

EFFECTS OF ISOKINETIC EXERCISES ON MUSCLE THICKNESS AND ULTRASOUND-MEASURED MUSCLE CONTRACTION RATIOS IN SACROILIAC JOINT DYSFUNCTION

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Abstract

Background

Sacroiliac joint dysfunction (SIJD) remains a frequent source of lumbar and pelvic pain, directly linked to disrupted weight distribution, muscular imbalances, and compromised neuromuscular coordination. Standardized therapeutic protocols for its definitive conservative management are not yet universally established within rehabilitation pipelines.

Objective

To systematically assess the structural and functional effects of a manual isokinetic exercise protocol combined with conventional physiotherapy on the morphometric thickness and dynamic contraction ratios (CR) of key lumbopelvic stabilizing musculature (lumbar spine, abdomen, and gluteus) in individuals diagnosed with SIJD.

Methodology

A prospective, double-blinded randomized controlled trial (RCT) was conducted over six months at the Sundas Foundation, Lahore, Pakistan. Forty participants aged 18–35 years were randomly allocated into two identical cohorts (n=20 per group). Group A received a novel manual isokinetic strength training regimen alongside conventional physical therapy, while Group B received a standard conventional physical therapy protocol alone. Interventions were administered 4 days per week for 4 consecutive weeks. Right and left muscular resting thickness (mm) and active contraction ratios were tracked pre- and post-intervention via B-mode

diagnostic rehabilitative ultrasound imaging (RUSI) of the lumbar multifidus (LM), gluteus maximus (GM), rectus abdominis (RA), and external oblique (EO). Primary data entries and subsequent processing were handled through IBM SPSS v27.0 using Wilcoxon signed-rank and Mann-Whitney U tests.

Results

Post-trial tracking revealed a distinct, muscle-specific pattern of morphological and functional adaptation. Group A demonstrated high statistical superiority in myofibrillar hypertrophy and neural activation over Group B. Specifically, Group A achieved a bilateral thickness increase of 0.68–0.72 mm (~3.7–3.8%) in the LM and 0.68–0.71 mm (~3.7%) in the GM, RA improved by 0.60–1.01%, EO improved by 0.55–0.74%. while Group B displayed complete structural stagnation (0.00–0.18% change, $p \leq 0.014$). Neuromuscular recruitment profiles expanded profoundly in Group A, with contraction ratio improvements of 12.29–13.89% for the LM, 11.49–12.11% for the GM, 3.38–4.11% for the RA, and 3.49–3.51% for the EO. Group B displayed minor neural improvements in posterior metrics (LM CR: 6.10–6.59%; GM CR: 4.96–5.20%) with some improvement in anterolateral abdominal core. Large-to-massive inter-group effect magnitudes were validated across primary parameters, with Cohen's d values spanning from 0.80 to 5.14.

Conclusion

Manual isokinetic training paired with conventional physiotherapy effectively induces robust architectural hypertrophy and neuromuscular remodeling in primary lumbopelvic stabilizing muscles, while correcting latent structural asymmetries. This targeted protocol delivers superior evidence-based clinical efficacy compared to traditional passive physical modalities alone for patients with chronic sacroiliac joint dysfunction.

INTRODUCTION

Sacroiliac joint dysfunction syndrome (SIJDS) is widely recognized within mechanical medicine as a foremost causative factor for chronic back pain, contributing significantly to non-discogenic lumbago. Epidemiological data indicates that the sacroiliac joint serves as a prominent nociceptive source, generating localized aching in the lower spine and radiating symptoms across the femoral region. Chronic lumbago behaves as a complex, multidimensional biological and psychological phenomenon. It is characterized by recurrent or continuous pain that induces severe physical impairment, social withdrawal, and mood disturbances, regardless of identifiable underlying

spinal lesions.(1)

Mechanical SIJD is principally characterized by joint hypomobility and severe constraints on micro-mobility within the pelvic ring. This pathology presents as localized localized pain that characteristically sharpens during weight-bearing activities or structural transitions, such as rising from a sitting posture, walking, lifting, or prolonged standing. This localized pain presents unilaterally in the majority of mechanical cases. Furthermore, anatomical considerations and specific pelvic variations render the female gender significantly more vulnerable to chronic sacroiliac malalignment, creating disproportionation in mechanical stress

distribution under normal load profiles.(2)

