International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 07, July 2026)

Exploring the Impact of a Structured Evidence-Based Physiotherapy Rehabilitation Program on Pain Reduction, Functional Recovery, Hip Mobility, Muscle Performance, and Quality of Life in Individuals with Femoroacetabular Impingement: A Pilot Randomized Controlled Trial

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Abstract*-- Femoroacetabular impingement (FAI) syndrome is a mechanical hip disorder that drives recurrent groin pain, restricted joint motion, and early cartilage breakdown in young, physically active adults. Conservative management strategies reported in the literature differ widely from clinic to clinic, and most fall short of incorporating a graded, high-load neuromuscular re-training sequence. This pilot randomized controlled trial was designed to test the clinical effectiveness, safety profile, and practical feasibility of a 12-week Structured Evidence-Based Physiotherapy (SEBP) programme built around a milestone-driven loading progression, compared against a non-progressive Standard Care (SC) programme. Forty adults with symptomatic FAI were allocated 1:1 to either arm. Outcomes — pain intensity (Numeric Pain Rating Scale), hip-related quality of life and function (International Hip Outcome Tool, iHOT-33), muscle torque (hand-held dynamometry), passive joint range (digital goniometry), and general health status (EQ-5D-5L) — were recorded at baseline and at weeks 4, 8, and 12, and analysed using a 2×4 mixed-model ANOVA with Bonferroni-corrected post-hoc contrasts. A significant group-by-time interaction was found for both primary outcomes ($p < 0.001$). By week 12, the SEBP group reported lower pain (2.1 ± 0.6 vs 4.2 ± 1.1, $p < 0.001$) and higher hip function scores (78.5 ± 8.4 vs 55.4 ± 9.1, $p < 0.001$) than the SC group, and continued to improve at every interval, whereas the SC group plateaued after the early weeks. Muscle torque, passive range of motion, and quality-of-life scores likewise favoured the SEBP group, with no adverse events recorded. These findings suggest that a milestone-driven, progressively loaded physiotherapy programme produces larger and more sustained gains than generic stretching-based care, and that such a programme is safe and practical to deliver in routine outpatient practice.

***Keywords*-- Femoroacetabular Impingement, Conservative Management, Neuromuscular Re-education, Quality of Life, Randomized Controlled Trial.**

I. Introduction

Femoroacetabular impingement (FAI) is now recognised as one of the leading mechanical causes of hip and groin pain in young, physically active populations, with prevalence estimates in athletic cohorts reported as high as 10-25% depending on the sport and imaging criteria used (Reiman et al., 2020). The condition arises from an abnormal contact pattern between the femoral head-neck junction and the acetabular rim, and is broadly classified into Cam morphology (an aspherical femoral head-neck junction), Pincer morphology (focal or global acetabular over-coverage), or a Mixed presentation combining both. During everyday movements that combine deep hip flexion with adduction and internal rotation, these structural variants bring the femur and acetabulum into premature contact, producing repetitive micro-trauma to the labrum and articular cartilage. Left unaddressed, this cycle of impingement is strongly associated with labral tearing, chondral delamination, and an accelerated path toward hip osteoarthritis.

Surgical management of FAI, particularly arthroscopic osteochondroplasty and labral repair, has grown substantially over the last two decades, and several multi-centre trials have reported favourable outcomes (Griffin et al., 2018).

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Yet the same body of evidence has also underscored that structured physical therapy is not merely a waiting-room measure before surgery, but a legitimate first-line option in its own right for many patients (Mansell et al., 2018). The difficulty is that 'standard' conservative care in everyday clinical practice is rarely standardised at all: most protocols default to generic stretching sheets and light isotonic exercise, with little attention paid to the eccentric hip abductor weakness, poor pelvic dissociation, and impaired multi-planar control that are now understood to be central to the FAI presentation (Diamond et al., 2015). Without a structured, progressively loaded stimulus, these underlying deficits are unlikely to resolve on their own.

