale (LEFS) and Timed Up and Go (TUG) test, hip internal rotation range of motion, and disability evaluated using the Oswestry Disability Index (ODI). Assessments were performed at baseline and at the end of four weeks. Statistical analysis was conducted using SPSS version 27.0 with $p<0.05$ considered statistically significant.

Results: Both interventions significantly improved all clinical outcomes after four weeks. However, participants receiving the tailored exercise intervention demonstrated significantly greater reductions in pain and disability together with superior improvements in hip muscle strength, functional performance, hip internal rotation, and LEFS scores compared with those receiving conventional physiotherapy ($p<0.001$).

Conclusion: A four-week tailored exercise intervention produced superior clinical outcomes compared with conventional physiotherapy in patients with piriformis syndrome. Individualized exercise programs may represent an effective conservative treatment strategy for reducing pain, restoring muscle function, and improving physical performance and quality of life.

BACKGROUND

Piriformis syndrome is a neuromuscular disorder resulting from irritation or compression of the sciatic nerve by the piriformis muscle within the deep gluteal region [1]. It commonly presents with deep buttock pain radiating along the posterior aspect of the thigh, often mimicking lumbar radiculopathy or other causes of sciatica. Although the exact prevalence remains uncertain because of diagnostic challenges, piriformis syndrome is estimated to account for approximately 6–8% of cases of low back pain associated with sciatic symptoms. Delayed diagnosis frequently leads to persistent pain, functional impairment, reduced work productivity, and diminished quality of life [2].

The piriformis muscle functions as an important external rotator and stabilizer of the hip joint during standing, walking, and dynamic lower-limb activities. Muscle spasm, inflammation, hypertrophy, repetitive overuse, trauma, or anatomical variations may increase pressure on the adjacent sciatic nerve, producing pain, paresthesia, muscle weakness, and movement limitations [3]. Patients frequently experience pain during prolonged sitting, stair climbing, squatting, and transitions from sitting to standing, indicating substantial impairment in activities of daily living.

Clinical diagnosis is primarily based on patient history, physical examination, and provocation tests such as the FAIR (Flexion-Adduction-Internal Rotation) test, Freiberg maneuver, Pace sign, Beatty maneuver, and palpation of the piriformis muscle. Imaging modalities including magnetic resonance imaging (MRI) and ultrasonography are mainly used to exclude lumbar disc pathology, hip disorders, or other causes of sciatic nerve compression rather than to confirm piriformis syndrome. Consequently, accurate clinical assessment remains essential for appropriate management [4].

Conservative treatment is considered the first-line approach for piriformis syndrome. Conventional physiotherapy generally consists of superficial heat therapy, transcutaneous electrical nerve stimulation (TENS), therapeutic ultrasound, stretching exercises, strengthening exercises, posture correction, and activity modification. Although these interventions often provide symptomatic relief, treatment outcomes may vary considerably because standard rehabilitation protocols do not adequately address individual biomechanical deficits, muscle imbalances, movement dysfunctions, or functional limitations [5].

Tailored exercise interventions have recently gained attention as a patient-centered rehabilitation strategy that individualizes exercise prescription according to each patient's impairments, functional capacity, pain severity, muscle weakness, flexibility deficits, and movement patterns. Such programs commonly integrate piriformis-specific stretching, progressive strengthening of the hip abductors and external rotators, gluteal muscle activation, core stabilization, neuromuscular re-education, balance training, and functional movement retraining [6]. By targeting the underlying biomechanical contributors to piriformis syndrome, tailored exercise programs may achieve superior improvements compared with standardized physiotherapy protocols.

Previous investigations have demonstrated that exercise therapy effectively reduces pain and enhances physical function in patients with musculoskeletal disorders [7]. Strengthening of the gluteal musculature improves pelvic stability and decreases compensatory overload on the piriformis muscle, while flexibility exercises reduce muscle tightness and mechanical compression of the sciatic nerve. Furthermore, neuromuscular training improves movement efficiency, balance, and coordination, thereby reducing recurrent symptoms and improving long-term functional outcomes. However, high-quality randomized clinical evidence specifically evaluating individualized exercise interventions for piriformis syndrome remains limited [8].

Assessment of treatment effectiveness requires comprehensive evaluation using validated outcome measures. The Visual Analog Scale (VAS) is widely accepted for quantifying pain intensity, whereas hip muscle strength measured using handheld dynamometry provides objective assessment of muscular recovery. Functional performance can be evaluated using the Lower Extremity Functional Scale (LEFS) and Timed Up and Go (TUG) test, while disability is commonly assessed using the Oswestry Disability Index (ODI). Hip internal rotation range of motion additionally reflects restoration of muscle flexibility and joint mobility following rehabilitation [9].

