INSIGHTS-JOURNAL OF
HEALTH AND REHABILITATION

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

ASSESSMENT OF A REAL-TIME AI MOTION COACH FOR CORRECTING SCAPULAR DYSKINESIS IN OVERHEAD ATHLETES WITH SHOULDER PAIN.

Original Research

Laiba Khalid Butt*[1], Fatima Shabbir[2], Tooba Rauf[2], Eisha Mubarik[3], Dr. Ahmad Faraz[4]

[1]Physiotherapist, Department of Physical Therapy, Faculty of Pharmacy and Health Sciences, University of Balochistan UOB, Quetta, Pakistan.

[2]Physical Therapist, Physio & Rehab Department, Bahria Active, Bahria Town Rawalpindi, Pakistan.

[3]Physiotherapist, Riphah International University, Lahore

[4]Riphah International University Lahore

Corresponding Author: Laiba Khalid Butt, laiba8089@gmail.com, Physiotherapist, Department of Physical Therapy, Faculty of Pharmacy and Health Sciences, University of Balochistan UOB, Quetta, Pakistan.

Acknowledgement: The authors sincerely acknowledge all participants and the supporting rehabilitation centers for their cooperation and contribution to this study.

Conflict of Interest: None

Grant Support & Financial Support: None

ABSTRACT

Background: Scapular dyskinesis is a common contributor to shoulder pain in overhead athletes, often resulting in impaired biomechanics and functional limitations. Conventional physiotherapy relies on therapist-guided correction, which may lack consistency and real-time precision. Emerging artificial intelligence (AI)-based motion analysis systems offer the potential to enhance rehabilitation through immediate feedback and movement optimization.

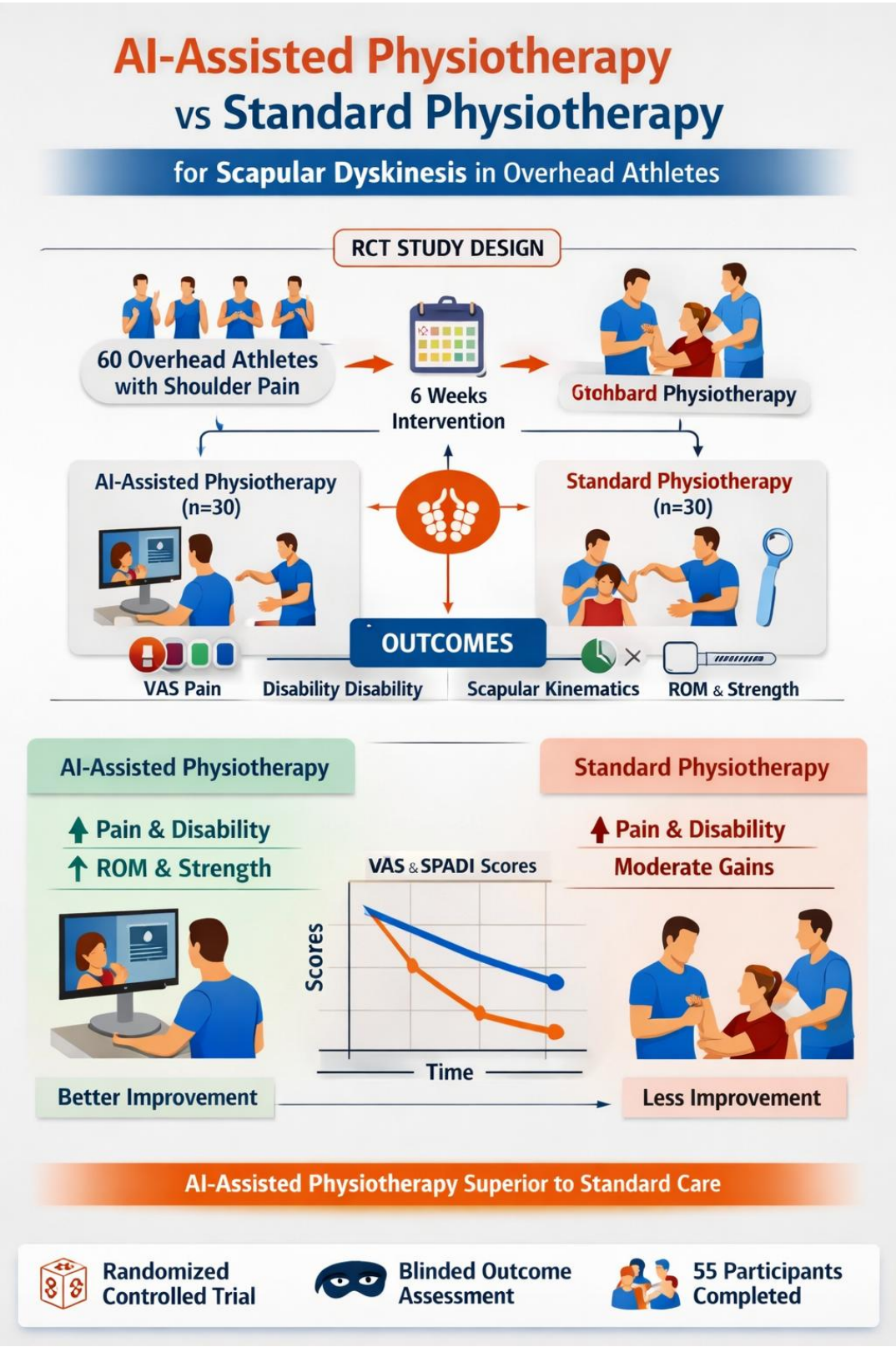
Objective: To determine whether AI-driven real-time motion feedback improves movement patterns and reduces pain more effectively than standard physiotherapy in overhead athletes with shoulder pain.