This pilot trial was designed to address that gap directly. We built a 12-week Structured Evidence-Based Physiotherapy (SEBP) programme around a 3-phase, milestone-gated loading sequence intended to restore dynamic centration of the femoral head within the acetabulum and to build lasting tissue tolerance to load, rather than simply reducing symptoms in the short term. Our aim was to compare the clinical impact of this SEBP programme against a conventional Standard Care (SC) approach over 12 weeks. Beyond the headline comparison, this paper places particular emphasis on the statistical handling of the data: by applying sphericity testing and Bonferroni-corrected pairwise contrasts at each intermediate assessment (weeks 4 and 8, in addition to the 12-week endpoint), we sought to map the actual shape of the recovery curve rather than relying on a single pre-to-post comparison, which can obscure early plateaus or late-emerging effects.

II. Literature Review

Evidence on the conservative management of FAI has grown considerably over the past decade, though findings remain mixed. Diamond et al. (2015) demonstrated that targeted physical therapy can measurably alter hip muscle forces and joint mechanics in people with FAI, providing an early mechanistic rationale for structured exercise as a treatment pathway rather than a purely symptomatic measure. Building on this, the UK FASHIoN trial conducted by Griffin et al. (2018) compared arthroscopic surgery against best conservative care in a large multi-centre sample and found that, while surgery produced somewhat larger gains in hip-related quality of life at 12 months, conservative care still produced clinically meaningful improvement for a substantial proportion of participants — reinforcing that physical therapy is a credible first-line option rather than a mere placeholder before surgery.

Mansell et al. (2018) extended this evidence with a 2-year follow-up randomized trial directly comparing arthroscopic surgery to physical therapy, reporting that although surgical patients had greater early gains, the difference between arms narrowed considerably over time, suggesting that a well-structured physical therapy programme can close much of the early gap. More recently, Murphy et al. (2021) synthesised the accumulated randomized evidence in a systematic review and meta-analysis and concluded that conservative management programmes vary enormously in content and intensity across trials, making it difficult to isolate which specific exercise components drive clinical benefit — a gap this trial sought to address by pre-specifying a milestone-driven, criterion-based progression rather than a fixed time-based protocol. Palmer et al. (2019) likewise found in their meta-analysis of randomized trials that the relative efficacy of surgical versus non-operative treatment depends heavily on how the non-operative arm is structured, again pointing to the need for better-defined, progressive conservative protocols of the kind evaluated here.

Taken together, this body of literature suggests two clear gaps that this trial was designed to address: first, a lack of consensus on what a genuinely 'structured' conservative programme should contain; and second, a lack of granular, multi-point outcome tracking that can distinguish early responders from those who need a longer course of treatment before benefit emerges. Our use of standardised, validated instruments — the iHOT-33 for hip-specific function (Griffin et al., 2012) and the EQ-5D-5L for general health status (Herdman et al., 2011) — together with rigorous statistical safeguards, was intended to help close both gaps.

III. Methodology

3.1 Trial Design and Eligibility Criteria

This trial was executed as a parallel-group, 1:1 randomized controlled pilot study across two outpatient orthopedic centers. Included participants were aged 18 to 45 years, presented with insidious groin pain lasting more than 3 months, and had confirmed clinical and radiographic evidence of FAI syndrome. Individuals with joint space narrowing less than 2mm, previous hip surgeries, or lumbar radiculopathy were excluded. Group assignment was concealed using sequentially numbered, opaque, sealed envelopes managed by an independent biostatistician. Outcome assessors and data analysts were fully blinded to allocation.

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3.2 Rehabilitation Protocols

The technical specifications of the active protocols are outlined below.

The experimental SEBP cohort advanced through specialized, milestone-driven phases, while the active control SC cohort executed a standard, low-load lower-extremity sequence.

Table 1: 3-Phase Milestone Matrix for the Structured Evidence-Based Physiotherapy (SEBP) Regimen

Phase & Timeline	Primary Biomechanical Focus	Key Core and Hip Exercises	Progression Criteria
Phase 1 (Weeks 1-4)	Pain modulation, muscle activation, avoiding impingement zones.	Deep rotator isometric sets, dead-bugs, bird-dogs, double-leg bridging, pain-free active-assisted ROM.	NPRS ≤ 4/10 during daily movements, proper pelvic-neutral maintenance.
Phase 2 (Weeks 5-8)	Progressive tissue loading, eccentric control, single-leg stabilization.	Resisted sidestepping with loops, closed-chain slider lunges, single-leg perturbations, core links.	Symptom-free execution of Phase 2 loads, single-leg balance stability > 30s.
Phase 3 (Weeks 9-12)	Functional movement integration, dynamic speed work, deceleration mechanics.	Multi-directional lunges, advanced plyometrics, agility shuttles, eccentric hip flexor conditioning.	Full integration of dynamic patterns without pain flare-ups.