Although exercise therapy is recommended for piriformis syndrome, uncertainty remains regarding whether individualized exercise programs provide clinically meaningful advantages over conventional physiotherapy [10]. Most published studies have included relatively small sample sizes, heterogeneous rehabilitation protocols, and short follow-up periods, limiting the generalizability of their findings. Moreover, few investigations have simultaneously evaluated pain, muscle strength, functional performance, disability, and hip mobility within a randomized controlled design.

Therefore, the present study was undertaken to evaluate the effects of a tailored exercise intervention on pain, muscle strength, functional performance, and disability in patients with piriformis syndrome by comparing individualized exercise therapy with conventional physiotherapy over a four-week rehabilitation period.

METHODOLOGY

Study design and setting

A prospective, parallel-group, pilot randomized controlled trial was conducted over a period of four weeks in the Department of Physiotherapy at a tertiary care teaching hospital after obtaining approval from the Institutional Ethics Committee. The study adhered to the ethical principles outlined in the Declaration of Helsinki, and written informed consent was obtained from all participants before enrollment.

Study population

A total of 100 patients aged 18–60 years with clinically diagnosed piriformis syndrome were recruited from the outpatient physiotherapy and orthopedic clinics. Diagnosis was established based on clinical history, physical examination, and positive piriformis-specific provocation tests, including the Flexion-Adduction-Internal Rotation (FAIR) test, Pace sign, Freiberg maneuver, and Beatty test, while excluding lumbar radiculopathy and other causes of sciatic pain.

Participants were randomly allocated into two equal groups using a computer-generated randomization sequence.

- **Group A (n=50):** Tailored Exercise Intervention
- **Group B (n=50):** Conventional Physiotherapy

Inclusion criteria

- Patients aged between 18 and 60 years.
- Clinical diagnosis of unilateral piriformis syndrome.
- Buttock pain with or without radiation along the posterior thigh for at least four weeks.
- Positive FAIR test and at least one additional positive piriformis provocation test.
- Visual Analog Scale (VAS) pain score ≥4.
- Ability to participate in supervised exercise sessions.
- Willingness to provide written informed consent.

Exclusion criteria

- Lumbar disc prolapse or lumbar radiculopathy confirmed clinically or radiologically.
- Previous hip or lumbar spine surgery.
- Hip osteoarthritis, sacroiliac joint dysfunction, or inflammatory arthropathies.
- Neurological disorders affecting gait or muscle strength.
- Pregnancy.
- Lower-limb fractures or major trauma within the previous six months.
- Corticosteroid injection to the piriformis muscle during the previous three months.
- Participation in any structured physiotherapy program within the previous month.
- Severe cardiovascular or systemic diseases preventing exercise participation.

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Sample size

A total sample size of **100 participants** was determined for this pilot randomized controlled trial based on previous rehabilitation studies evaluating exercise interventions for musculoskeletal disorders. The sample size was considered adequate to assess the feasibility of the intervention, estimate treatment effects, and provide preliminary evidence for future adequately powered randomized clinical trials. Participants were equally allocated into two groups (50 participants per group) using block randomization to ensure balanced group distribution.

Randomization and allocation concealment

Eligible participants were randomly assigned to either the tailored exercise intervention group or the conventional physiotherapy group using a computer-generated randomization sequence prepared by an independent investigator. Allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes that were opened only after baseline assessment. Outcome assessors were blinded to group allocation to minimize assessment bias.

INTERVENTION PROTOCOL

Group A: Tailored Exercise Intervention

Participants assigned to Group A underwent an individualized exercise program designed according to their baseline pain intensity, muscle strength, flexibility deficits, functional limitations, and movement impairments. Treatment sessions were conducted **three times per week for four weeks**, with each session lasting approximately **45–60 minutes** under the supervision of an experienced physiotherapist.

The intervention consisted of:

- Moist heat application (10 minutes)
- Piriformis muscle stretching
- Hip flexor and hamstring stretching
- Progressive strengthening of the hip abductors and external rotators using resistance bands
- Gluteus medius and gluteus maximus strengthening
- Core stabilization exercises
- Neuromuscular control and balance training
- Functional movement retraining (sit-to-stand, step-ups, squatting, gait retraining)
- Home exercise program performed on non-treatment days

Exercise intensity and repetitions were progressively increased according to each participant's tolerance and clinical improvement.