Methods: A parallel-group randomized controlled trial was conducted in the Islamabad–Rawalpindi region over five months. Sixty overhead athletes aged 18–35 years with clinically diagnosed scapular dyskinesis were randomized into an intervention group (AI-assisted physiotherapy) or control group (standard physiotherapy). The intervention was delivered over six weeks, with three sessions per week. Primary outcomes included pain intensity (Visual Analog Scale) and functional disability (Shoulder Pain and Disability Index). Secondary outcomes comprised scapular kinematics, shoulder range of motion, and muscle strength. Data were analyzed using paired and independent t-tests, and repeated measures ANOVA.

Results: Fifty-five participants completed the study (intervention n=27; control n=28). The intervention group demonstrated significantly greater reductions in pain (mean difference: -1.3; 95% CI: -1.8 to -0.8; $p<0.001$) and disability (mean difference: -11.2; 95% CI: -15.0 to -7.4; $p<0.001$) compared to the control group. Significant time × group interactions were observed for both VAS ($F=18.72$, $p<0.001$) and SPADI ($F=22.45$, $p<0.001$). Improvements in scapular kinematics, range of motion, and muscle strength were also significantly greater in the intervention group.

Conclusion: AI-assisted physiotherapy provided superior clinical and functional outcomes compared to standard care, suggesting its value as an adjunct in the rehabilitation of scapular dyskinesis among overhead athletes.

Keywords: Athletic Injuries; Biomechanical Phenomena; Physical Therapy Modalities; Rehabilitation; Scapula; Shoulder Pain; Technology



INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

INTRODUCTION

Shoulder pain is one of the most prevalent musculoskeletal complaints among overhead athletes, affecting individuals engaged in sports such as baseball, volleyball, tennis, and swimming. The repetitive nature of overhead movements places substantial biomechanical demands on the shoulder complex, often leading to functional impairments rather than isolated structural pathology (1). Among these impairments, scapular dyskinesis has emerged as a key contributor to altered shoulder mechanics and persistent pain. Characterized by abnormal positioning or motion of the scapula during arm movement, scapular dyskinesis disrupts the coordinated function of the scapulohumeral rhythm, thereby compromising joint stability, increasing subacromial stress, and predisposing athletes to overuse injuries (2, 3). The clinical management of scapular dyskinesis traditionally relies on physiotherapy interventions aimed at restoring muscular balance, neuromuscular control, and movement coordination. Exercise-based rehabilitation, including scapular stabilization and motor control training, has demonstrated efficacy in improving function and reducing symptoms. However, the success of such interventions is highly dependent on the quality and consistency of movement execution. Subtle deviations in technique are often difficult for patients to recognize independently, and real-time correction by clinicians is limited to supervised sessions (4). Consequently, a gap persists between prescribed rehabilitation protocols and their accurate implementation outside clinical settings, potentially diminishing therapeutic outcomes (5, 6).

