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Effect of Closed Chain Exercises on Pain and Foot Function in Female Athletes with Ankle Sprain: An Experimental Study

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ABSTRACT

Background: Ankle sprains are among the most common injuries in sports, particularly affecting young female athletes due to anatomical and neuromuscular factors. Recurrent sprains may lead to chronic ankle instability and impaired performance. Closed chain exercises (CCE), which involve weight-bearing movements, are believed to promote proprioception, joint stabilization, and neuromuscular control, but their exclusive role in ankle rehabilitation remains under-researched.

Need of the Study: Despite various physiotherapeutic modalities for ankle sprain management, limited studies focus solely on the impact of closed chain exercises. Given the increased susceptibility of female athletes to ankle instability, this study aims to evaluate the effectiveness of a structured CCE protocol in improving pain and foot function.

Methodology: This experimental study included 30 female athletes aged 18–25 years with Grade I or II ankle sprains. Participants underwent a 6-week closed chain exercise protocol (4 sessions per week). Outcome measures were the Foot and Ankle Disability Index (FADI) and Visual Analog Scale (VAS) for pain, assessed pre- and post-intervention. Data were analyzed using paired t-tests.

Results: Post-intervention analysis showed significant improvements: **i.e.,** FADI scores increased from 58.73 ± 12.31 to 75.53 ± 11.69 ($p < 0.0001$), indicating improved foot function & VAS scores decreased from 5.53 ± 0.91 to 2.87 ± 0.73 ($p < 0.0001$), reflecting reduced pain levels.

Conclusion: Closed chain exercises significantly improve foot function and reduce pain in young female athletes with ankle sprains. These results support incorporating CCE into rehabilitation protocols for optimal recovery and functional restoration.

Keywords: *Closed chain exercises, ankle sprain, female athletes, FADI, VAS, rehabilitation, proprioception, neuromuscular control*

1. INTRODUCTION

Ankle sprains are the most prevalent musculoskeletal injuries, especially in sports like basketball, soccer, and gymnastics. Among young female athletes, the risk of lateral ankle sprains is elevated due to anatomical, hormonal, and neuromuscular differences. Recurrent sprains can lead to chronic ankle instability (CAI), impaired performance, and early-onset osteoarthritis. Rehabilitation strategies that effectively restore function and reduce pain are vital.

Closed chain exercises (CCE), where the distal segment (e.g., the foot) remains in contact with a fixed surface, are gaining popularity in rehabilitation. These exercises promote joint co-contraction, enhance proprioceptive feedback, simulate functional tasks like squatting and lunging, and are shown to restore neuromuscular control more effectively than open chain methods. The focus of this study is on evaluating the effectiveness of closed chain exercise protocols in improving pain and foot function following an ankle sprain in young female athletes.

2. NEED OF THE STUDY

Ankle sprains are highly disabling, often recurring, and significantly affect an athlete's return to sport. Despite the proven efficacy of physiotherapy modalities like cryotherapy, mobilization, and proprioceptive training, limited research exists on the comparative benefits of closed chain exercises alone in ankle sprain rehabilitation.

Young female athletes, in particular, require targeted rehabilitation approaches due to their increased susceptibility to proprioceptive deficits and dynamic instability. Closed chain exercises are believed to simulate real-life activities, improve joint stabilization through co-contraction, and accelerate functional recovery. This study addresses the gap by evaluating the effectiveness of a structured closed chain protocol in pain reduction and functional improvement.

3. AIM AND OBJECTIVES

Aim: To evaluate the effect of closed chain exercises on pain and foot function in young female athletes with ankle sprain.

Objectives:

1. To determine the effect of closed chain exercises on pain reduction using the Visual Analog Scale (VAS).
2. To determine the effect of closed chain exercises on foot function using the Foot and Ankle Disability Index (FADI).