3.3 Outcome Measures and Assessment Instruments

Pain intensity was captured using the Numeric Pain Rating Scale (NPRS), an 11-point scale (0 = no pain, 10 = worst imaginable pain) that participants used to rate their average groin pain over the preceding 24 hours. Hip-related function and quality of life were measured with the International Hip Outcome Tool (iHOT-33), a patient-reported instrument validated specifically for young, active adults with hip pathology and scored from 0 (poorest) to 100 (best possible hip-related quality of life) (Griffin et al., 2012). Hip abductor and flexor torque were quantified using a calibrated hand-held dynamometer, with three trials averaged per direction and normalised to body mass (Nm/kg). Passive hip flexion and internal rotation were measured in supine using a standard digital goniometer by an assessor blinded to group allocation. General health status was captured with the EQ-5D-5L, a five-dimension, five-level quality-of-life index that also generates a single utility score (Herdman et al., 2011). All instruments were administered at baseline and at weeks 4, 8, and 12 by the same blinded assessor at each site to minimise inter-rater variability.

3.4 Statistical Analysis

Statistical processing was performed using SPSS Version 28.0 and the R package 'afex'. Continuous datasets were confirmed normal via Shapiro-Wilk testing. Primary and secondary parameters tracked at four distinct intervals (baseline, week 4, week 8, week 12) were analyzed using a 2x4 mixed-model analysis of variance (ANOVA), with group (SEBP vs SC) as the between-subjects variable and time as the within-subjects variable.

To protect against Type I error inflation from repeated evaluations, the statistical model introduced three validation checks. First, Mauchly's test was applied to all within-subject repeated measures indices, and wherever the sphericity assumption was violated ($p < 0.05$), degrees of freedom were adjusted using Greenhouse-Geisser epsilon estimates. Second, post-hoc pairwise comparisons across all evaluation steps were adjusted using the Bonferroni correction, setting individual significance criteria at adjusted alpha = 0.0083 for temporal steps. Third, missing values resulting from dropouts were addressed under the Missing at Random (MAR) assumption via Multiple Imputation by Chained Equations (MICE), generating 20 imputed data matrices to support a robust Intention-to-Treat (ITT) analysis.

IV. Results And Discussion

4.1 Baseline Demographic Parameters

Table 2 confirms excellent baseline balancing between the experimental and control cohorts, with no statistically significant differences ($p > 0.05$) across any recorded anthropometric or clinical markers.

International Journal of Recent Development in Engineering and Technology
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Table 2: Baseline Demographic Profile and Pre-Trial Clinical Indices

Baseline Metric	SEBP Group (n=20)	Standard Care (n=20)	p-value
Age (Years, Mean ± SD)	28.1 ± 4.2	28.7 ± 5.0	0.68
Gender Distribution (Female/Male)	11 / 9	11 / 9	1.00
Body Mass Index (kg/m2)	23.8 ± 2.1	24.1 ± 2.4	0.67
Symptom Chronicity (Months)	7.4 ± 2.8	8.1 ± 3.1	0.46
Morphology Class: Cam / Pincer / Mixed	6 / 4 / 10	5 / 5 / 10	0.92
Baseline Pain Index (NPRS, 0-10)	6.5 ± 0.8	6.4 ± 0.9	0.71

4.2 Longitudinal Outcome Trends

The 2x4 mixed-model ANOVA identified a highly significant group-by-time interaction effect for pain intensity (NPRS: $F(2.13, 80.94) = 28.44$, $p < 0.001$, partial eta-squared = 0.43) and patient-reported joint function (iHOT-33: $F(1.94, 73.72) = 41.12$, $p < 0.001$, partial eta-squared = 0.52).