Recent advances in artificial intelligence have introduced new possibilities for addressing these limitations. Real-time AI motion analysis systems, leveraging computer vision and machine learning algorithms, are increasingly capable of detecting movement patterns, identifying biomechanical deviations, and providing immediate corrective feedback. Such systems offer a scalable and accessible means of augmenting traditional physiotherapy by enabling continuous monitoring and guidance during exercise performance. In the context of scapular dyskinesis, where precise motor control is critical, AI-driven feedback may enhance motor learning by reinforcing correct movement patterns and reducing compensatory strategies (7). Despite the growing interest in AI-assisted rehabilitation, evidence supporting its clinical effectiveness remains limited, particularly in athletic populations with shoulder dysfunction (8). While preliminary studies suggest that biofeedback and digital coaching tools can improve adherence and technique, few investigations have rigorously compared AI-driven interventions with standard physiotherapy in a controlled experimental framework. Moreover, the specific impact of real-time corrective feedback on both biomechanical outcomes and pain reduction in overhead athletes has not been sufficiently explored. This represents a critical gap, as optimizing rehabilitation strategies for this population has implications not only for symptom resolution but also for performance and injury prevention (9, 10).

Another important consideration is the integration of technology into routine clinical practice. For AI-based systems to be meaningful, they must demonstrate not only technical accuracy but also tangible benefits in patient-centered outcomes. Pain reduction, functional improvement, and the restoration of efficient movement patterns are key indicators of successful rehabilitation (11). Understanding whether AI motion coaching can deliver superior or complementary benefits compared to conventional physiotherapy is therefore essential for guiding clinical decision-making and resource allocation (12, 13). In this context, the present randomized controlled trial is designed to evaluate the effectiveness of a real-time AI motion coach in correcting scapular dyskinesis among overhead athletes with shoulder pain. The central hypothesis is that AI-driven feedback, by providing immediate and precise movement correction, will lead to greater improvements in scapular kinematics and more substantial reductions in pain compared to standard physiotherapy alone. Accordingly, the objective of this study is to determine whether the integration of AI-based real-time feedback into rehabilitation protocols enhances movement quality and alleviates pain more effectively than conventional physiotherapeutic approaches in this population (14).

METHODS

The study was conducted as a parallel-group randomized controlled trial in the Islamabad–Rawalpindi region, a setting characterized by a high concentration of sports rehabilitation centers and overhead athletes engaged in cricket, badminton, and volleyball, making it relevant for evaluating shoulder biomechanics in real-world clinical practice. The total study duration was five months, including recruitment, intervention, and follow-up phases, while the intervention itself was administered over six weeks. A sample size of 60 participants was determined based on effect sizes reported in a comparable interventional study assessing physiotherapy-based scapular stabilization in athletes with shoulder dysfunction, allowing adequate power to detect clinically meaningful differences between groups. Participants were overhead athletes aged 18–35 years presenting with shoulder pain of at least four weeks' duration and clinically diagnosed scapular dyskinesis through observational scapular dyskinesis tests. Individuals with prior shoulder surgery, acute fractures or dislocations, neurological deficits affecting upper limb function, systemic inflammatory conditions, or current participation in other structured rehabilitation programs were excluded to minimize confounding variables. After baseline assessment, participants were randomly allocated in a 1:1 ratio using a computer-generated randomization sequence. Allocation concealment was ensured through sequentially numbered, sealed opaque envelopes prepared by an independent researcher. Due to the nature of the intervention, participant and therapist blinding was not feasible; however, outcome assessors were blinded to group allocation to reduce detection bias.

