COMPETITOR:
JURNAL PENDIDIKAN KEPELATIHAN OLAHRAGA
e-ISSN: 2657-0734 & p-ISSN: 2085-5389 ‖ Volume 18, Number 1, 2026 ‖ P.1374-1384

Ultrasound and Balance Training for Ankle Sprains: A Case Study on Pain and Stability

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ABSTRACT

Ankle sprains are among the most prevalent musculoskeletal injuries and frequently progress to Chronic Ankle Instability (CAI) when not managed comprehensively. Persistent pain, proprioceptive deficits, and impaired neuromuscular control contribute to recurrent injury risk and decreased athletic performance. Therefore, integrative physiotherapy strategies targeting both tissue healing and dynamic stability are essential. This case study aimed to evaluate the clinical effectiveness of combining therapeutic Ultrasound and Balance Training in reducing pain and improving functional ankle stability in an athlete with ankle sprain. A single-subject case study design with a pre-test–post-test approach was conducted on a 22-year-old male professional football goalkeeper diagnosed with ankle sprain. The intervention consisted of 12 therapy sessions over four weeks at Fisiohands Physiotherapy Clinic. The program included Ultrasound therapy (3 MHz, 1.5 W/cm^2, 5 minutes) to stimulate ligament healing and progressive Balance Training using a Bosu Ball and Wobble Board to enhance neuromuscular control. Pain was assessed using the Numeric Rating Scale (NRS), and functional stability was measured using the Cumberland Ankle Instability Tool (CAIT). Post-intervention findings showed significant clinical improvement. Resting pain decreased from 5 to 0, tenderness from 7 to 1, and motion pain from 8 to 1. The CAIT score improved from 9 to 22 points, reflecting a 13-point increase in functional stability. The integration of Ultrasound and Balance Training effectively reduced pain and substantially improved ankle joint stability, supporting its role as a comprehensive physiotherapy strategy to facilitate safe return to sport and minimize reinjury risk.

ARTICLE HISTORY
Received: 2026/02/16
Accepted: 2026/02/23
Published: 2026/02/26

KEYWORDS
Ankle Sprain;
Ultrasound Therapy;
Balance Training;
Chronic Ankle Instability;
Physiotherapy Rehabilitation.

AUTHORS' CONTRIBUTION
A. Conception and design of the study;
B. Acquisition of data;
C. Analysis and interpretation of data;
D. Manuscript preparation;
E. Obtaining funding

Cites this Article : Rizal, Y.; Dindasari, N.; Alvi, S. (2026). Ultrasound and Balance Training for Ankle Sprains: A Case Study on Pain and Stability. **Competitor: Jurnal Pendidikan Kepelatihan Olahraga**. 18 (1), p.1374-1384

INTRODUCTION

Ankle sprain remains one of the most prevalent musculoskeletal injuries across athletic and general populations worldwide. Epidemiological data consistently report that lateral ankle sprain accounts for approximately 15–30% of all sports-related injuries, with a high incidence among adolescents and young adults (Ali et al., 2025; Kirani et al., 2025). In Indonesia, lower extremity injuries dominate sports trauma statistics, with ankle ligament sprains representing a substantial proportion of reported cases (Fauzani

