Comparative Effectiveness of Core Strengthening Combined with TENS versus Conventional Physical Therapy among Individuals with Anterior Pelvic Tilt Associated with Non-Specific Low Back Pain: A Randomized Controlled Trial

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Abstract

Background: Non-specific low back pain (NSLBP) affects up to 80% of adults, impairing daily function and quality of life while burdening healthcare systems. Core stability exercises target deep trunk muscles to enhance spinal mobility and pelvic alignment, while Transcutaneous Electrical Nerve Stimulation (TENS) offers non-invasive neuromodulation for pain relief. Their combination may yield superior therapeutic outcomes.

Objective: To compare Core Strengthening exercises with TENS versus conventional physiotherapy in reducing pain, correcting anterior pelvic tilt (APT), and improving balance in NSLBP patients.

Methods: A single-blinded randomized controlled trial, conducted from 15th June 20225 till 30th August 2025, included 40 participants (mean age: 29.0 ± 5.45 years; 47.5% male), equally allocated to intervention (Core Strengthening + TENS) and control groups. Pain (Numeric Pain Rating Scale), APT angle (digital photography via MicroDicom), and Y-Balance were assessed pre- and post-intervention. ANCOVA adjusted for baseline values. The clinical trial has already been registered at the PRS clinical trial registry USA on 01 August 2025 (ID: NCT07098741).

Results: Groups were comparable at baseline ($p > 0.05$). Post-intervention, pain scores were significantly lower in the intervention group (0.99, 95% CI: 0.42–1.55) than controls (6.31, 95% CI: 5.75–6.88; mean difference = −5.33, $p < 0.001$, partial $\eta^2 = 0.828$, d = −4.29). APT angle decreased more with intervention (14.61°, 95% CI: 14.33–14.89) versus controls (16.16°, 95% CI: 15.87–16.44; mean difference = −1.54°, $p < 0.001$, partial $\eta^2 = 0.605$, d = −1.78). Y-Balance improved significantly (96.72 vs. 94.28; mean difference = 2.43, $p < 0.001$, partial $\eta^2 = 0.354$, d = 1.11).

Conclusion: Core strengthening with TENS is significantly more effective than conventional physiotherapy in reducing pain, correcting APT, and enhancing balance in NSLBP patients.

Clinical Trial Registration:

Keywords: Non-Specific Low Back Pain, Anterior Pelvic tilt, MicroDicom, Y-Balance Test

Introduction

The term low back pain (LBP) is referred to non-specific low back pain (NSLBP) due to the inability to identify the pain's source in most cases (Airaksinen et al, 2006). Most of the individuals with low back pain do not exhibit identifiable or specific pathologies, such as nerve compression or significant spinal disorders, protective spasm, strain, ankylosing spondylitis, Potts disease, or significant spinal disorders (Saragiotto BT et al,2016). Consequently, this pathological condition is commonly termed non-specific LBP (Cuenca-Martinez F et al,2018).

Low back pain continues to be a condition with considerable incidence and prevalence. In 2017, it was projected that more than 551 million individuals suffered from low back pain, which was identified as the main reason for disability around LBP (Pain Collaborators, 2021). After a new episode, the pain generally diminishes significantly but does not fully abate within the initial 4–6 weeks. In the majority of individuals, pain and its relationship with disability endure for months; nevertheless, only a small percentage remains profoundly disabled (Koes et al,2010).

Pelvic asymmetry has been considered as a potential contributor in the onset of lower back pain and a principal source of discomfort (Yu et al, 2020). Asymmetrical position of the pelvis has been posited as a possible contributor to the onset of non-specific chronic LBP (Kurki, 2017). Prior research indicated that a greater anterior pelvic tilt angle correlates with lower back pain, as it heightens the over-stretch on soft tissues in the lumbar area (Krol, 2017).

Various physiotherapy interventions such as core strengthening and electrotherapy have shown promising outcomes in alleviating symptoms associated with NSLBP (Wang et al, 2012). Exercise therapy, in conjunction with educational strategies grounded in behavioral-treatment principles, must be employed as the fundamental intervention for chronic non-specific low back pain. It provides superior pain alleviation and enhances functional capacity compared to general medical care and passive approaches to therapeutic interventions (Hayden et al, 2005).