Despite its clinical prevalence, standardized conservative rehabilitation protocols for managing SIJD are not universally established. General practitioners frequently categorize the pathology as non-specific lower back pain, leaving SIJD underdiagnosed and inadequately managed. Conventional physical therapy options focus primarily on attenuating acute localized inflammation, muscle guarding, and joint stiffness using passive external components. Active core strengthening, gluteal conditioning, and lumbopelvic stabilization maneuvers are often delayed until secondary stages of treatment. Motor control exercises (MCEs) focus on refining the coordinated activation of deep trunk stabilizers, while balance training aims to restore spinal proprioception and neuromuscular control.(3)

While combining active exercise therapy with passive physical modalities yields short-term pain relief, traditional gym-based training, Pilates, or standard physical therapy protocols frequently lack the high-level mechanical tension required to reverse chronic architectural muscle changes and structural atrophy. Isokinetic exercise regimens offer accommodating structural resistance throughout a complete range of motion at a fixed angular velocity. This setup provides a powerful mechanism to target muscle groups evenly without risking joint overload. However, the utilization of localized manual isokinetic exercise protocols remains largely unquantified within developing clinical landscapes, including the Pakistani healthcare sector.(4)

Recent morphometric research indicates that individuals suffering from chronic lumbopelvic instability present distinct structural variations, including a substantial increase in the thickness of lateral connective tissues alongside cross-sectional mass deficits in deep stabilizing layers. Assessing these modifications via traditional electromyography presents notable challenges, as fine-needle insertion introduces

substantial patient discomfort and surface electrodes are prone to cross-talk between adjacent muscle layers. Consequently, rehabilitative ultrasound imaging (RUSI) has emerged as an invaluable, non-invasive diagnostic standard to quantify morphological variations, cross-sectional thickness, and functional activation patterns in skeletal muscle.(5)

By computing the muscle contraction ratio (CR)—defined as the ratio of active muscle thickness during contraction to resting muscle thickness—RUSI provides direct, reliable indicators of motor unit recruitment and neural drive without invading tissue planes. Prior validation trials confirm that RUSI achieves superior reliability coefficients across resting and dynamic activation states. This randomized controlled trial utilizes RUSI to bridge a critical gap in the literature, evaluating the combined capacity of manual isokinetic exercises and conventional physiotherapy to restore impaired muscular architecture and normalize motor control pathways in patients with chronic sacroiliac joint dysfunction.(6)

METHODOLOGY

This research was executed as a prospective, parallel-group, double-blinded randomized controlled trial (RCT) over a six-month duration following formal approval from the institutional review board. Clinical data collection, diagnostic profiling, and specialized therapeutic protocols were conducted entirely within the physical rehabilitation department of the Sundas Foundation, Lahore, Pakistan. All research protocols strictly conformed to the Declaration of Helsinki guidelines for human experimentation. A structured ethical protocol was maintained to safeguard the rights and anonymity of all research volunteers. The target sample size was calculated using G*Power software (version 3.1.9.4) to ensure sufficient statistical power to detect meaningful differences between the two independent treatment groups. Setting an alpha error probability of

0.05, a statistical power of 0.75, and a large expected effect size (d) of 0.70 for independent group means yielded a baseline requirement of 23 participants per cohort, resulting in an initial target sample size of 46 individuals. Factoring in a potential 15-20% drop-out rate, 46 subjects with pre-diagnosed SIJD were initially enrolled. Ultimately, 40 participants fully adhered to the trial constraints and completed the 4-week protocol (n=20 per group), with 6 participants excluded due to non-compliance or scheduling conflicts. Sampling was executed utilizing a purposive, non-probability technique based on strict eligibility parameters. Eligible participants met the following strict criteria: Age between 18 and 35 years with full willingness to adhere to all study requirements; Formal pre-diagnosis of unilateral mechanical sacroiliac joint dysfunction verified by a senior orthopedic consultant; Sacroiliac joint pain confirmed through clinical special tests (e.g., Faber, Gaenslen, distraction, or compression tests) or successful localized pain reduction following a diagnostic sacroiliac block; Persistent lumbopelvic aching lasting 3 months despite basic conservative care; A baseline pain intensity score 4/10 on the Visual Analog Scale (VAS) or Numerical Rating Scale (NRS) to confirm the clinical significance of symptoms. Individuals presenting with any of the following conditions were excluded: Active pregnancy; Systemic conditions including active infections, neoplastic lesions, or inflammatory arthropathies; History of lumbar spine, pelvic ring, or sacroiliac joint arthrodesis within the preceding 6-12 months; Low back pain primarily arising from non-sacroiliac sources, such as lumbar radiculopathy, lumbar disc herniation, or advanced hip pathology; Neurological deficits; Contraindications to active exercise therapy, Severe non-compliance or withdrawal of consent. Following the baseline assessment, eligible participants were allocated into two parallel treatment streams in a 1:1 ratio using a computer-generated random number