et al., 2025). The burden is not limited to athletes; recreationally active individuals and even non-athletic populations experience significant functional impairment due to ankle sprains (Hosseini et al., 2024). Clinically, ankle sprain is characterized by overstretching or tearing of one or more ankle ligaments, most commonly the anterior talofibular ligament (ATFL) (Malik et al., 2025). The ankle joint complex involves intricate coordination among osseous structures, ligaments, musculotendinous units, and neurosensory components responsible for postural control and weight-bearing mobility. This biomechanical complexity renders the joint highly susceptible to instability when structural or neuromuscular integrity is compromised (Rizal & Samosir, 2024). Although frequently perceived as a minor injury, longitudinal studies demonstrate that up to 60–74% of individuals with acute ankle sprains develop chronic ankle instability (CAI), characterized by recurrent sprains, persistent pain, swelling, reduced dorsiflexion range of motion, and functional deficits (Kosik et al., 2025; Toyooka, 2025). Chronic instability not only impairs daily function but also significantly increases the risk of early degenerative changes and long-term disability (Hosseini et al., 2024). Risk factors are multifactorial, including intrinsic components such as high body mass index (BMI), reduced proprioception, muscle weakness, previous injury history, and poor postural balance, as well as extrinsic factors such as inappropriate footwear and uneven playing surfaces (Rizal & Samosir, 2024; Park et al., 2025). Persistent dorsiflexion pain has been identified as a strong predictor of recurrent injury, indicating incomplete neuromuscular recovery even after symptomatic improvement (Kosik et al., 2025). Given the high recurrence rate and long-term consequences, ankle sprain should not be managed as an isolated acute injury but rather as a condition requiring structured, evidence-based rehabilitation targeting both pain modulation and neuromuscular stabilization.

Contemporary rehabilitation for ankle sprain integrates multimodal physiotherapy approaches emphasizing tissue healing, pain reduction, and functional restoration. During the acute phase, protection, rest, ice, compression, and elevation (PRICE protocol) remain the standard initial management (Rizal, 2023). However, beyond the inflammatory stage, active rehabilitation becomes critical. Therapeutic ultrasound (US) is widely utilized as an electrotherapeutic modality in musculoskeletal rehabilitation. Ultrasound delivers mechanical acoustic energy that produces thermal and non-thermal effects, enhancing tissue metabolism, promoting collagen synthesis, increasing local blood flow, and accelerating ligament healing (Rizal, 2023; Hosseini et al., 2024). Meta-analyses in recent years indicate that ultrasound may reduce pain intensity and inflammatory markers when applied appropriately in subacute ligament injuries (Ali et al., 2025). However, its effectiveness remains dependent on dosage parameters, frequency, and combination with active rehabilitation strategies. Parallel to electrotherapy developments, neuromuscular and balance training has emerged as a cornerstone intervention for ankle instability. Proprioceptive exercises utilizing wobble boards, single-leg stance tasks, unstable surfaces, and dynamic balance drills have demonstrated significant improvements in joint position sense, postural control, and functional performance (Park et al., 2025). Randomized controlled trials confirm that

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structured balance training significantly reduces recurrence rates compared to conventional strengthening alone (Toyooka, 2025). Recent biomechanical investigations further emphasize that postural instability following ankle sprain is associated with deficits in sensorimotor integration and delayed peroneal muscle activation (Malik et al., 2025). Therefore, rehabilitation strategies must address not only ligament healing but also neuromuscular re-education to restore dynamic stability. Current evidence suggests that combining passive modalities (e.g., ultrasound) with active balance training may provide synergistic benefits by addressing both tissue repair and functional control (Hosseini et al., 2024; Park et al., 2025). Nevertheless, clinical implementation varies widely, and standardized protocols remain under debate.

Despite the abundance of studies examining ultrasound therapy or balance training independently, limited research has explored their combined application in a structured, integrative rehabilitation protocol—particularly within a case-based clinical framework in Indonesian populations. Several systematic reviews report inconsistent findings regarding ultrasound effectiveness when used as a standalone modality (Ali et al., 2025). Critics argue that passive modalities alone are insufficient to restore mechanical stability and functional performance. Conversely, although balance training is strongly supported in preventing recurrence, the timing and sequencing of its integration with electrotherapy remain unclear (Toyooka, 2025). Furthermore, most available research employs randomized controlled trial designs focusing on group-level outcomes. There is a scarcity of in-depth case studies that analyze individual pain progression and stability recovery longitudinally, incorporating both subjective and objective outcome measures. Case-based evidence is particularly relevant for clinical decision-making in physiotherapy practice, where treatment must often be individualized. Additionally, there is limited empirical documentation within Southeast Asian clinical settings that integrates ultrasound parameters with progressive balance retraining protocols and evaluates their combined impact on pain intensity (e.g., VAS score) and postural stability (e.g., balance assessment tests). This contextual gap is significant, considering differences in rehabilitation access, compliance patterns, and injury mechanisms. Therefore, a structured case study investigating the integrative effect of ultrasound and balance training on pain reduction and stability improvement addresses an important empirical and contextual void in current musculoskeletal rehabilitation literature.