Pain management for patients with chronic low back pain should focus on therapies that diminish central excitability and enhance central inhibition (Correa at al, 2015). TENS is a treatment protocol designed to diminish central excitability and enhance central inhibition (Dailey et al, 2020). TENS is a cost-effective, safe, and user-friendly non-pharmacological intervention for pain management. Previous research indicates that TENS interacts with opioid receptors at spinal and supraspinal levels to reduce the sensitivity of dorsal horn neurons, the production of excitatory neurotransmitters, and hyperalgesia. TENS may be particularly advantageous for individuals with chronic low back pain, since it can activate descending inhibitory pathways (which are reduced in chronic low back pain patients) and diminish central excitability (which is increased in chronic low back pain patients (Liebano et al, 2024).

Despite ongoing debate regarding optimal management strategies, maintaining physical activity positively influences the reduction of non-specific LBP. Utilizing exercises to engage and fortify the core stability training (i.e., CSE) has demonstrated efficacy as a promising approach for addressing NSLBP. The objective of CSE is to enhance and restore spinal control capabilities. This method focuses on reeducating the function of deep trunk muscles and the coordination between deep and superficial muscles of trunk during stability, dynamic or static, and functional activities. (Smrcina et al, 2022).

Previous research has primarily examined pain intensity, postural parameters, or functional performance in isolation when evaluating physiotherapy interventions for non-specific low back pain (NSLBP). However, there is a scarcity of studies investigating the combined effects of such interventions on anterior pelvic tilt (APT), dynamic balance, measured via Y-Balance Test, and pain intensity assessed by the Numeric Pain Rating Scale (NPRS). This gap is particularly evident in the context of randomized controlled trials conducted in Southern Punjab, Pakistan. Therefore, the present study was designed to evaluate the integrated effects of a combined core strengthening and TENS intervention on NPRS scores, APT angle, and Y-Balance performance in individuals with NSLBP, thereby providing comprehensive clinical insights to guide region-specific rehabilitation strategies.

The primary goal of this study was to compare the combined effects of Core Strengthening and TENS with a conventional physiotherapy protocol on pain, anterior pelvic tilt, and dynamic balance in participants with anterior pelvic tilt related to non-specific chronic low back pain (NSCLBP).

Methodology

A randomized controlled trial was executed in the Department of Physiotherapy, National Orthopedic and General Hospital, Bahawalpur. The study commenced from 15th June 2025 and data collection was completed on 30th August 2025. A total of forty participants were recruited and randomly allocated to two equal groups who were selected based on inclusion and exclusion criteria as follows:

Inclusion Criteria

Participants aged 20 to 40 years of both genders with a confirmed diagnosis of nonspecific low back pain (NSLBP) were included. Eligibility required an anterior pelvic tilt angle greater than 110° in males and 130° in females, along with mild to moderate low back pain.

Exclusion Criteria

Participants with a history of trauma or fracture in the lumbopelvic region, previous orthopedic or neurological surgery in the pelvic or lumbar area, malignancies, autoimmune disorders affecting musculoskeletal function, referred or radiating visceral pain, gait abnormalities, or neurological disorders were excluded.

Randomization and Group Allocation:

Participants of the study meeting the inclusion and exclusion criteria were randomly allocated to one of the interventional or control groups using computer-generated randomization table.

Allocation concealment was ensured to prevent selection bias, with treatment assignments concealed from both participants and investigators.

Intervention Group(n=20): Core Strengthening + TENS

Exercises (Basic Phase): Abdominal drawing-in, supine bridges, standard plank, leg lifts, rotational knee tuck

Exercises (Advanced Phase): Crunches, plank with opposite limb lift, reverse crunch, crisscross, single-leg glute bridge

Cool down: Static stretching, including knee-to-chest, straight leg raise, and Russian twist

TENS Protocol: Frequency range of 100 Hz, pulse width of 175–200 µs, 20 minutes per session.

The placement of electrode was such that two negative electrodes were placed at Posterior Superior Iliac Spines (PSISs) and positive electrodes were placed about 6-7cm superior to their respective negative electrodes. The skin beneath the pad implantation must retain intact feeling.

Control Group (n = 20): combination of electrotherapy (Infra-red and Hot Pad) with stretching and flexibility exercises group.

Electrotherapy: Infra-red position of the lamp was approximately 12 to 18 inches away from the affected area, ensuring that the light is directed at the lower back. Before starting the treatment, any clothing or coverings that may obstruct the light's penetration were removed. Lamp was turned on and left to emit for 15 to 30 minutes per session (Tsagkaris et al, 2022)

Stretching: Gentle stretching exercises, such as knee-to-chest, cat-cow, and pelvic tilts were employed (Qaseem et al, 2017; Shnayderman and Katz-Leurer, 2013).