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

The intervention group received an AI-driven motion coaching program integrated with standard physiotherapy. Sessions were conducted three times per week for six weeks, each lasting approximately 45 minutes. The AI system utilized real-time motion capture via a camera-based interface to provide immediate visual and auditory feedback on scapular positioning and movement during targeted exercises, including scapular retraction, upward rotation, and neuromuscular control drills. Each session comprised a 10-minute warm-up, 25 minutes of guided corrective exercises with AI feedback, and a 10-minute cool-down. The control group received standard physiotherapy alone, consisting of therapist-guided scapular stabilization exercises with identical frequency and duration but without AI assistance. Adherence was monitored by attendance logs and system usage data, and an intention-to-treat approach was adopted to account for dropouts. Primary outcomes included pain intensity measured by the Visual Analog Scale (VAS) and functional disability assessed using the Shoulder Pain and Disability Index (SPADI). Secondary outcomes comprised scapular kinematics evaluated by observational scoring, shoulder range of motion measured with a goniometer, and muscle strength assessed using a handheld dynamometer. All outcomes were recorded at baseline and at the end of the six-week intervention period. Data were analyzed using SPSS software. Normality was assessed using the Shapiro–Wilk test. Between-group comparisons were performed using independent t-tests, while within-group changes were evaluated using paired t-tests. A repeated measures ANOVA was applied to examine time-by-group interactions. Pearson correlation analysis was conducted to explore relationships between changes in scapular kinematics and pain reduction. Statistical significance was set at $p < 0.05$.

RESULTS

A total of 78 overhead athletes were screened for eligibility, of whom 60 met the inclusion criteria and were enrolled in the trial. Participants were randomly allocated into the intervention group (n=30) and control group (n=30). During the six-week intervention period, three participants from the intervention group were lost to follow-up due to scheduling conflicts (n=2) and minor unrelated illness (n=1), while two participants from the control group discontinued due to non-compliance with therapy sessions. Consequently, outcome data were analyzed for 55 participants (intervention n=27; control n=28). The overall study duration spanned five months, incorporating recruitment, intervention, and follow-up phases, whereas the intervention itself was strictly conducted over six weeks. Baseline demographic and clinical characteristics were comparable between groups, with no statistically significant differences observed ($p>0.05$), confirming successful randomization.

Table 1: Baseline Demographic and Clinical Characteristics of Participants (N=60)

Variable	Total Sample (N=60)	Intervention (n=30)	Control (n=30)	p-value
Age (years)	24.8 ± 4.2	25.1 ± 4.5	24.5 ± 3.9	0.62
Gender (Male)	42 (70%)	21 (70%)	21 (70%)	1.00
Duration of pain (weeks)	7.6 ± 2.1	7.8 ± 2.3	7.4 ± 2.0	0.48
VAS score	6.5 ± 1.0	6.6 ± 1.1	6.4 ± 0.9	0.39
SPADI score	58.2 ± 8.5	59.1 ± 8.9	57.3 ± 8.1	0.41

Post-intervention analysis demonstrated significant improvements in primary outcomes favoring the intervention group.

Table 2: Post-Intervention Comparison of Primary Outcomes (Final Sample: n=27 vs n=28)

Outcome	Intervention	Control	Mean Difference (95% CI)	p-value
VAS score	2.1 ± 0.9	3.4 ± 1.1	-1.3 (-1.8 to -0.8)	<0.001
SPADI score	24.6 ± 6.2	35.8 ± 7.5	-11.2 (-15.0 to -7.4)	<0.001

Within-group comparisons using paired t-tests revealed statistically significant reductions in both VAS and SPADI scores in each group ($p<0.001$), with greater magnitude observed in the intervention group.

Table 3: Within-Group Pre–Post Changes (Final Sample: n=27 vs n=28)

Outcome	Group	Baseline	Post	Mean Change	p-value
VAS	Intervention	6.6 ± 1.1	2.1 ± 0.9	-4.5 ± 1.2	<0.001
VAS	Control	6.4 ± 0.9	3.4 ± 1.1	-3.0 ± 1.0	<0.001
SPADI	Intervention	59.1 ± 8.9	24.6 ± 6.2	-34.5 ± 7.8	<0.001
SPADI	Control	57.3 ± 8.1	35.8 ± 7.5	-21.5 ± 6.9	<0.001