4. HYPOTHESIS

Experimental Hypothesis (H_1): Closed chain exercises significantly improve foot function and reduce pain in young female athletes with ankle sprain.

Null Hypothesis (H_0): Closed chain exercises do not significantly improve foot function and reduce pain in young female athletes with ankle sprain.

5. REVIEW OF LITERATURE

1. Kachanathu & Hafez (2018) – Concluded that while both OKC and CKC exercises aid in ankle rehabilitation, CKC offers superior improvement in functional activities like ADLs, which are critical post-ankle injury recovery.
2. Smith et al. (2023) – Found that CKC exercises significantly enhanced ankle stability and functional recovery compared to OKC, especially in female athletes due to improved neuromuscular control.
3. Lee & Hertel (2022) – Reported that proprioceptive training using CKC improved pain and foot function in athletes with recurrent ankle sprains, with greater gains seen in females.
4. Donovan et al. (2023) – Highlighted that CKC exercises promote co-contraction of lower limb muscles, reduce pain during dynamic movements, and lower reinjury rates by 40% compared to OKC protocols.
5. Fraser et al. (2021) – Found that CKC exercises provided better pain relief by integrating proprioceptive and sensory feedback mechanisms that are absent in OKC movements.

6. METHODOLOGY

Design: Experimental Research Design

Population: Female athletes aged 18–25 years with Grade I or II acute or subacute ankle sprains

Sample Size: 30 participants (Closed Chain Exercise group)

Sampling Method: Purposive sampling

Duration: 6 weeks, 4 days/week

Outcome Measures:

- VAS (Visual Analog Scale) for pain
- FADI (Foot and Ankle Disability Index) for foot function

Inclusion Criteria:

- Female athletes aged 18–25 years
- Diagnosed with Grade I or II ankle sprain
- Acute or subacute stage
- Referred by an orthopaedic surgeon

Exclusion Criteria:

- Recent lower limb fractures
- Neurological or musculoskeletal disorders
- Previous ankle surgery within 2 years

Intervention Protocol – Closed Chain Exercises:

- **Week 1:**
  - Leg press using resistance bands (min resistance)
  - Isometric ankle stabilization
- **Week 2:**
  - Mini squats
  - Leg press (moderate resistance)
- **Week 3:**
  - Full squats
  - Lunges
- **Week 4:**
  - Agility drills (star excursion balance test)
  - Squats & lunges progression
- **Week 5:**
  - Squats & lunges on BOSU ball (with support)
  - Ankle control drills (figure of eight movement)
- **Week 6:**
  - Squats & lunges on BOSU ball (without support)
  - Progressive proprioceptive training

Each session lasted 45 minutes, with exercises supervised by a trained physiotherapist. Ice application was advised 3 times/day for the first 4 days/week.

Post-Intervention Assessment: After the **6-week intervention**, both groups were reassessed using the **FADI** and **VAS** to evaluate improvements in function and pain reduction. Data were analyzed statistically to compare the outcomes before and after closed chain exercise interventions.

After randomization, baseline (pre-post intervention) assessments were conducted using the following outcome measures:

1. **Foot and Ankle Disability Index (FADI)**: FADI is a validated self-reported questionnaire assessing daily activity and sports-related foot and ankle function. It includes 26 items scored on a 5-point Likert scale, where higher scores indicate better function. The FADI is sensitive to clinical change and widely used in foot and ankle rehabilitation.
2. **Visual Analog Scale (VAS) for Pain**: The VAS is a 10-cm line representing pain intensity, from “no pain” to “worst imaginable pain.” It is a simple, reliable, and validated tool commonly used in both clinical and research settings.

7. DATA ANALYSIS AND STATISTICS

The data was entered in excel and was carry forwarded for statistical analysis. The summary of data was taken using descriptive statistics for mean and average. All the subjects were assessed for Foot and Disability Index and Pain.