Flexibility exercises: Hamstring stretches, hip flexor stretches, and lumbar rotations were applied (Hayden et al., 2021; Gordon and Bloxham, 2016).

Interventions were applied for total of four weeks, with a frequency of two sessions a week. Each patient received a total of eight sessions from a qualified and licensed physical therapist.

Measures of Outcome:

Level of Pain: The Numeric Pain Rating Scale (NPRS) is an outcome measure that is a uni-dimensional measure of the intensity of pain experienced by individuals. The eleven-point numeric scale spans from '0' indicating one pain extreme (for example, "no pain") to '10' representing the other pain extreme (for example, "pain as bad as you can imagine" or "worst pain imaginable"), with '0' being the least amount of pain possible (Nugent et al, 2021)

APT Angle Measurement: MicroDicom analysis of digital photographs Via MicroDicom (M A Bhutto et al, 2021). For data collection, participants were photographed in a standardized setting with a non-reflective background, using a tripod-mounted camera positioned 0.90 m high and 2.90 m away. Subjects stood with arms crossed, and anatomical landmarks (ASIS and PSIS) were marked to determine pelvic tilt. Digital images were analyzed with MicroDicom software, calculating pelvic tilt angles from right and left side views. A horizontal line between ASIS and PSIS was used to measure the angle, with normative anterior tilt values reported as ~9.5° in males and ~13° in females.

Balance: Y-Balance Test (Plisky et al, 2021)

The Y Balance Test (YBT) assesses dynamic balance and functional symmetry by requiring participants to stand on one leg with hands on hips while reaching in three directions: anterior, posteromedial, and posterolateral. Each reach is attempted three times, with the best distance recorded. The procedure is repeated on both legs, and a composite score is calculated by summing the best reach distances. This test provides an objective measure of balance and helps identify asymmetries or injury risks.

Statistical Analysis: SPSS version 26 was used to do statistical analysis. The significance level was set at $\alpha = .05$. Univariate ANCOVAs were used for each outcome measure, pain score, anterior pelvic tilt angle, and Y-Balance, using the pre-intervention values as factors to make up for differences at the start. Least Significant Difference (LSD) method was used to do pairwise comparisons.

Results

A total of 40 individuals completed the study, with 20 assigned to the Core Strengthening with TENS group and 20 to the Control group.

Demographics

The pre interventional demographic and clinical features were similar among groups, showing no significant variations in age, gender distribution, or baseline outcome indicators (all $p > 0.05$). (Fig-III). Table-1 delineates the demographic features of the Core Strengthening & TENS group and the Control group. Calculations are presented as Mean ± SD (Standard Deviation) with p-value.

NPRS Scores:

After adjusting for baseline pain scores (pre-intervention mean = 8.83), ANCOVA showed a statistically significant decrease pain at post-interventional time in the Core Strengthening along with TENS group (adjusted mean = 0.99, 95% CI: 0.42–1.55) compared with the Control group (adjusted mean = 6.31, 95% CI: 5.75–6.88). The between-group difference was −5.33 points (SE = 0.40, $p < 0.001$), indicating a significant and clinically meaningful reduction in pain. (Table-II, Figure-IV)

Anterior Pelvic Tilt Angle:

For the anterior pelvic tilt angle, baseline means were similar (Core Strengthening + TENS = 16.52°, Control = 16.51°). Post-intervention adjusted means demonstrated a significantly reduced APT in the intervention group (14.61°, 95% CI: 14.33–14.89) contrast with conventional protocol group (16.16°, 95% CI: 15.87–16.44). The between-group difference was -1.54 ° (SE = 0.21, $p < 0.001$), reflecting a significant improvement in pelvic alignment. (Table-II, Figure-IV)

Y-Balance Test Scores:

Baseline Y-Balance scores were also comparable between groups (Core Strengthening + TENS = 91.18, Control = 91.17). Following the intervention, the adjusted mean score was significantly increased in the intervention group (96.72, 95% CI: 95.97–97.47) than in the conventional treatment group (94.28, 95% CI: 93.54–95.03). The between-group improvement of 2.43 points (SE = 0.54, $p < 0.001$) indicates enhanced dynamic balance performance.