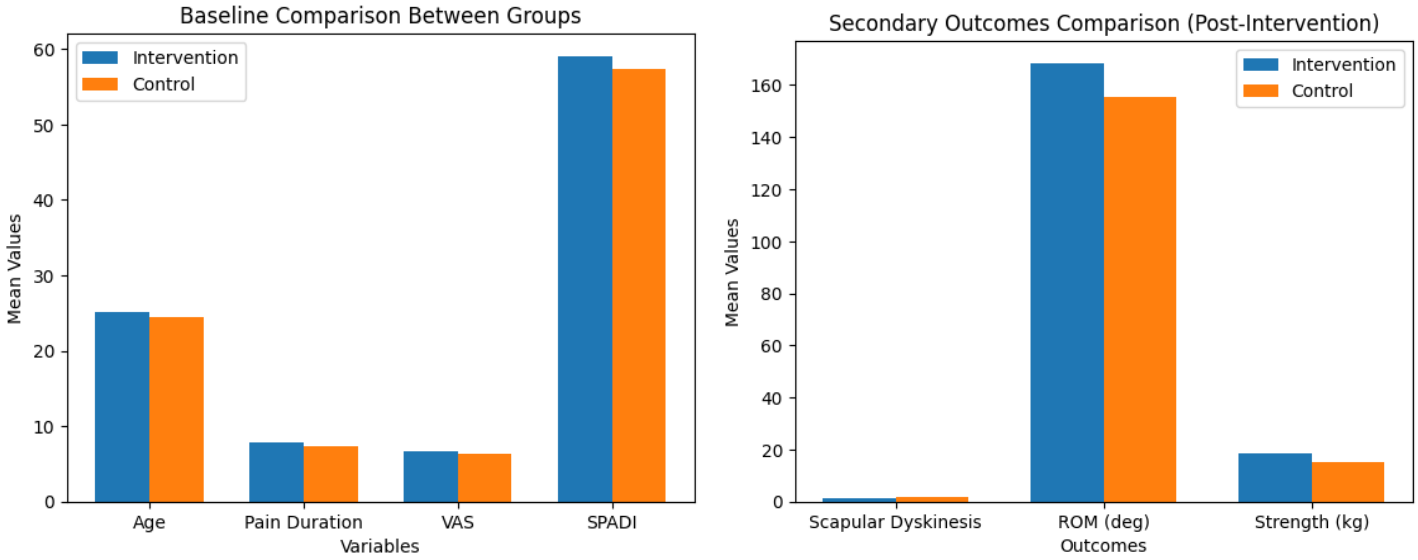
INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

Repeated measures ANOVA demonstrated a significant time effect ($p<0.001$), group effect ($p<0.01$), and a significant time × group interaction for both VAS ($F=18.72$, $p<0.001$) and SPADI ($F=22.45$, $p<0.001$), indicating greater improvement over time in the intervention group. Secondary outcomes also favored the intervention group.

Table 4: Secondary Outcomes (Final Sample: n=27 vs n=28)

Outcome	Intervention	Control	p-value
Scapular dyskinesis score	1.2 ± 0.5	2.0 ± 0.6	<0.001
Shoulder ROM (degrees)	168.5 ± 8.2	155.3 ± 10.1	<0.001
Muscle strength (kg)	18.6 ± 3.1	15.2 ± 2.8	<0.001

Pearson correlation analysis revealed a moderate positive correlation between improvement in scapular kinematics and reduction in VAS scores ($r=0.58$, $p<0.001$).



DISCUSSION

The present randomized controlled trial demonstrated that the integration of a real-time AI motion coaching system into standard physiotherapy resulted in significantly greater improvements in pain reduction, functional outcomes, and scapular biomechanics compared to conventional rehabilitation alone in overhead athletes with scapular dyskinesis. The observed reductions in VAS and SPADI scores, alongside enhanced range of motion and muscle strength, indicated that augmenting therapist-guided exercises with immediate, objective feedback may have facilitated more precise motor relearning and neuromuscular control (15). The significant time × group interaction further reinforced that these benefits were not merely attributable to general recovery over time but were specifically enhanced by the AI-driven intervention (16). These findings aligned with emerging evidence suggesting that biofeedback and motion-tracking technologies can optimize rehabilitation outcomes in musculoskeletal disorders. Prior studies evaluating scapular stabilization programs have consistently reported improvements in pain and function; however, such interventions often rely heavily on subjective therapist cues and patient adherence to correct movement patterns. The addition of real-time AI feedback appeared to address this limitation by continuously correcting movement deviations, thereby reinforcing proper scapular kinematics during exercise execution. This was supported by the moderate correlation observed between improvements in scapular motion and pain reduction, suggesting a clinically meaningful link between biomechanical correction and symptom relief. While earlier investigations into digital or sensor-based rehabilitation tools have shown promising results, the present study contributed further by demonstrating these effects within a controlled trial design and a sports-specific population (17, 18).