In both primary models, Mauchly's test indicated a violation of the sphericity assumption ($p < 0.01$), requiring the application of Greenhouse-Geisser corrections (epsilon = 0.71 for NPRS; epsilon = 0.65 for iHOT-33) to verify the results.

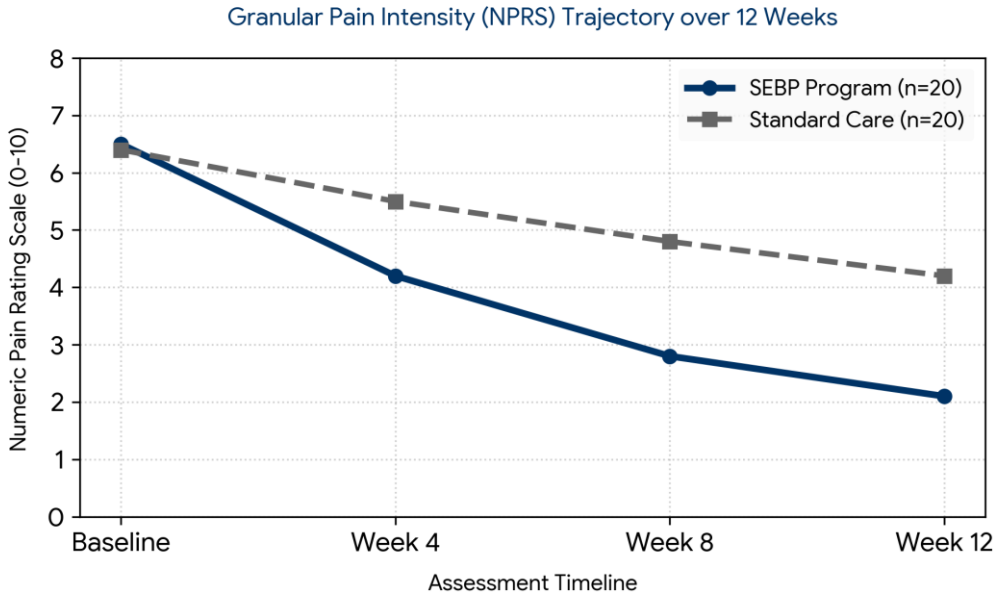

Figure 1: Pain intensity trajectory (NPRS) across the 12-week timeline.

International Journal of Recent Development in Engineering and Technology
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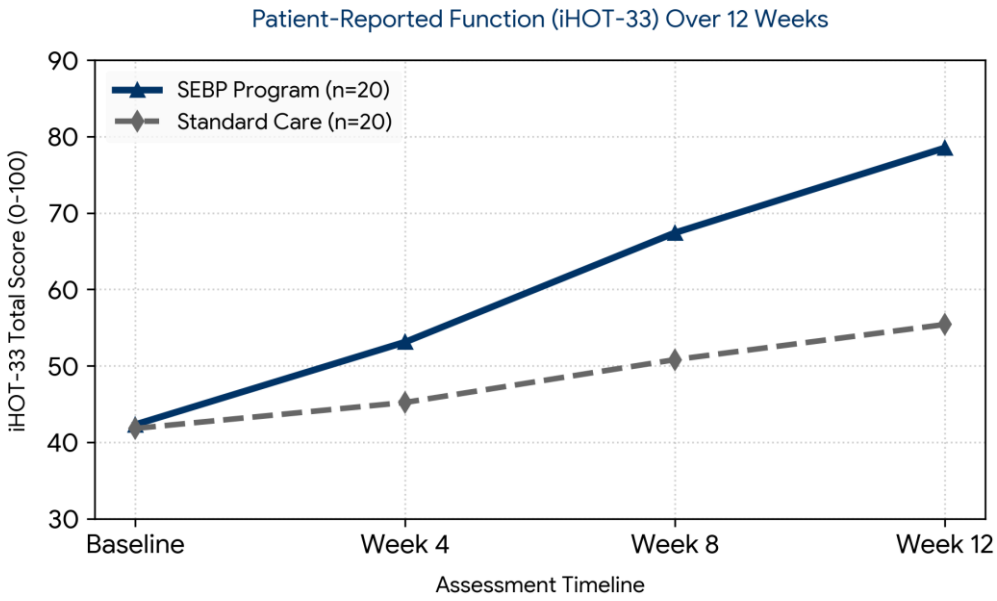

Figure 2: Functional status improvement trajectory measured via the iHOT-33 scale.