At baseline, both groups were comparable across all outcome measures. The Core Strengthening + TENS group demonstrated marked improvements from pre- to post-intervention. Pain scores declined dramatically from 8.83 ± 1.12 to 0.90 ± 1.07 (Δ = –7.93 ± 1.21), reflecting a large and clinically significant reduction in pain. Similarly, the anterior pelvic tilt angle decreased from 16.52° ± 1.38 to 14.03° ± 1.32 (Δ = –2.49° ± 1.35), indicating improved postural alignment. Functional performance, as measured by Y-Balance, improved substantially from 91.18 ± 4.93 to 98.75 ± 4.59 (Δ = +7.57 ± 2.12), demonstrating enhanced dynamic stability.

In contrast, the Control group showed only modest changes. Pain scores remained elevated, declining from 8.83 ± 1.09 to 6.40 ± 1.47 (Δ = –2.43 ± 1.36), while anterior pelvic tilt angle exhibited minimal change (16.51° ± 1.41 to 16.74° ± 1.71, Δ = –0.35° ± 1.42). Y-Balance improved slightly from 91.17 ± 5.18 to 92.25 ± 6.87 (Δ = +3.11 ± 2.48), but this improvement was substantially lower than in the intervention group. (Table-II, Figure-IV)

Across all three outcome measures, the Core Strengthening + TENS group outperformed the control group, achieving substantial reductions in pain, improvements in pelvic alignment, and gains in functional balance. These findings provide strong evidence for the clinical utility of combining core stability training with TENS in the management of non-specific low back pain. (Table-III)

Effect Size & Magnitude Measurement

Magnitude interpretation adhered to current standards: for d—small = 0.2, medium ≈ 0.5, large > 0.8, very large ≥ 1.2, huge ≥ 2.0 (Sawilowsky, 2009); for partial η^2—small ≈ 0.01, medium ≈ 0.06, large ≥ 0.14 (Richardson, 2011). Table III- Shows magnitude of treatment effects was substantial across all outcome measures.

Pain reduction in the Core Strengthening + TENS group demonstrated a huge effect size (Cohen's *d* = −4.29; partial η^2 = 0.828), indicating a profound and clinically significant decrease in pain compared to the conventional physiotherapy. Anterior pelvic tilt (APT) correction showed a *very large* effect (Cohen's *d* = −1.78; partial η^2 = 0.605), indicating marked improvement in pelvic alignment. Y-Balance performance had a *large* effect (Cohen's *d* = 1.11; partial η^2 = 0.354), suggesting a notable enhancement in dynamic balance. These results collectively emphasize the substantial efficacy of the intervention in producing clinically significant and statistically relevant improvements in critical parameters related to non-specific low back pain. (Table-IV)

Pre and Post-Interventional Comparison

Figure-V illustrates the pre–post changes in pain score, anterior pelvic tilt (APT) angle, and Y-Balance performance for both groups. In the Core Strengthening + TENS group, there was a sharp decline in pain scores from baseline (8.83) to post-intervention (0.99), accompanied by a marked reduction in APT angle (16.52° to 14.61°) and a clear improvement in Y-Balance performance (91.18 to 96.72). In contrast, the Control group showed minimal change in APT angle (16.51° to 16.16°) and modest improvement in Y-Balance (91.17 to 94.28), while pain scores remained substantially elevated (8.83 to 6.31). The concurrent downward (Pain and APT angle) and upward (balance) trends in the intervention group across all outcomes demonstrate consistent, clinically significant improvements, while the control group exhibited very little improvements, underscoring the efficacy of the integrated core strengthening along TENS protocol.

Discussion

This RCT demonstrated that Core Strengthening along with TENS program significantly reduced pain intensity, improved anterior pelvic tilt (APT), and enhanced dynamic balance in participants with NSLBP. The intervention group achieved an adjusted post-intervention NPRS score of 0.99 in contrast to 6.31 in the control group, representing a mean difference of −5.33 points and an extremely large effect size ($d = -4.29$). This exceeds the minimal clinically important difference (MCID) for NSLBP, confirming both statistical and clinical significance.

Our findings are consistent with the meta-analysis by Johnson et al (2022), which reported strong evidence for TENS in reducing acute and chronic musculoskeletal pain, and with Sluka and Walsh (2003) and Vance et al (2014), who described TENS-mediated analgesia through activation of large-diameter afferents and descending inhibitory pathways. The CSE along with TENS likely enhanced the analgesic effect by concurrently addressing nociceptive modulation and underlying biomechanical dysfunction, as suggested by Dailey et al (2020) and Liebano et al (2024)**.**

Post-intervention, the intervention group showed a significant decrease in APT (14.61°) compared to the conventional group (16.16°) with a very large effect size ($d = -1.78$). Even modest angular changes can have meaningful implications for lumbopelvic mechanics, as shown in Lee et al (2011), where pelvic tilt was strongly correlated with low back pain severity.