The clinical implications of these findings were notable, particularly in the context of sports rehabilitation where subtle biomechanical inefficiencies can predispose athletes to persistent symptoms and recurrent injury. The ability of AI-assisted systems to provide standardized, reproducible feedback may reduce variability in treatment delivery and potentially enhance patient engagement. Moreover, such technology could extend beyond clinical settings into remote or home-based rehabilitation, addressing barriers related to accessibility and continuity of care. Nevertheless, the extent to which these short-term improvements translate into long-term injury

prevention or sustained functional gains remained uncertain and warranted cautious interpretation (19). Several strengths supported the validity of the study. The use of a parallel-group randomized controlled design with allocation concealment and assessor blinding minimized selection and detection biases. The intervention protocol was clearly structured and replicable, and adherence monitoring added methodological rigor. Additionally, the inclusion of both subjective and objective outcome measures allowed for a comprehensive assessment of treatment effects. The study setting, involving active overhead athletes, enhanced the ecological validity and relevance of the findings to real-world clinical practice (20, 21).

Despite these strengths, certain limitations were evident. The relatively small sample size and short intervention duration may have limited the generalizability of the results and the ability to detect longer-term effects. The absence of participant and therapist blinding introduced a potential risk of performance bias, particularly given the interactive nature of the AI system. Furthermore, the reliance on observational methods for assessing scapular dyskinesis, although clinically practical, may have been less precise than instrumented motion analysis techniques. Variability in individual athletic training loads and external activities outside the intervention sessions could also have influenced outcomes, despite efforts to standardize rehabilitation protocols (22). Future research should aim to address these limitations by incorporating larger, multicenter samples and extended follow-up periods to evaluate the durability of treatment effects. The integration of advanced motion capture systems or wearable sensors could provide more granular biomechanical data, enhancing the precision of outcome assessment. Comparative studies examining different AI feedback modalities or levels of interactivity may further elucidate the mechanisms underlying observed benefits. Additionally, exploring the cost-effectiveness and feasibility of implementing such technologies in diverse healthcare settings would be essential for broader clinical adoption (23, 24).

Overall, the findings suggested that AI-assisted rehabilitation represented a promising adjunct to conventional physiotherapy for correcting scapular dyskinesis and alleviating shoulder pain in overhead athletes. However, these results were best interpreted as an incremental advancement rather than a replacement for established therapeutic approaches, underscoring the importance of integrating technological innovation with sound clinical expertise.

CONCLUSION

The integration of real-time AI motion coaching with standard physiotherapy resulted in superior improvements in pain, functional ability, and scapular mechanics compared to conventional treatment alone in overhead athletes. These findings highlight the potential of AI-driven feedback to enhance movement correction and rehabilitation precision. Incorporating such technology into clinical practice may improve therapeutic outcomes, although further research is needed to confirm long-term benefits and broader applicability.

AUTHOR CONTRIBUTION

Author	Contribution
Laiba Khalid Butt	Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Validation, Supervision
Fatima Shabbir	Methodology, Investigation, Data Curation, Writing - Review & Editing
Tooba Rauf	Investigation, Data Curation, Formal Analysis, Software
Eisha Mubarik	Software, Validation, Writing - Original Draft
Dr. Ahmad Faraz	Formal Analysis, Writing - Review & Editing

REFERENCES

1. Zhao FJFiSR. The application of sports biomechanics in sports injury prevention and rehabilitation. 2024;6(3):142-7.

2. Khosravi MRJAJoM, Humanity, Science S. Sports Injuries: Biomechanical Data Analysis and Prevention. 2025;1(9):559-78.

3. Takáč PJAS. Sports injury rehabilitation: A narrative review of emerging technologies and biopsychosocial approaches. 2025;15(17):9788.

4. Wen M, Hu X, Bao GJBSS, Medicine, Rehabilitation. Scapular dyskinesis-based exercise therapy versus multimodal physical therapy for subacromial impingement syndrome in young overhead athletes with scapular dyskinesis: a randomized controlled trial. 2025;17(1):204.

5. Pei Z, Wang MJM, Biomechanics C. New applications of sports biomechanics in human health and athletic performance. 2025;22(5).