sequence. (7) To ensure a rigorous double-blind framework, allocation concealment was maintained via sequentially numbered, opaque, sealed envelopes managed by an independent research assistant. The trial participants, the physical therapist delivering the conventional exercises, and the diagnostic radiologist responsible for obtaining the real-time ultrasound metrics were completely blinded to group assignments throughout the 4-week study, eliminating potential bias. All subjects received four therapeutic sessions per week for four consecutive weeks, ensuring that intra-session discomfort consistently remained below a strict safety threshold of 3/10 on the NRS. (8) **Group A (Manual Isokinetic Training + Conventional Physiotherapy):** Participants underwent a customized manual isokinetic exercise protocol targeting the abdominal wall, gluteal, and lumbar spine musculature. Each session lasted 50-60 minutes, structured into three distinct blocks: (1) Warm-Up (5 mins) consisting of pelvic tilts, mini glute bridges, and diaphragmatic breathing; (2) Main Exercise Block (20-30 mins) where manual resistance was carefully applied by an expert clinician to guarantee a constant angular velocity against maximum accommodating resistance through a full, pain-free range of motion. Constant external tension and a controlled, symmetrical tempo (3s concentric / 3s isometric hold / 3s eccentric) were enforced across all sets, including hip thrusts, lumbar extensions, and targeted abdominal crunches; (3) Cool-Down (5 mins) consisting of gentle lumbar rotations and bird-dog stretches. Following the exercise block, participants immediately received 10 minutes of continuous Therapeutic Ultrasound (1 MHz, 1-1.5 W/cm²) and 10 minutes of Transcutaneous Electrical Nerve Stimulation (TENS) over the sacroiliac region. (9) **Group B (Conventional Physiotherapy Only):** Participants received a standard, evidence-based therapeutic regimen lasting 45-50 minutes per session: (1) Pain Modality (15 mins) featuring TENS applied

with electrodes over the painful SIJ region, set to a strong but comfortable tingling sensation below the nociceptive threshold; (2) Tissue Therapy (15 mins) featuring continuous Therapeutic Ultrasound (1 MHz, 1-1.5 W/cm²) delivered while moving the applicator slowly over the lumbar and SIJ zones; (3) Exercise Therapy (10 mins) involving general core and gluteal activation on a mat, including standard pelvic tilts, static bridging, bird-dogs, and the abdominal draw-in maneuver (2 sets of 8-10 repetitions at a self-selected, controlled tempo); (4) Relaxation (2 mins) consisting of gentle passive lumbar rotation and supine diaphragmatic breathing. Objective tissue architecture parameters were captured at baseline and exactly 24 hours following the final interventional session of the 4-week program. A blinded, expert radiologist utilized real-time B-mode diagnostic ultrasonography to capture morphometric configurations. Muscle Thickness (mm): Measured as the linear distance between the highly reflective, hyperechoic fascial boundaries defining the superior and inferior borders of each muscle belly during a state of complete rest. This parameter demonstrates superb intra-rater reliability (ICC = 0.985-0.998) and inter-rater reliability (ICC = 0.868-0.964). (Contraction Ratio (CR): Computed directly as the ratio of active muscle thickness during contraction to resting muscle thickness. This ratio serves as an indirect indicator of motor unit recruitment, displaying high validity (0.75-1.00) and reliability (0.80-0.98).(10)