Group B: Conventional Physiotherapy

Participants in Group B received standard physiotherapy for four weeks consisting of supervised sessions three times weekly, each lasting 45–60 minutes.

The conventional treatment protocol included:

- Moist heat application (10 minutes)
- Transcutaneous Electrical Nerve Stimulation (TENS) for 20 minutes
- Therapeutic ultrasound (1 MHz, continuous mode, 1.5 W/cm² for 5 minutes)
- General lower-limb stretching exercises
- Basic strengthening exercises for hip and lower-limb muscles

- Postural education
- Standard home exercise advice

No individualized progression or neuromuscular retraining was incorporated into the conventional treatment protocol.

OUTCOME MEASURES

Primary outcome

- **Pain intensity** measured using the **Visual Analog Scale (VAS, 0–10 cm).**

Secondary outcomes

- Hip abductor muscle strength measured using a handheld dynamometer.
- Hip external rotator muscle strength measured using a handheld dynamometer.
- Functional performance assessed using the **Lower Extremity Functional Scale (LEFS).**
- Functional mobility assessed using the **Timed Up and Go (TUG) test.**
- Disability assessed using the **Oswestry Disability Index (ODI).**
- Hip internal rotation range of motion measured using a universal goniometer.

Data collection

Baseline demographic data, including age, sex, body mass index (BMI), duration of symptoms, affected side, occupation, and physical activity level, were recorded before intervention. Clinical assessments were performed at **baseline (Week 0)** and **after completion of the four-week intervention (Week 4)** by an independent physiotherapist who was blinded to group allocation. All measurements were obtained using standardized assessment procedures to ensure consistency and reliability.

Statistical analysis

Data were entered into Microsoft Excel and analyzed using **IBM SPSS Statistics version 27.0** (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as **mean ± standard deviation (SD)**, whereas categorical variables were presented as **frequency and percentage**. Baseline demographic characteristics were compared using the independent-samples *t*-test for continuous variables and the Chi-square test for categorical variables. Within-group changes from baseline to Week 4 were analyzed using the paired *t*-test, while between-group comparisons were performed using the independent-samples *t*-test. Effect sizes (Cohen's *d*) were calculated to determine the magnitude of treatment effects. A **p-value <0.05** was considered statistically significant for all analyses.

RESULTS

A total of **100 patients** diagnosed with piriformis syndrome were enrolled in the study and randomly allocated into two equal groups. **Group A** received the tailored exercise intervention (n=50), while **Group B** received conventional physiotherapy (n=50). All participants completed the four-week intervention and post-treatment assessment, with no loss to follow-up. Baseline demographic and clinical characteristics were comparable between the two groups (p>0.05), indicating successful randomization. The mean age of the participants was **41.6 ± 10.4 years** in Group A and **42.1 ± 9.8 years** in Group B. No statistically significant differences were observed regarding sex distribution, body mass index (BMI), duration of symptoms, affected side, or baseline pain and functional scores (Table 1).

Table 1. Baseline demographic and clinical characteristics of the study population (n=100)

Variable	Group A (Tailored Exercise) (n=50)	Group B (Conventional Physiotherapy) (n=50)	p-value
Age (years), mean ± SD	41.6 ± 10.4	42.1 ± 9.8	0.804
Male, n (%)	21 (42.0)	23 (46.0)	0.687

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Female, n (%)	29 (58.0)	27 (54.0)	0.687
BMI (kg/m²), mean ± SD	25.8 ± 3.4	26.2 ± 3.6	0.571
Duration of symptoms (weeks)	9.6 ± 3.5	9.9 ± 3.7	0.691
Right-sided involvement, n (%)	31 (62.0)	29 (58.0)	0.683
Left-sided involvement, n (%)	19 (38.0)	21 (42.0)	0.683
Baseline VAS score	7.5 ± 1.0	7.4 ± 1.1	0.641
Baseline LEFS score	39.2 ± 7.1	38.8 ± 7.4	0.782
Baseline ODI (%)	46.3 ± 7.8	45.8 ± 8.1	0.751

Following the four-week intervention, pain intensity significantly decreased in both groups. However, the reduction was significantly greater among participants receiving the tailored exercise intervention. The mean Visual Analog Scale (VAS) score decreased from **7.5 ± 1.0 to 1.8 ± 0.9** in Group A compared with **7.4 ± 1.1 to 3.5 ± 1.2** in Group B (p<0.001), demonstrating the superior effectiveness of individualized exercise therapy in pain reduction (Table 2).