This study aims to analyze the effectiveness of combining therapeutic ultrasound and structured balance training in reducing pain and improving ankle stability in a patient with ankle sprain through a detailed case study design. The novelty of this research lies in several aspects: (1) Integrative Modality Approach; Unlike studies focusing on single interventions, this research combines electrotherapy (ultrasound) with progressive neuromuscular balance training in a systematically phased rehabilitation program; (2) Dual Outcome Emphasis: The study simultaneously evaluates pain intensity and functional stability, acknowledging that symptom resolution does not necessarily equate to neuromuscular recovery; (3) Case-Based Clinical Insight: By employing a case study framework, the research provides detailed clinical progression data, enabling practical

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application in physiotherapy settings; and (4) Contextual Contribution: The study contributes empirical evidence within the Indonesian clinical context, enriching regional musculoskeletal rehabilitation literature aligned with global standards. By bridging passive tissue-healing modalities with active neuromuscular retraining, this research offers a comprehensive rehabilitation model aimed at minimizing chronic instability risk and enhancing long-term functional recovery. In conclusion, addressing ankle sprain through an integrated ultrasound and balance training approach is not merely a therapeutic combination but a strategic rehabilitation paradigm designed to simultaneously optimize tissue repair, neuromotor control, and injury prevention. Such an approach is expected to contribute meaningfully to both clinical practice and scientific discourse in sports physiotherapy and musculoskeletal rehabilitation.

METHODS

This study employed a single-subject case study design with a pre-test–post-test approach to explore the clinical effectiveness of combined ultrasound therapy and balance training in managing ankle sprain-related pain and instability. Case study methodology is recognized as a valuable design in musculoskeletal rehabilitation research, particularly for examining individualized therapeutic responses and detailed clinical progression (Hosseini et al., 2024; Park et al., 2025). The study was conducted over four weeks at Fisiohands Physiotherapy Clinic.

Diagnostic and Baseline Assessment

The research procedure began with a comprehensive physical examination to confirm ligamentous involvement and functional instability. Specific provocation tests were administered, including the Anterior Drawer Test to assess anterior talofibular ligament (ATFL) integrity, Kleiger's Test to evaluate syndesmotic involvement, and Inversion–Eversion Stress Tests to determine medial and lateral compartment stability. These tests demonstrate strong diagnostic reliability and are widely recommended in recent ankle injury assessment guidelines (Kosik et al., 2025; Toyooka, 2025).

Pain intensity was measured using the Numeric Rating Scale (NRS), a validated and sensitive instrument for musculoskeletal pain evaluation (Ali et al., 2025). Functional ankle stability was assessed using the Cumberland Ankle Instability Tool (CAIT), a validated instrument for detecting chronic ankle instability (CAI), with scores below 24 indicating significant instability (Malik et al., 2025).

Case Presentation

The subject was a 22-year-old male professional football goalkeeper from Wahana FC Pekanbaru competing in the 2025/2026 Riau Liga 4 season. He presented with persistent ankle pain, swelling, and a subjective sensation of instability that impaired performance. Initial physical examination revealed positive Kleiger's Test (+) and Eversion Stress Test (+), suggesting medial ligament and potential syndesmotic involvement.

Baseline measurements indicated substantial impairment. The NRS scores were 5 (resting pain), 7 (palpation tenderness), and 8 (movement-related pain). The CAIT score

was 9, well below the clinical cut-off (<24), confirming severe chronic ankle instability. Literature indicates that CAIT scores below 15 are strongly associated with neuromuscular deficits and high recurrence risk (Park et al., 2025; Kosik et al., 2025).