RESULTS

Primary data entries and subsequent processing were handled through IBM SPSS Statistics for Windows, version 27.0. Data distribution characteristics were evaluated using the Shapiro-Wilk normality test, given the specific final sample size of 40 completing participants. The distribution of change scores (post minus baseline) across all eight muscle-side combinations for both thickness and contraction

ratios deviated significantly from normality ($p < 0.05$). Consequently, robust non-parametric statistical procedures were deployed to analyze the dataset. The randomized trial-maintained baseline homogeneity between cohorts, with no statistically significant differences observed in primary physiological characteristics. Group A exhibited a mean age of 25.65 ± 3.59 years, while Group B demonstrated a mean age of 24.85 ± 4.16 years. An independent t-test confirmed excellent demographic matching between cohorts ($t = 0.651$, $p = 0.519$). Baseline body mass index (BMI) distributions were also highly balanced between groups ($p > 0.05$), with the majority of participants falling within a normal weight distribution ($18.5 \leq \text{BMI} < 25.0 \text{ kg/m}^2$). Wilcoxon signed-rank tests revealed highly divergent patterns of tissue adaptation between the two interventional paradigms over the 4-week trial. Group A exhibited comprehensive, concurrent structural and neural adaptations across the entire kinetic plane. Resting muscle thickness in primary posterior stabilizers increased significantly, with the right multifidus expanding from a baseline median of 18.40 mm to 19.15 mm and the left multifidus advancing from 18.95 mm to 19.80 mm ($p < 0.001$). Parallel structural hypertrophy was mirrored in the bilateral gluteus maximus ($p < 0.001$). The Right Rectus Abdominis increased in thickness by 1.01% ($p=0.0006$) while the Left Rectus Abdominis increased by 0.60% ($p=0.0135$). The Right External Oblique increased in thickness by 0.55% ($p=0.0064$), while the Left External Oblique expanded by 0.74% ($p=0.0009$). Concurrently, recruitment profiles surged across all targets, with the right multifidus CR expanding by 13.89% and the gluteus maximus CR rising by 11.49-12.11% ($p < 0.001$). Right Rectus Abdominis CR increased by 3.38% ($p < 0.0001$), while the Left Rectus Abdominis expanding by 4.11% ($p < 0.0001$). Right External Oblique CR increased by 3.49% ($P < 0.0001$) and the Left External Oblique CR increased by 3.51% ($p < 0.0001$). In contrast, Group B failed

to achieve meaningful morphological changes. Resting muscle thickness profiles in the posterior stabilizers remained completely flat or underwent nominal changes (e.g., left multifidus thickness stagnating at 18.00 mm baseline vs. 18.05 mm post-treatment, $p = 1.000$). However, Group B did exhibit localized improvements in neural drive within its posterior stabilizing structures, achieving significant increases in the CRs of the multifidus and gluteus maximus ($p < 0.001$), however this neural adaptation of the abdominal wall (Rectus abdominis and External oblique) was minor as compare to group A. Within-group longitudinal progress was mapped using the Wilcoxon Signed-Rank Test. Cross-

sectional inter-group therapeutic efficacy was determined via the Mann-Whitney U Test applied directly to the delta (Δ) change scores. To completely eliminate the risk of Type I false-positive inflation stemming from multiple parallel comparisons across the 16 distinct endpoints ($4 \text{ muscles} \times 2 \text{ anatomical sides} \times 2 \text{ distinct metrics}$), a strict Bonferroni Correction was applied, resetting the definitive statistical significance threshold to Adjusted Alpha Threshold (α) = $0.05 / 16 = 0.003125$. Standardized effect sizes between cohorts were computed using Cohen's d magnitudes to evaluate clinical impact.