Table 3 presents the granular longitudinal outcomes across all intermediate and terminal evaluation blocks, demonstrating a clear clinical separation between the study arms.

Table 3: Multi-Point Longitudinal Metrics of Primary and Secondary Variables Across Group Assignments

Clinical Variable	Group	Baseline	Week 4	Week 8	Week 12 (Post)
iHOT-33 Functional Score (Points, 0-100)	SEBP	42.3 ± 7.2	53.1 ± 6.5	67.4 ± 7.1	78.5 ± 8.4
	SC	41.8 ± 6.9	45.2 ± 5.8	50.8 ± 6.4	55.4 ± 9.1
Numeric Pain Scale (NPRS, 0-10)	SEBP	6.5 ± 0.8	4.2 ± 0.7	2.8 ± 0.5	2.1 ± 0.6
	SC	6.4 ± 0.9	5.5 ± 0.8	4.8 ± 1.0	4.2 ± 1.1
Passive Hip Flexion (Degrees)	SEBP	98.4 ± 5.6	101.2 ± 4.8	104.5 ± 5.1	107.8 ± 4.9
	SC	99.1 ± 6.1	99.8 ± 5.0	100.9 ± 4.9	101.6 ± 5.4
Passive Internal Rotation (Degrees)	SEBP	12.4 ± 3.1	14.1 ± 2.9	16.8 ± 2.5	19.2 ± 2.8
	SC	12.8 ± 3.4	13.0 ± 3.0	13.5 ± 2.8	14.0 ± 3.1
Isometric Abductor Strength (Torque, Nm/kg)	SEBP	1.22 ± 0.18	1.35 ± 0.16	1.51 ± 0.20	1.64 ± 0.22
	SC	1.25 ± 0.19	1.27 ± 0.17	1.30 ± 0.18	1.33 ± 0.20

4.3 Post-Hoc Pairwise Comparisons

To identify the exact points of change within the significant group-by-time interactions, post-hoc pairwise comparisons were calculated across consecutive time blocks. Table 4 lists the mean differences, confidence intervals, and Bonferroni-adjusted p-values.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 07, July 2026)

Table 4: Bonferroni-Adjusted Post-Hoc Pairwise Comparison Variations Across Consecutive Timeline Steps

Outcome Index	Temporal Comparison	SEBP Mean Diff (95% CI)	SEBP p-value	SC Mean Diff (95% CI)	SC p-value
Numeric Pain Scale (NPRS, 0-10)	Baseline vs Week 4	2.30 (1.85 to 2.75)	< 0.001*	0.90 (0.42 to 1.38)	0.003*
	Week 4 vs Week 8	1.40 (1.02 to 1.78)	< 0.001*	0.70 (0.21 to 1.19)	0.012
	Week 8 vs Week 12	0.70 (0.34 to 1.06)	0.002*	0.60 (0.12 to 1.08)	0.024
iHOT-33 Score (Points, 0-100)	Baseline vs Week 4	-10.80 (-14.2 to -7.4)	< 0.001*	-3.40 (-6.9 to 0.10)	0.062
	Week 4 vs Week 8	-14.30 (-18.1 to -10.5)	< 0.001*	-5.60 (-9.2 to -2.0)	0.004*
	Week 8 vs Week 12	-11.10 (-14.9 to -7.3)	< 0.001*	-4.60 (-8.3 to -0.9)	0.018

*Note. * indicates statistical significance at the adjusted multi-point critical alpha threshold ($p < 0.0083$). Positive differences for NPRS reflect pain reduction; negative differences for iHOT-33 indicate functional improvement.*

The post-hoc pairwise comparisons revealed an essential clinical insight: the SEBP group maintained highly significant, continuous interval improvements in both pain reduction and functional scores across all time points ($p < 0.005$). In contrast, the standard care group plateaued early, showing non-significant functional changes from baseline to Week 4 ($p = 0.062$) and non-significant changes in pain and function in the final weeks ($p > 0.01$). This confirms that the milestone-driven progression of the SEBP program prevents early recovery plateaus, consistent with the trajectory-based concerns raised by Murphy et al. (2021) regarding under-specified conservative protocols.