Our findings align with Bhutto et al (2021), who corroborated the efficacy of digital photogrammetry for accurate pelvic tilt measurement in both clinical and research contexts, hence endorsing the reliability of our measuring technique. Additionally, Yu et al (2020) emphasized the correlation between asymmetry of pelvis and NSLBP, reinforcing the clinical significance of our postural adjustments.

The enhancement in APT is due to increased neuromuscular activation of the deep muscles of lumber region stability, as previously indicated by Koumantakis et al (2005), Wang et al (2012), and Smrcina et al (2022), who determined that core stability training is far effective than general exercise in alleviating lumbar postural deviations and pain.

The intervention group exhibited a substantial improvement in Y-Balance test performance (mean difference = 2.43; d = 1.11), signifying greater proprioceptive control and functional stability. This discovery corresponds with the findings of Granacher et al (2013) and Hlaing et al (2021), who asserted that core stabilization improves balance and lumbopelvic movement by increasing trunk muscular endurance and sensorimotor integration. Considering that balance deficiencies are a recognized risk factor for recurrent nonspecific low back pain, these enhancements indicate an additional preventative advantage of the intervention.

The large to extremely large effect sizes across all outcomes highlight the clinical potency of the Core Strengthening combined with TENS protocol. Pain modulation through TENS enables greater engagement in exercise, while core stabilization directly targets the muscular imbalances and motor control deficits underlying APT and functional instability. This dual-action mechanism aligns with the multimodal rehabilitation philosophy advocated by Cuenca-Martinez et al (2018) and Kandil et al (2024).

Conclusion

This randomized controlled trial demonstrates that the combination of Core Strengthening and TENS produces clinically and statistically significant improvements in patients with non-specific low back pain compared to a control group. The intervention group showed a substantial reduction in pain intensity, a notable correction of anterior pelvic tilt angle and a greater enhancement in dynamic balance performance measured by Y-Balance. These improvements consistently exceeded the minimal clinically important difference thresholds, underscoring their practical relevance for rehabilitation.

By contrast, the control group exhibited only marginal improvements, suggesting that natural recovery or nonspecific effects were insufficient to produce meaningful functional gains. The concurrent reductions in pain and pelvic tilt, together with improvements in balance, support the integrative effectiveness of neuromuscular re-education and electrotherapy in restoring lumbopelvic alignment and functional stability.

Collectively, these findings highlight Core Strengthening combined with TENS as a superior, evidence-based intervention for addressing the multidimensional impairments associated with non-specific low back pain.

Limitations:

The study, albeit possessing sufficient statistical power, was constrained by its modest sample size (n = 40) and its singular location in Southern Punjab, potentially diminishing the generalizability of the results to broader populations.

Future Scope

Future research may include multicenter, larger-scale randomized controlled trials with more diverse populations to improve external validity, as well as longitudinal designs incorporating 6-12-month follow-ups to evaluate the persistence of functional and postural improvements.

Recommendations

Physiotherapists may consider the use of combined core strengthening and TENS regimens for individuals experiencing NSLBP and anterior pelvic tilt, especially in the early to mid-stage rehabilitation phase. Furthermore, the use of standardized digital photogrammetry protocols should be promoted in low-resource settings as a cost-effective and non-invasive alternative to radiographic assessment.

Ethical Approval & Clinical Trial Registration

Ethical approval was obtained from the Institutional Review Board (Ref. No. NOGH/ERC/0125/012. The clinical trial has already been registered at the PRS clinical trial registry USA, on 01 August 2025 (ID: NCT07098741).

Conflict of Interest

Author declares no conflict of interest.