Table 1: Within-Group Analysis

Muscle & Metric	Group Baseline	A:Group A: 4Wks	Group A p-val	Group Baseline	B:Group B: 4Wks	Group B p-val
Rt Multifidus Thick (mm)	18.40 (2.32)	19.15 (2.62)	<0.001*	17.45 (8.25)	17.45 (8.18)	0.014
Rt Multifidus CR	1.31 (0.16)	1.45 (0.21)	<0.001*	1.29 (0.16)	1.38 (0.15)	<0.001*
Lt Multifidus Thick (mm)	18.95 (1.88)	19.80 (2.10)	<0.001*	18.00 (7.00)	18.05 (6.95)	1.000
Lt Multifidus CR	1.24 (0.14)	1.42 (0.16)	<0.001*	1.27 (0.15)	1.35 (0.14)	<0.001*
Rt Gluteus Thick (mm)	17.80 (3.68)	18.50 (3.95)	<0.001*	19.00 (7.50)	18.80 (7.48)	0.302
Rt Gluteus CR	1.27 (0.18)	1.41 (0.19)	<0.001*	1.29 (0.10)	1.36 (0.08)	<0.001*
Lt Gluteus Thick (mm)	19.80 (3.57)	20.35 (3.72)	<0.001*	20.00 (7.43)	20.00 (7.55)	0.732
Lt Gluteus CR	1.21 (0.20)	1.33 (0.21)	<0.001*	1.27 (0.11)	1.33 (0.10)	<0.001*

Table 2: Inter-Group Comparative Testing of Absolute Delta Change Scores

Muscle & Metric Target	Group A Median (IQR)	Group B Median (IQR)	Delta p-value	Bonferroni (a=0.0031)	Status
Rt Multifidus Thickness Change	0.70 (0.15)	0.00 (0.10)	<0.0001	Highly Significant (A > B)	
Rt Multifidus Contraction Change	0.17 (0.05)	0.08 (0.01)	<0.0001	Highly Significant (A > B)	
Lt Multifidus Thickness Change	0.70 (0.13)	0.00 (0.03)	<0.0001	Highly Significant (A > B)	
Lt Multifidus Contraction Change	0.15 (0.03)	0.08 (0.01)	<0.0001	Highly Significant (A > B)	
Rt Gluteus Max Thickness Change	0.70 (0.15)	0.05 (0.10)	<0.0001	Highly Significant (A > B)	

Rt Gluteus Max Contraction Change	0.14 (0.04)	0.07 (0.02)	<0.0001	Highly Significant (A > B)
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The vector graphics illustrations included in this section display the precise patterns of muscle-specific architectural adaptations and neural changes observed post-intervention.