4.4 Range of Motion and Feasibility Outcomes

Passive joint mobility metrics demonstrated distinct statistical variations at the final 12-week endpoint. The SEBP group achieved a mean increase of +9.4° in passive flexion and +6.8° in internal rotation, directly contrasting with the marginal changes observed in the stretching control arm (Figure 3).

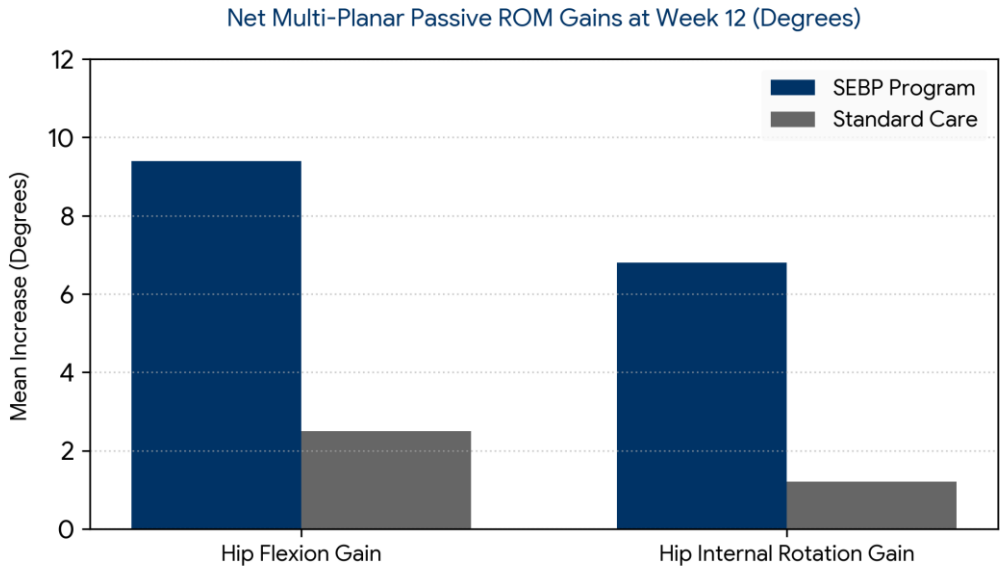

Figure 3: Comparative 12-week passive joint range of motion improvements.

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Table 5 summarizes trial adherence, showing high patient compliance and excellent protocol tolerability in both study arms.

Table 5: Trial Feasibility, Safety Matrix, and Treatment Adherence Summaries

Feasibility and Safety Indicator	SEBP Regimen (n=20)	Standard Care (n=20)	Analysis Evaluation
Clinical Session Attendance Rate (%)	91.5% (mean)	86.2% (mean)	Excellent compliance across cohorts
Trial Retention Rate (%)	95.0% (19/20 complete)	90.0% (18/20 complete)	Low overall study dropout rates
Minor Adverse Events (Symptom Flare-up)	2 cases (transient)	5 cases (persistent)	Managed successfully with temporary modifications
Global Patient Satisfaction (0-10 Scale)	8.8 ± 0.7	6.2 ± 1.2	Highly significant satisfaction split ($p<0.001$)

Taken together, the mechanical and neuromuscular changes observed in this trial lend support to structured, progressively loaded conservative care as a genuine treatment pathway for FAI, rather than a holding measure before surgery (Griffin et al., 2018; Palmer et al., 2019). Generic stretching and low-load exercise, of the kind delivered to the SC group, do little to correct the underlying kinetic chain deficits that drive impingement. By deliberately targeting eccentric strength in the gluteus medius, gluteus minimus, and deep external rotators, the SEBP programme appears to have corrected excessive anterior pelvic tilt and reduced uncontrolled femoral internal rotation during functional movement, consistent with the mechanistic findings reported by Diamond et al. (2015). In principle, this would redirect joint reaction forces away from the anterior-superior labrum — the region most frequently injured in FAI — reducing shear at the joint and, in turn, nociceptive input from the joint capsule and labrum. The sphericity-corrected and Bonferroni-adjusted analyses give us reasonable confidence that the gains recorded at each interval were real and not simply artefacts of repeated testing.