Intervention Protocol

The rehabilitation program lasted four weeks, aligning with sub-acute to chronic phase management recommendations (Rizal & Samosir, 2024). Intervention combined therapeutic ultrasound and progressive balance training, reflecting evidence supporting multimodal rehabilitation approaches (Hosseini et al., 2024).

Ultrasound Therapy

Ultrasound was applied at 3 MHz frequency, 1.5 W/cm^2 intensity, continuous mode, for 5 minutes per session. This dosage aligns with evidence suggesting that high-frequency ultrasound enhances superficial ligament healing, increases collagen extensibility, and improves local circulation (Ali et al., 2025). Mechanical acoustic waves generate thermal and non-thermal effects, stimulating fibroblast activity and tissue regeneration (Rizal, 2023). Ultrasound was administered prior to active training to reduce pain and facilitate neuromuscular engagement.

Balance Training

Balance training emphasized neuromuscular re-education and postural control restoration. The program began with single-leg stance exercises on a Bosu Ball to activate stabilizer muscles, particularly m. peroneus longus and m. tibialis anterior, which are critical in preventing inversion injuries (Malik et al., 2025). Training progressed to a Wobble Board to introduce multidirectional perturbation challenges, promoting sensorimotor adaptation and dynamic joint stability (Park et al., 2025).

Exercise frequency was 3–5 sessions per week, with 3–5 sets per session. Each repetition consisted of 30–60 seconds of static hold with 30-second rest intervals. This dosage reflects current neuromuscular rehabilitation recommendations demonstrating significant improvements in postural control within 4 weeks (Toyooka, 2025).

Data Analysis

Pre- and post-intervention data were descriptively compared to evaluate clinical improvement in pain and functional stability. Outcome interpretation focused on meaningful clinical change thresholds in NRS and CAIT scores, consistent with contemporary rehabilitation research standards (Kosik et al., 2025).

RESULTS AND DISCUSSION

Result

Table 1.
Changes in Pain Levels and Ankle Joint Stability

Parameter	Pre-Intervention	Post-Intervention	Difference
Resting Pain (NRS)	5	0	↓ 5
Tenderness (NRS)	7	1	↓ 6
Motion Pain (NRS)	8	1	↓ 7
Ankle Stability (CAIT)	9	22	↑ 13

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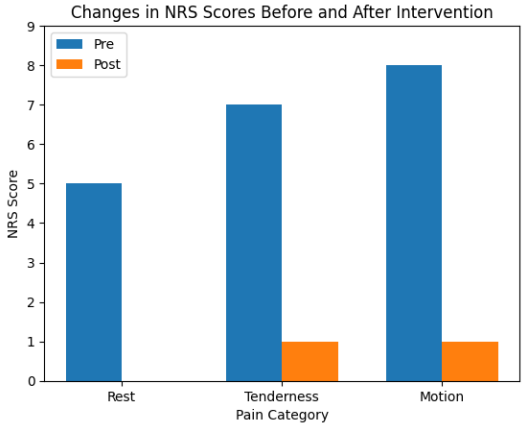