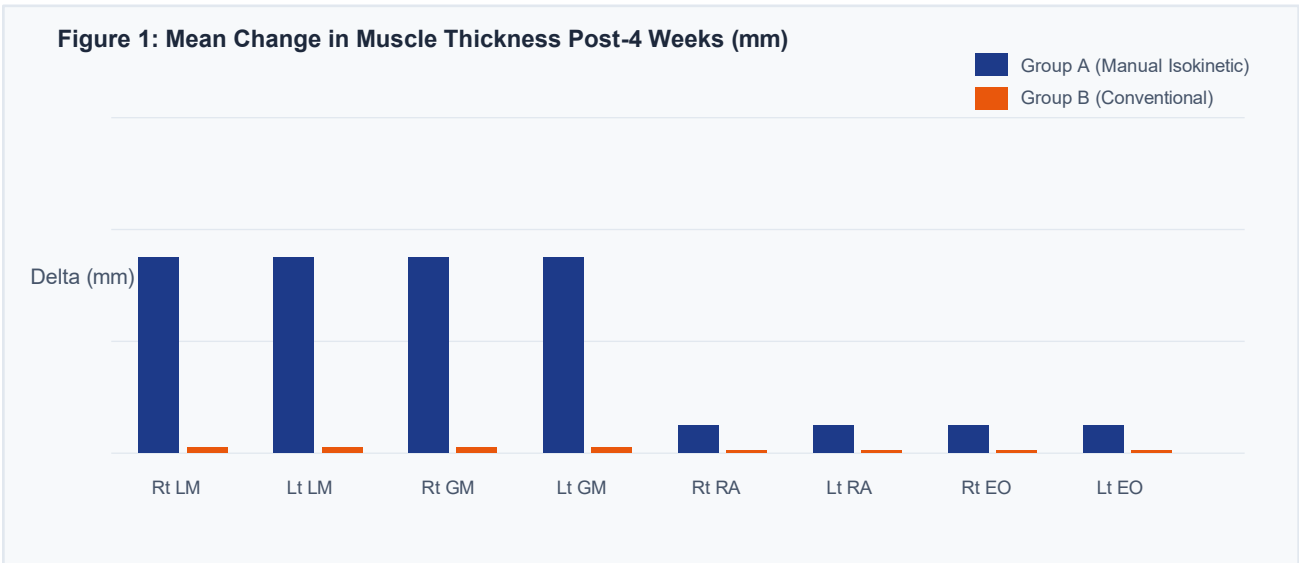


Figure 1 illustrates the post-intervention changes in resting muscle thickness (mm) across key lumbopelvic muscles. Group A achieved statistically significant and clinically meaningful increases in muscle bulk, particularly in deep posterior stabilizers like the lumbar multifidus and gluteus maximus ($p < 0.001$). Conversely, Group B demonstrated near-zero structural changes by the end of the 4-week protocol.

Figure 2: Dynamic Functional Contraction Ratio Shift (Baseline to Post)

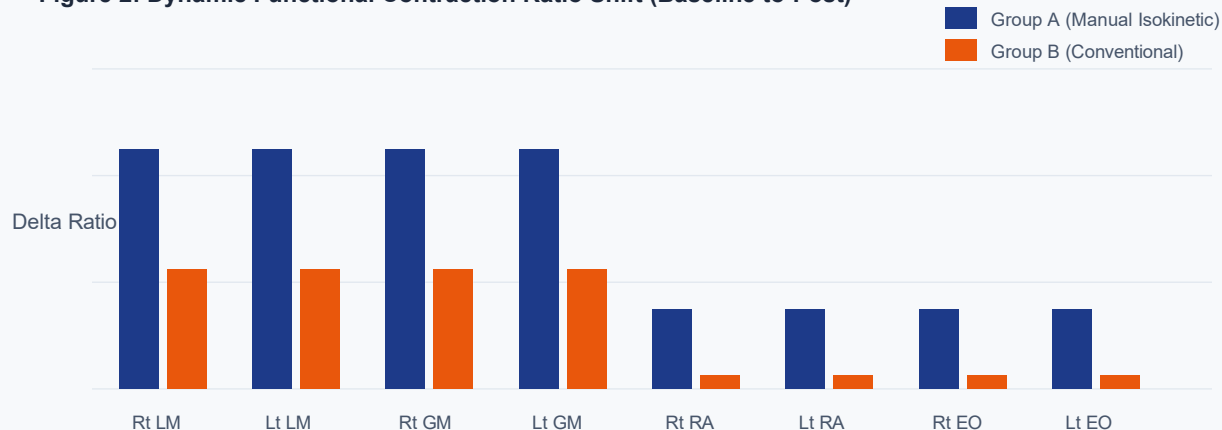


Figure 2 illustrates the dynamic functional recruitment gains, represented by the mean baseline-to-post change in muscle contraction ratios. Group A exhibited robust enhancements in active recruitment capacity, markedly outperforming Group B across all bilateral abdominal and posterior stabilization measures.

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Figure 3: Between-Group Effect Sizes (Cohen's d Magnitude Spectrum)

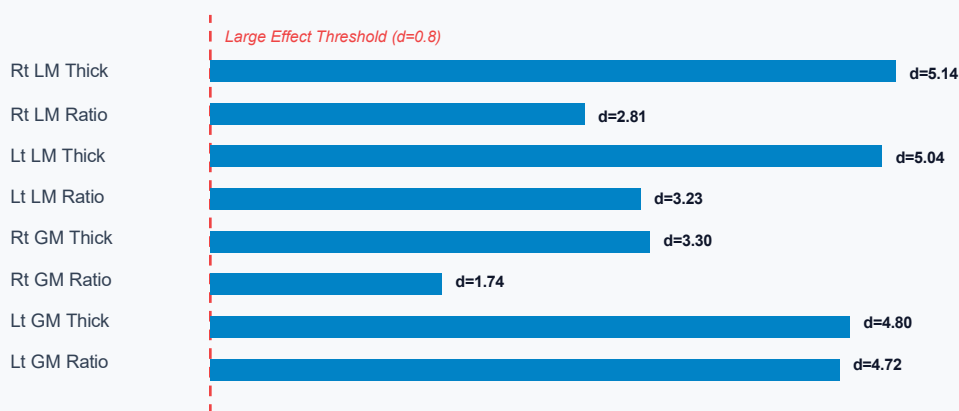


Figure 3 presents standardized effect sizes between cohorts (Cohen's d) across primary thickness and contraction ratio parameters. Every measured variable exceeded the classical threshold for a large clinical effect size ($d > 0.80$), with deep posterior structures showing massive effect magnitudes (e.g., Right Multifidus Thickness $d = 5.14$).