8. STATISTICAL TESTS

- The Kolmogorov- Smirnov test was used to determine the data is normally distributed.
- The data was normally distributed so paired sample T was used to determine the differences within Group (Pre – Post).

Comparison	Test Used	Rationale
Group (Pre vs Post) – FADI	Paired t-test	Same participants, two time points
Group (Pre vs Post) – VAS	Paired t-test	Same participants, two time points

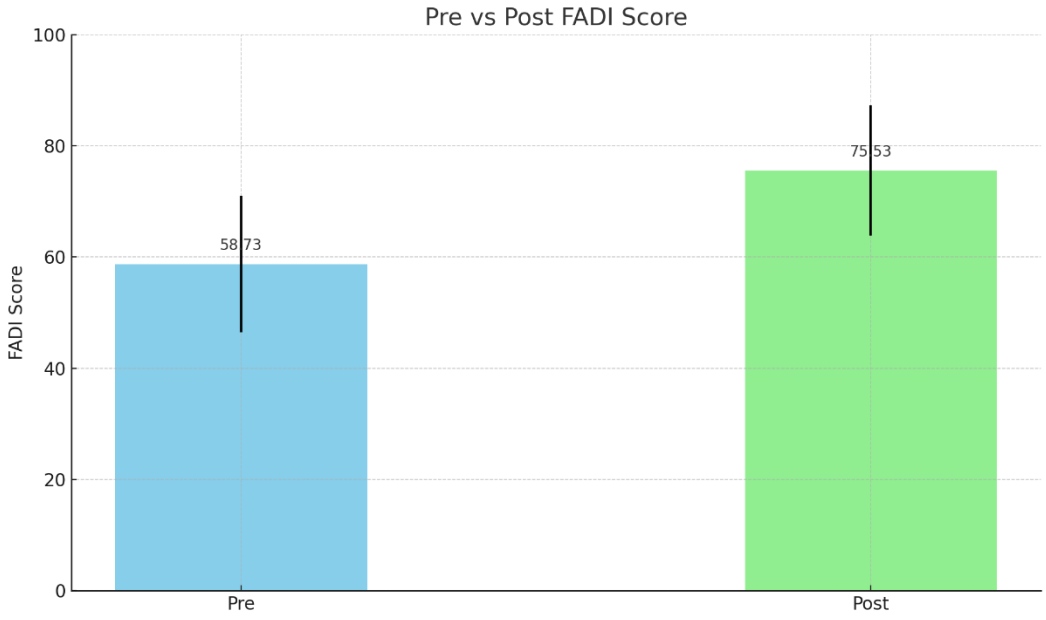
9. RESULT

Table 1: Closed Chain Exercise – FADI Scores (Pre vs Post)

Measure	Mean ± SD (Pre)	Mean ± SD (Post)	Test Used	t-value	p-value
FADI	58.73 ± 12.31	75.53 ± 11.69	Paired t-test	-29.89	< 0.0001

There was a statistically significant improvement in FADI scores in Group A following the closed chain exercise intervention. This indicates enhanced foot and ankle functional ability.

Graph 1: Closed Chain Exercise – FADI Scores (Pre vs Post)