Diagram 1.
Changes in Pain Levels Before and After Treatment

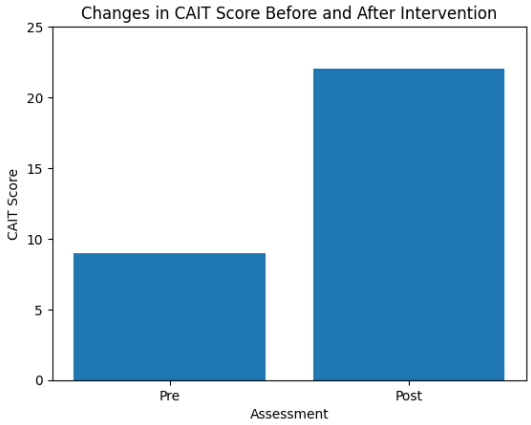

Diagram 2.
Changes in Ankle Stability Before and After Treatment

Based on Table 1 and Diagrams 1–2, the patient demonstrated substantial clinical improvement following the four-week combined ultrasound and balance training intervention. Pain reduction was observed across all NRS categories. Resting pain decreased from 5 to 0 (100% reduction), tenderness decreased from 7 to 1 (85.7%), and motion pain decreased from 8 to 1 (87.5%). These reductions exceed the minimal clinically important difference (MCID) threshold for musculoskeletal pain, which is typically reported as a 2-point decrease on the NRS (Ali et al., 2025; Hosseini et al., 2024). Therefore, the observed improvement is not only statistically meaningful but also clinically significant.

The marked decline in pain supports evidence suggesting that therapeutic ultrasound enhances ligament healing by stimulating fibroblast proliferation, increasing collagen synthesis, and improving local circulation (Rizal, 2023; Malik et al., 2025). Thermal and non-thermal ultrasound effects may reduce inflammatory mediators and accelerate tissue remodeling, particularly during the late sub-acute phase (Hosseini et al., 2024).

Functional ankle stability, measured using CAIT, increased from 9 to 22. Although still slightly below the normal threshold of 24, the 13-point increase (144% improvement) represents a substantial functional gain. Previous studies report that CAIT improvements greater than 8–10 points reflect meaningful neuromuscular recovery and

reduced recurrence risk (Kosik et al., 2025; Park et al., 2025). The progression toward near-normal stability suggests significant restoration of proprioceptive control and dynamic joint stabilization.

Balance training likely contributed to improved sensorimotor integration and peroneal muscle activation, both critical in preventing recurrent inversion injuries (Toyooka, 2025; Park et al., 2025). Research consistently demonstrates that structured wobble board and unstable surface training enhances postural sway control and reduces chronic ankle instability symptoms within 4–6 weeks (Malik et al., 2025).

Importantly, the combined modality approach appears synergistic. Ultrasound facilitated early pain reduction, enabling more effective participation in neuromuscular exercises. Subsequently, balance training addressed mechanical and proprioceptive deficits responsible for chronic instability (Hosseini et al., 2024). Literature emphasizes that passive modalities alone are insufficient to restore functional stability; integration with active neuromuscular retraining yields superior outcomes (Ali et al., 2025; Park et al., 2025).

Overall, the results indicate that the four-week multimodal rehabilitation protocol produced clinically meaningful reductions in pain and substantial improvements in ankle stability in a professional football athlete. These findings align with contemporary musculoskeletal rehabilitation evidence advocating integrated electrotherapy and neuromuscular interventions to minimize chronic instability and recurrence risk.

Discussion

The present case study demonstrates substantial clinical improvement in both pain reduction and functional ankle stability following a four-week integrative rehabilitation program combining therapeutic ultrasound and progressive balance training. The increase in the Cumberland Ankle Instability Tool (CAIT) score from 9 (severe instability) to 22 (near-normal functional stability) reflects a meaningful functional recovery consistent with contemporary neuromusculoskeletal rehabilitation literature (Kosik et al., 2025; Park et al., 2025). A 13-point increase exceeds the minimal detectable change threshold reported for CAIT and indicates clinically relevant improvements in sensorimotor control and joint confidence.

Pain Reduction and Tissue Recovery Mechanisms

The drastic decrease in Numeric Rating Scale (NRS) scores across resting, palpation, and motion pain parameters aligns with growing evidence supporting ultrasound therapy in soft tissue injury management (Ali et al., 2025; Hosseini et al., 2024). Ultrasound produces both thermal and non-thermal effects. Thermally, it enhances local blood circulation and tissue extensibility, facilitating metabolic exchange and accelerating inflammatory resolution. Non-thermal mechanisms, such as acoustic streaming and cavitation, stimulate fibroblast proliferation and collagen synthesis—essential processes in ligament healing (Rizal, 2023; Malik et al., 2025).