Table 2. Comparison of pain intensity (VAS score)

Assessment	Group A	Group B	p-value
Baseline	7.5 ± 1.0	7.4 ± 1.1	0.641
Week 4	1.8 ± 0.9	3.5 ± 1.2	<0.001
Mean improvement	5.7 ± 1.1	3.9 ± 1.2	<0.001

Hip muscle strength improved significantly in both groups after treatment. Nevertheless, participants undergoing the tailored exercise program demonstrated significantly greater gains in both hip abductor and external rotator muscle strength compared with the conventional physiotherapy group (p<0.001), indicating enhanced muscular recovery following individualized rehabilitation (Table 3).

Table 3. Comparison of hip muscle strength after four weeks

Outcome	Group A	Group B	p-value
Hip abductor strength (kg)	19.2 ± 2.8	16.4 ± 2.6	<0.001
Hip external rotator strength (kg)	17.8 ± 2.5	15.2 ± 2.4	<0.001

Functional performance improved significantly in both treatment groups. However, the tailored exercise group achieved significantly higher Lower Extremity Functional Scale (LEFS) scores and shorter Timed Up and Go (TUG) times than the conventional physiotherapy group after four weeks (p<0.001), reflecting greater restoration of lower-limb function and mobility (Table 4).

Table 4. Comparison of functional performance after four weeks

Outcome	Group A	Group B	p-value
LEFS score	70.4 ± 5.8	61.5 ± 6.7	<0.001
Timed Up and Go (seconds)	8.2 ± 1.1	9.9 ± 1.4	<0.001

Disability scores decreased significantly following treatment in both groups. The mean Oswestry Disability Index (ODI) score was significantly lower in the tailored exercise group (**18.6 ± 5.2%**) than in the conventional physiotherapy group (**27.4 ± 6.3%**) after four weeks ($p<0.001$). Similarly, hip internal rotation range of motion improved significantly more in Group A than in Group B ($p<0.001$), indicating greater restoration of flexibility and joint mobility (Table 5).

Table 5. Comparison of disability and hip range of motion

Outcome	Group A	Group B	p-value
ODI (%)	18.6 ± 5.2	27.4 ± 6.3	<0.001
Hip internal rotation (°)	39.6 ± 4.8	33.2 ± 5.1	<0.001

Overall clinical improvement favored the tailored exercise intervention. A successful treatment outcome, defined as a reduction in pain of at least 50% together with meaningful improvement in functional performance and disability, was achieved in **46 (92.0%)** participants in Group A compared with **37 (74.0%)** participants in Group B ($p=0.015$). Persistent moderate symptoms were more frequently observed in the conventional physiotherapy group (Table 6).

Table 6. Overall treatment outcomes after four weeks

Outcome	Group A (n=50)	Group B (n=50)	p-value
Successful clinical outcome, n (%)	46 (92.0)	37 (74.0)	0.015
Partial improvement, n (%)	3 (6.0)	9 (18.0)	
Minimal or no improvement, n (%)	1 (2.0)	4 (8.0)	

DISCUSSION

The present pilot randomized controlled trial evaluated the effectiveness of a four-week tailored exercise intervention on pain, muscle strength, functional performance, and disability in patients with piriformis syndrome. The findings demonstrated significant improvements in all clinical outcomes in both treatment groups; however, participants receiving the tailored exercise intervention exhibited significantly greater reductions in pain and disability together with superior improvements in hip muscle strength, functional performance, and hip mobility compared with those receiving conventional physiotherapy. These findings suggest that individualized rehabilitation programs targeting patient-specific impairments are more effective than standardized physiotherapy protocols for managing piriformis syndrome.

The greater reduction in pain observed in the tailored exercise group is likely attributable to the combined effects of piriformis-specific stretching, progressive strengthening of the hip abductors and external rotators, core stabilization, and neuromuscular retraining, which collectively reduce mechanical compression of the sciatic nerve and improve lumbopelvic stability. These findings are consistent with those reported by **Kizaki et al. (2020)** [11], who described conservative rehabilitation as the cornerstone of treatment for deep gluteal syndrome and emphasized that targeted exercise therapy effectively alleviates pain by correcting underlying biomechanical dysfunctions. Similarly, **Geler Külcü (2024)** [12] highlighted that individualized physiotherapy focusing on muscle flexibility, strengthening, and movement correction significantly improves pain and functional recovery in patients with deep gluteal syndrome.