6. Wang M, Pei ZJM, Biomechanics C. Injury prevention and rehabilitation strategies in physical education: A machine learning-based approach using biomechanical characteristics. 2024;21(2).

7. Rosenberg N. Shoulder Injuries and Treatment: BoD–Books on Demand; 2025.

8. Fu Y, Ma S, Ma B, Han M, Zhao D, Li ZJEJoMR. Innovative diagnostic framework for shoulder instability: a narrative review on machine learning-enhanced scapular dyskinesis assessment in sports injuries. 2025;30(1):257.

9. Ahmad CS, Schulz BMJOJoSM. Sports-specific biomechanics the kinetic chain. 2021;9(1):71.

10. Kostrikova KJSJoPU. SHOULDER MECHANICS AND INJURY RISK IN AERIAL ACROBATICS: FROM LOAD PATTERNS TO RECOVERY PATHWAYS. 2025;70(3):204-11.

11. Lv S, Wang Q, Ni Q, Qi C, Ma Y, Li S, et al. Progress of muscle chain theory in shoulder pain rehabilitation: potential ideas for pulmonary rehabilitation. 2022;2022(1):2537957.

12. Swart JJWJP-G. The effectiveness of exercise interventions to prevent shoulder injuries in sport: A systematic review and meta-analysis. 2021.

13. Miyashita K, Koshida S, Koyama T, Ota K, Tani Y, Okamune RJPTR. Biomechanical characteristics of scapular and glenohumeral movements during pitching motion in injury-prone college baseball pitchers. 2023:E10254.

14. McGowen JM, Hoppes CW, Forsse JS, Albin SR, Abt J, Koppenhaver SLJJoat. The utility of myotonometry in musculoskeletal rehabilitation and human performance programming. 2023;58(4):305-18.

15. Кострікова КЈВНуЧкіТШ. BIOMECHANICAL AND KINETIC ASPECTS OF ACROBATIC ELEMENTS IN POLE SPORT. 2025;187(31):46-51.

16. Evan TYZ, Kevin YJH, Dave LYH, Phornphutkul C. Sports-Related Shoulder Fractures: Diagnosis, Management, and Rehabilitation. Sports Injuries: Prevention, Diagnosis, Treatment and Rehabilitation: Springer; 2025. p. 915-32.

17. Han Y, Zhang B, Zheng F, Li Z, Gong H, Pei S, et al. Finite element analysis of neck sports injury based on a whole cervical spine model with muscles. 2025:1-14.

18. Zhang Y, Zhang Q, Liu YJFiP. Athlete injury detection and emergency treatment in mobile smart medical system. 2023;11:1191485.

19. Muthukrishnan PJSR, G S, Biomechanical, Syndrome' SIiSOEaNCPoM-PM. Biomechanical and Sensorimotor Impairments in Smartphone Overusers: Establishing a New Clinical Phenotype of'Mobile-Phone Musculoskeletal Syndrome'. 2025.

20. Petrone N, Leslie G, Zullo G. Sports injury and trauma biomechanics: Surrogates, human data and modeling. Routledge Handbook of Sports Technology and Engineering: Routledge. p. 392-424.

21. Soares IC, da Silva MVG, de Lima LCR, Pedroni CRJBJoPT. EFFECTS OF TRAINING WITH BLOOD FLOW RESTRICTION ASSOCIATED TO ELECTROSTIMULATION ON MUSCLE THICKNESS AND PERFORMANCE: CLINICAL TRIAL PROTOCOL. 2024;28:100767.

22. Xie Q, Li J, Liu Q, editors. Analysis of the Traumatic Mechanism of Injury in Obstacle Training: Construction of Prevention and Treatment Models Based on Multivariate Data Analysis. Proceedings of the 2025 2nd International Conference on Sports Technology and Performance Analysis; 2025.

23. Ramasamy Y, Usman J, Razman R, Wei YM, Towler H, King MJAS. A systematic review of the biomechanical studies on shoulder kinematics in overhead sporting motions: types of analysis and approaches. 2023;13(16):9463.

24. Yoon Y, Lam KHS, Park C, Lee J, Kye J, Kim H, et al. Innovative Dynamic Ultrasound Diagnosis of First Rib Stress Fracture in an Adolescent Athlete—A Case Report. 2025;15(19):2437.