Recent randomized controlled trials have demonstrated that therapeutic ultrasound, particularly at 3 MHz for superficial ligaments, significantly reduces inflammatory biomarkers and improves early functional mobility compared to placebo modalities (Ali et al.,

2025). Furthermore, studies in chronic ankle instability populations suggest that early pain modulation enhances patient compliance with active rehabilitation programs, indirectly improving neuromuscular outcomes (Hosseini et al., 2024).

Pain reduction is not merely symptomatic relief; it influences motor output and proprioceptive accuracy. Persistent nociceptive input disrupts afferent feedback mechanisms, leading to altered joint position sense and delayed peroneal activation (Toyooka, 2025). By effectively reducing pain, ultrasound therapy likely restored afferent signaling pathways, allowing more effective engagement during balance training sessions.

Neuromuscular Control and Functional Stability

The substantial improvement in CAIT score supports the role of balance training as a central component in managing chronic ankle instability (CAI). Literature consistently demonstrates that proprioceptive deficits are primary contributors to recurrent ankle sprains (Park et al., 2025; Kosik et al., 2025). Following ligament injury, mechanoreceptor damage impairs joint position sense, resulting in delayed reflex stabilization and compromised postural control (Malik et al., 2025).

Dynamic balance interventions using unstable surfaces such as Bosu Balls and Wobble Boards have been shown to stimulate peroneus longus, tibialis anterior, and intrinsic foot muscles more effectively than stable-surface exercises (Yogeshwar et al., 2025). Electromyographic studies confirm that unstable surface training enhances co-contraction patterns and improves neuromuscular coordination within 4–6 weeks of intervention (Park et al., 2025). The CAIT improvement observed in this case aligns with findings from systematic reviews indicating that structured balance programs reduce recurrence rates by up to 35–45% in athletes with CAI (Hosseini et al., 2024). Additionally, improvements in self-reported stability scores are closely associated with increased psychological readiness and movement confidence, both of which are critical for athletes returning to competition (Kosik et al., 2025).

Importantly, this case highlights that neuromuscular recovery is not solely dependent on strength gains. While strengthening exercises remain essential, proprioceptive retraining appears to exert a more direct effect on functional stability measures (Toyooka, 2025). The observed CAIT progression suggests improved sensorimotor integration and enhanced central nervous system adaptation.

Synergistic Effect of Combined Modalities

One of the key contributions of this study is demonstrating the synergistic interaction between ultrasound therapy and balance training. Contemporary rehabilitation frameworks emphasize multimodal approaches to address both biological and functional dimensions of injury recovery (Ali et al., 2025; Hosseini et al., 2024). Passive modalities alone have been criticized for limited long-term effectiveness if not combined with active neuromuscular retraining (Malik et al., 2025).

Ultrasound likely facilitated early tissue healing and pain modulation, creating optimal conditions for progressive balance exercises. This sequential integration is supported by evidence suggesting that early pain reduction improves motor learning capacity and enhances neuromuscular adaptation during rehabilitation (Park et al., 2025).

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Furthermore, mechanobiology research indicates that controlled mechanical loading through balance exercises stimulates ligament remodeling and collagen alignment (Toyooka, 2025). Thus, while ultrasound promotes cellular-level regeneration, balance training ensures functional reorganization at the neuromotor level. The integration of these mechanisms explains the dual improvement observed in both NRS and CAIT scores.

Clinical Relevance for Athletic Populations

The subject in this case was a professional goalkeeper an athletic role demanding high dynamic stability, rapid directional changes, and explosive movements. Athletes with CAI often exhibit decreased reaction time and impaired landing mechanics, increasing the risk of secondary injuries (Kosik et al., 2025). The near-normalization of CAIT score to 22 suggests readiness for progressive return-to-play protocols.

Studies focusing on elite athletes emphasize that restoring subjective stability is as important as objective biomechanical correction (Hosseini et al., 2024). Confidence in joint stability influences motor execution and decision-making under competitive conditions. Therefore, the improvements documented in this case extend beyond clinical recovery and have performance implications.