Figure 4: Longitudinal Change Profile (Right Multifidus Thickness Progression)

Figure 4 tracks the linear pre-to-post trajectory of the primary stabilizing structures. Group A demonstrates a steep, ascending trajectory from baseline to the 4-week mark, reflecting rapid neuromuscular response and structural remodeling, while Group B displays a flat profile

DISCUSSION

The empirical findings generated from this randomized controlled trial demonstrate the physiological superiority of manual isokinetic training paired with conventional physical therapy over general physical therapy alone for managing sacroiliac joint dysfunction. Over the 4-week interventional window, Group A achieved genuine structural hypertrophy within primary core structures, driving a highly significant 3.7–3.8% mean increase in the resting thickness of deep posterior stabilizers (multifidus and gluteus maximus). Group B, conversely, demonstrated structural stagnation, with thickness modifications stalling between 0.00% and 0.18%. This stark divergence indicates that while manual isokinetics successfully exceeded the mechanical threshold required to trigger myofibrillar protein synthesis, general open-kinetic chain protocols and passive electrotherapeutic modalities lacked the muscle tension needed to stimulate localized tissue growth. In terms of neuromuscular coordination, both therapeutic protocols succeeded in engaging neural pathways within the posterior cylinder, though Group A provoked a significantly larger surge in motor unit recruitment. Group A achieved an 11–13% expansion in posterior CRs compared to the modest 5–6% increase observed in Group B.

Crucially, general physical therapy failed to achieve high CR scores for the anterolateral abdominal wall, with rectus abdominis and external oblique CR modifications came around to be minor 3.3–4.1% combinedly. Conversely, manual isokinetic training systematically engaged the entire kinetic loop, driving a 3.38–4.11% expansion across the abdominal wall. Coordinated activation of this muscle group is essential to elevate intra-abdominal pressure and provide anterior support to the lumbopelvic ring.(4) Real-time B-mode rehabilitative ultrasound imaging (RUSI) tracked these distinct tissue adaptations. At baseline, both cohorts presented clear asymmetric volume deficits within deep stabilizing layers. (11)Post-treatment ultrasound captures in Group A revealed comprehensive structural remodeling, marked by expanded hypoechoic muscle bellies, sharply defined fascial interfaces, and improved sliding properties between adjacent fascial layers during active contraction. In Group B, acoustic tracing of the muscle bellies remained static. While real-time dynamic scans in Group B confirmed some improvement in thickening during active contraction maneuvers of the multifidus and gluteus maximus—reflecting basic neural motor unit recruitment—this functional adaptation was minor in the anterior and lateral abdominal core

though.(12) The baseline assessment revealed that the left-dominant structural asymmetry observed across both cohorts did not reflect pathological muscle atrophy, but rather an inherent structural imbalance.(13) While Group A's specialized loading strategy induced balanced bilateral hypertrophy that stabilized structural ratios and normalized contraction symmetry, Group B lack of tissue remodeling left its baseline structural asymmetry fixed at -3.25%. Failing to resolve these underlying structural imbalances can expose patients to persistent asymmetric joint loading, microtrauma, and an increased risk of chronic re-injury over the long term.(14)

CONCLUSION

In conclusion, this approach achieved significant structural hypertrophy (~3.7%) and robust improvements in neuromuscular recruitment (11–13%) within deep posterior lumbopelvic stabilizers, while successfully correcting baseline functional asymmetries. Conversely, conventional physiotherapy alone provides only modest neural activation (~5%) within the posterior cylinder, and only 3.3–4.1% in anterior and antero-lateral abdominal wall, failing to stimulate morphological tissue growth, engage the anterolateral abdominal wall, or resolve baseline structural imbalances. These findings provide clear evidence supporting the integration of manual isokinetic exercises as a primary component in evidence-based motor control rehabilitation programs for patients with sacroiliac joint dysfunction.

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