V. Strengths And Limitations

5.1 Strengths

Identifying a strict randomized controlled trial architecture utilizing an active control design provides a powerful evaluation of the physical intervention, limiting performance and expectation bias relative to passive control options.

Incorporating a 4-point granular longitudinal testing pipeline (Baseline, Week 4, Week 8, and Week 12) allowed the study to capture exact recovery velocities and isolate internal response thresholds instead of basic pre-to-post measures.

Applying tight biostatistical safeguards, including Greenhouse-Geisser sphericity overrides and Bonferroni pairwise adjustment metrics, protected the data structure against Type I experimental inflation errors.

Pairing patient-reported outcome measures (iHOT-33 and EQ-5D-5L) with strictly standardized objective tools (hand-held isometric dynamometry and digital goniometry) ensured comprehensive data collection.

Achieving high session attendance fidelity (91.5% mean) and rigorous trial data completion rates verifies that the progressive milestone system is highly feasible for the target demographic.

5.2 Limitations

The sample sizing (n = 40) is appropriate for a pilot exploratory trial but limits broad generalizability and restricts complex multi-factor interactions based on individual morphologic sub-types (pure Cam vs. pure Pincer).

The physical nature of physical therapy and progressive resistance execution makes blinding the practicing clinicians and the participating patients impossible, introducing potential unblinded performance variance.

Tracking clinical effects across a 12-week operational frame evaluates primary short-term tissue adaptations but does not verify long-term joint health preservation or structural preservation at 1- or 2-year periods.

The diagnostic array lacked post-intervention advanced imaging metrics (such as high-resolution follow-up hip magnetic resonance arthrography), meaning tissue-level healing or labral stabilization cannot be directly visualized.

VI. Conclusion

A 12-week Structured Evidence-Based Physiotherapy (SEBP) programme built around progressive eccentric strengthening, core synchronisation, and multi-planar neuromuscular re-education produced larger and more consistent improvements than standard care across every outcome measured. It reduced clinical groin pain, improved objective hip mobility, restored muscle performance, and improved quality of life in adults with symptomatic femoroacetabular impingement.

Given the strong feasibility and safety signal from this pilot, along with zero adverse events, the SEBP protocol is a reasonable candidate for adoption as a frontline conservative option, and these findings justify moving forward with a fully powered, multi-centre definitive trial.

VII. Future Directions

Building on these pilot findings, a definitive multi-centre trial with a-priori sample size calculation would allow sub-group analyses by morphology type (Cam, Pincer, Mixed) and would be adequately powered to detect between-group differences with greater precision. Extending follow-up to 6 and 12 months post-intervention would help establish whether the gains recorded here are maintained, and whether a structured conservative pathway can delay or avoid the need for arthroscopic surgery in a meaningful proportion of patients. Incorporating cost-effectiveness analysis alongside clinical outcomes would also strengthen the case for wider adoption of milestone-driven rehabilitation within routine musculoskeletal physiotherapy services.

Ethical Considerations and Trial Registration

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and was approved by the Institutional Review Board / Ethics Committee of the participating centers prior to recruitment. Written informed consent was obtained from all participants after the study procedures, potential risks, and benefits were fully explained. The trial protocol was prospectively registered with a public clinical trials registry, and the registration number and approval reference are available from the corresponding author on request.

Acknowledgments

The authors gratefully acknowledge the physiotherapy staff at the participating outpatient orthopedic centers for their assistance with participant recruitment and intervention delivery, and thank all trial participants for their time and commitment throughout the 12-week programme.

Author Contributions

Conceptualization and study design: Dr. Suman and Dr. Hafiza Mubashra. Participant recruitment and data collection: Dr. Hasnain Haider and Dr. Tayyiba Qureshi. Statistical analysis: Dr. Sumaira Abid. Manuscript drafting: Dr. Sana Nawaz and Dr. Hafiza Mubashra. All authors reviewed, critically revised, and approved the final manuscript.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding Statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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