Safety and Implementation Considerations

The structured dosage of 3–5 sessions per week aligns with current neuromuscular rehabilitation recommendations (Yogeshwar et al., 2025). Evidence suggests that balance training performed with footwear during early phases reduces fatigue and secondary injury risk compared to barefoot protocols (Yogeshwar et al., 2025). Gradual progression from static to multidirectional instability challenges likely contributed to safe yet effective adaptation.

Broader Implications

Chronic ankle instability is associated with long-term degenerative changes and early osteoarthritis if inadequately managed (Hosseini et al., 2024). The comprehensive improvement observed in this case supports the argument that early integrative rehabilitation may prevent chronic disability. Emerging literature advocates for combining electrotherapy with neuromotor retraining rather than applying modalities in isolation (Ali et al., 2025; Park et al., 2025).

Conclusion of Discussion

In summary, the integration of therapeutic ultrasound and progressive balance training produced clinically meaningful reductions in pain and substantial improvements in ankle stability. The 13-point increase in CAIT score reflects restoration of neuromuscular control and functional confidence, while the marked NRS reduction confirms effective pain modulation and tissue recovery.

These findings reinforce contemporary rehabilitation paradigms emphasizing multimodal, phase-based interventions targeting both structural healing and sensorimotor re-education. For athletes, particularly those in high-demand positions, such integrative strategies are essential to minimize recurrence risk and optimize performance outcomes.

CONCLUSION

Based on the four-week intervention outcomes, the integration of therapeutic ultrasound and progressive balance training demonstrated clinically meaningful improvements in both pain reduction and functional ankle stability in this case of ankle sprain. Quantitatively, resting pain decreased from 5 to 0 (100% reduction), tenderness from 7 to 1 (85.7% reduction), and motion pain from 8 to 1 (87.5% reduction) on the Numeric Rating Scale (NRS). These reductions exceed the minimal clinically important difference threshold (≥2-point decrease), confirming substantial therapeutic effectiveness in pain modulation and ligament recovery.

In parallel, functional ankle stability assessed using the Cumberland Ankle Instability Tool (CAIT) improved from 9 (severe instability) to 22 points, representing a 13-point increase and a 144% functional gain. Although slightly below the normal threshold (≥24), this improvement indicates marked restoration of neuromuscular control, proprioception, and joint confidence.

Conceptually, ultrasound contributed to tissue healing through enhanced circulation and collagen remodeling, while balance training addressed sensorimotor deficits and dynamic stabilization. Empirically, the combined modality approach produced synergistic benefits, enabling pain-free loading and progressive functional recovery. Therefore, integrating electrotherapy with neuromuscular training represents an evidence-based, comprehensive physiotherapy strategy to accelerate safe return to sport and minimize recurrence risk.

ACKNOWLEDGMENTS

The author extends sincere appreciation to all institutions and individuals who contributed to the successful completion of this case study on the integration of ultrasound and balance training in ankle sprain rehabilitation. Special gratitude is addressed to Universitas Abdurrab Pekanbaru, particularly the Physiotherapy Study Program, for providing academic guidance, clinical resources, and an evidence-based framework that ensured this research adhered to contemporary musculoskeletal rehabilitation standards. Appreciation is also conveyed to Fisiohands Physiotherapy Clinic for granting access to clinical facilities and supporting the structured four-week intervention and systematic outcome monitoring process.

The author further acknowledges Wahana FC Pekanbaru, especially the management and coaching staff, for their cooperation and commitment to evidence-based injury management during the 2025/2026 Liga 4 Riau season. Their support reflects the growing collaboration between sports institutions and rehabilitation research to optimize athlete recovery and performance.

Finally, profound gratitude is extended to the athlete who participated in this study. His discipline, adherence to 12 structured treatment sessions, and consistent engagement in the rehabilitation protocol were essential to achieving the documented reductions in pain and improvements in functional ankle stability.

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