In the present study, participants undergoing the tailored exercise intervention demonstrated significantly greater improvements in hip abductor and external rotator muscle strength than those receiving conventional physiotherapy. Strengthening of these muscle groups enhances pelvic stability, optimizes lower-limb biomechanics, and decreases excessive loading of the piriformis muscle during functional activities. These findings are in agreement with **Raju et al. (2024)** [13], who reported that progressive strengthening exercises play a critical role in restoring hip muscle function and reducing recurrent symptoms in patients with piriformis syndrome. Improved muscle performance may also contribute to enhanced dynamic stability during gait and weight-bearing activities, thereby facilitating long-term functional recovery.

Functional performance, assessed using the Lower Extremity Functional Scale (LEFS) and Timed Up and Go (TUG) test, improved significantly in both treatment groups but was superior in the tailored exercise group. Individualized exercise progression likely enhanced neuromuscular coordination, balance, movement efficiency, and confidence during functional activities. These findings are comparable with those reported by **Brochado and Pereira (2024)** [14], who demonstrated significant improvements in pain, disability, and lower-extremity function following structured rehabilitation programs for piriformis syndrome. Their randomized clinical trial emphasized that rehabilitation strategies incorporating progressive therapeutic exercises produce greater functional improvements than conventional treatment alone.

Disability, measured using the Oswestry Disability Index (ODI), decreased significantly in both groups, with a markedly greater reduction observed among participants receiving the tailored exercise intervention. The improvement in disability likely reflects the cumulative effects of pain reduction, restoration of muscle strength, increased hip mobility, and enhanced functional capacity achieved through individualized rehabilitation. Similar findings were reported by **Monteleone et al. (2025)** [15], whose systematic review and meta-analysis demonstrated that conservative therapeutic interventions significantly improve pain and disability in patients with piriformis syndrome. Their findings support the concept that multimodal rehabilitation strategies targeting multiple impairments simultaneously produce better clinical outcomes than isolated treatment approaches.

Overall, the tailored exercise intervention achieved a significantly higher clinical success rate than conventional physiotherapy, with more than 90% of participants demonstrating meaningful improvements after four weeks. The superior outcomes observed in the present study may be attributed to individualized exercise progression based on each patient's baseline impairments rather than the application of a uniform rehabilitation protocol. Personalized rehabilitation enables clinicians to optimize exercise intensity, progression, and functional training according to individual patient needs, thereby maximizing treatment effectiveness and reducing persistent symptoms.

LIMITATIONS

The present study has several limitations that should be considered when interpreting the findings. First, although the sample size of 100 participants was adequate for a pilot randomized controlled trial, the study was conducted at a single tertiary care center, which may limit the generalizability of the results to broader populations. Second, the intervention period was limited to four weeks, and no long-term follow-up was performed to determine the sustainability of improvements in pain, muscle strength, functional performance, and disability. Third, the diagnosis of piriformis syndrome was based primarily on clinical examination and provocation tests rather than advanced imaging or electrodiagnostic confirmation, which may have introduced diagnostic variability. Finally, factors such as participant adherence to the home exercise program, individual differences in physical activity levels, and therapist-dependent variations in exercise supervision could have influenced treatment outcomes despite the use of standardized intervention protocols. Future multicenter randomized controlled trials with larger sample sizes, longer follow-up periods, and objective imaging or biomechanical assessments are warranted to validate these findings and strengthen the evidence supporting tailored exercise interventions for piriformis syndrome. Emerging artificial intelligence approaches, including deep learning-based segmentation and transfer learning-based classification of medical images [16,17], federated learning models for privacy-preserving image classification in smart health systems [18], and machine learning models that predict patient outcomes from electronic health records [19], may further support objective assessment and individualized rehabilitation planning in future research.

CONCLUSION

The present study demonstrated that both tailored exercise intervention and conventional physiotherapy significantly improved clinical outcomes in patients with piriformis syndrome after four weeks. However, the tailored exercise intervention produced significantly greater reductions in pain and disability, along with superior improvements in hip muscle strength, functional performance, and hip mobility. These findings highlight the effectiveness of individualized rehabilitation programs in addressing the biomechanical and functional impairments associated with piriformis syndrome. Tailored exercise therapy may therefore be considered a valuable first-line conservative treatment for optimizing patient recovery and functional independence. Further multicenter randomized controlled trials with longer follow-up periods are recommended to confirm these findings and establish evidence-based clinical guidelines.

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