Table-I: Participant Demographics and Group Comparisons

Variable	Core Strengthening + TENS (Mean ± SD)	Control Group (Mean ± SD)	p-value	Interpretation
Weight (kg)	72.05 ± 15.51	77.70 ± 10.99	0.192	No significant difference
Age (years)	29.85 ± 6.03	28.20 ± 4.80	0.344	No significant difference
Height (inches)	63.00 ± 3.57	64.33 ± 5.26	0.357	No significant difference

Table-II: Pre- and Post-Intervention Outcomes with Mean Differences

Outcome Measure	Core Strengthening + TENS (Mean ± SD)	Control Group (Mean ± SD)
Pain Score (Pre)	8.83 ± 1.12	8.83 ± 1.09
Pain Score (Post)	0.90 ± 1.07	6.40 ± 1.47
Pain Score (Δ)	-7.93 ± 1.21	-2.43 ± 1.36
Anterior Pelvic Tilt Angle (°) (Pre)	16.52 ± 1.38	16.51 ± 1.41
Anterior Pelvic Tilt Angle (°) (Post)	14.03 ± 1.32	16.74 ± 1.71
Anterior Pelvic Tilt Angle (Δ)	-2.49 ± 1.35	-0.35 ± 1.42
Y-Balance (Pre)	91.18 ± 4.93	91.17 ± 5.18
Y-Balance (Post)	98.75 ± 4.59	92.25 ± 6.87
Y-Balance (Δ)	+7.57 ± 2.12	+3.11 ± 2.48

Table-III: Post-Intervention Outcomes and Between-Group Comparisons

Outcome Measure	Core Strengthening + TENS (Mean ± SD)	Control Group (Mean ± SD)	Mean Difference (I–J)	95% CI	p-value
Pain Score	0.90 ± 1.07	6.40 ± 1.47	-5.327	[-6.135, -4.520]	0.001
Anterior Pelvic Tilt Angle (°)	14.03 ± 1.32	16.74 ± 1.71	-1.544	[-1.960, -1.129]	0.001
Y-Balance	98.75 ± 4.59	92.25 ± 6.87	2.431	[1.338, 3.525]	0.001

Table IV: Effect Sizes and Magnitude of NPRS, APT angle, and Y-Balance

Outcome Measure	Cohen's d	Magnitude (Cohen's d)	Partial η^2	Magnitude (Partial η^2)
Pain Score	−4.29	Extremely Large	0.828	Large
Anterior Pelvic Tilt Angle (°)	−1.78	Very Large	0.605	Large
Y-Balance	1.11	Large	0.354	Large

Figure-I: Photography and APT angle measurement by MicroDicom software.

Figure-II: Y Balance test performance

Figure -III: Gender distribution between the groups

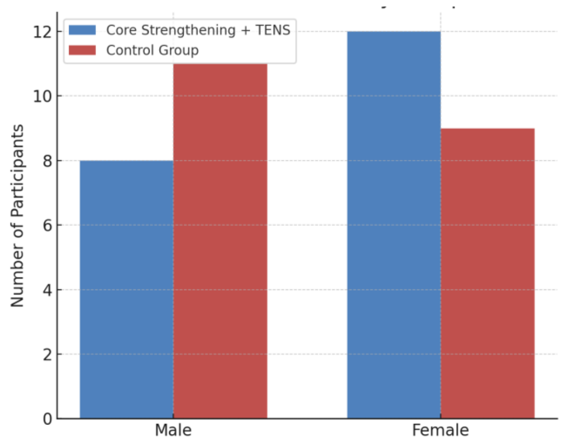
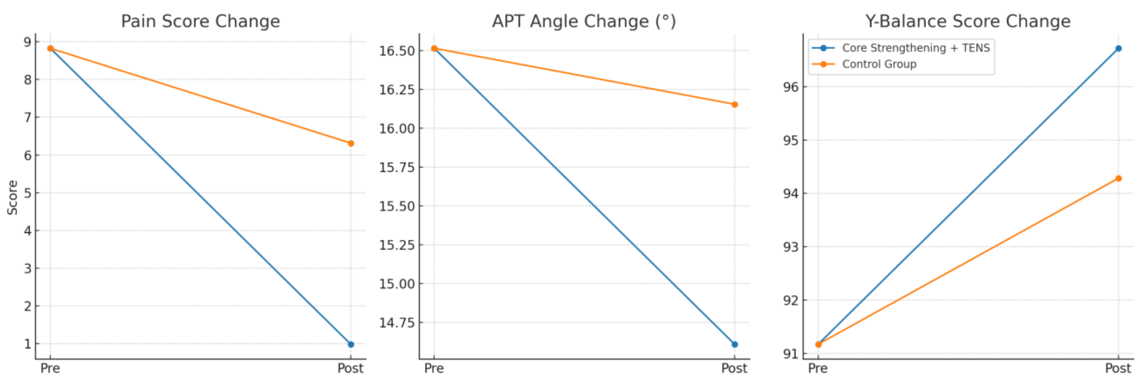


Figure-IV: Pre and Post-Interventional Comparison



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