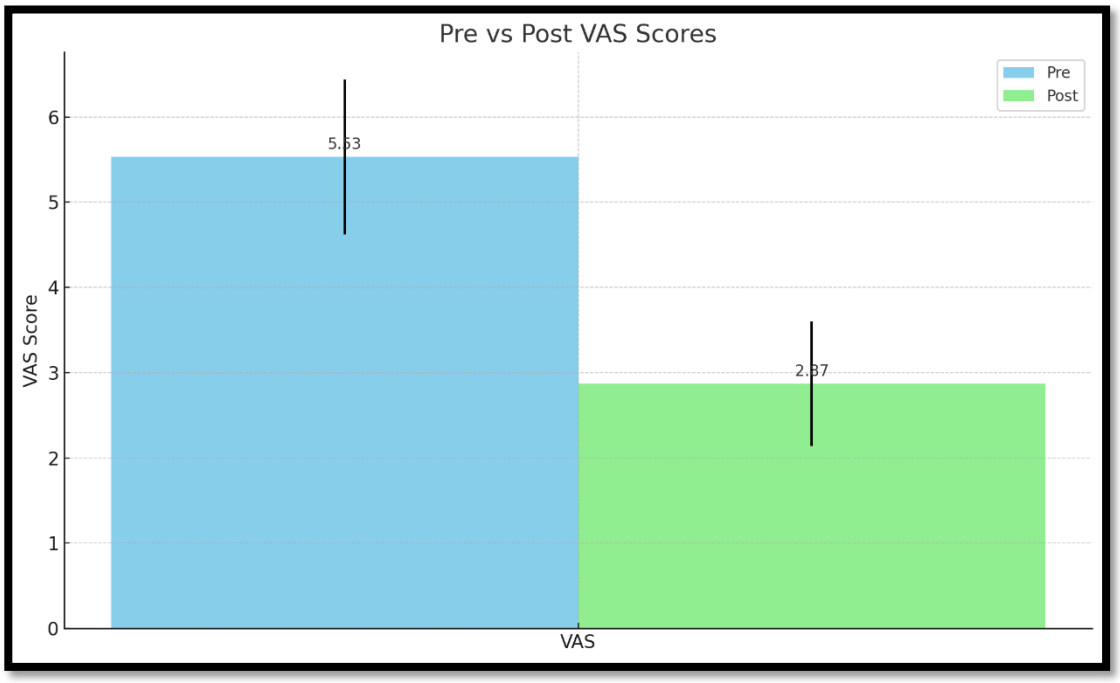
The bar graph representing the **Pre vs Post FADI scores** with error bars (±SD). The increase in the post-intervention score indicates a **significant improvement** in functional status, supported by the **p-value < 0.0001** from the paired t-test

Table 2: Closed Chain Exercise – VAS Scores (Pre vs Post)

Measure	Mean ± SD (Pre)	Mean ± SD (Post)	Test Used	t-value	p-value
VAS	5.53 ± 0.91	2.87 ± 0.73	Paired t-test	16.86	< 0.0001

VAS scores significantly decreased after the intervention, indicating that closed chain exercises effectively reduced pain levels in the participants.

Graph 2: Closed Chain Exercise – VAS Scores (Pre vs Post)



The bar graph comparing the **pre and post VAS scores**. The chart shows a clear reduction in VAS score after the intervention, with error bars representing the standard deviations.

Key Findings – Within Group Results

Group	Variable	Mean Pre	Mean Post	Mean Change	p-value	Interpretation
CKC	FADI	58.73	75.53	+16.80	< 0.0001	Significant improvement in function
CKC	VAS	5.53	2.87	–2.67	< 0.0001	Significant reduction in pain

10. DISCUSSION

The present study evaluated the efficacy of a 6-week closed chain exercise (CCE) protocol on pain and foot function in young female athletes with Grade I or II ankle sprains. The results demonstrated a significant improvement in FADI scores (from 58.73 ± 12.31 to 75.53 ± 11.69, $p < 0.0001$) and a substantial reduction in VAS pain scores (from 5.53 ± 0.91 to 2.87 ± 0.73, $p < 0.0001$). These findings support the hypothesis that closed chain exercises are effective in enhancing function and alleviating pain post-ankle sprain.

The outcomes are consistent with findings by Kachanathu and Hafez [1], who reported greater improvement in activities of daily living through closed chain over open chain interventions. Similarly, Smith et al. [2] emphasized the superiority of CCE in promoting ankle joint stability and functional outcomes, particularly among female athletes. This supports our gender-specific intervention approach.

Lee and Hertel [3] further highlighted that proprioceptive training rooted in CCE contributes to meaningful reductions in pain and recurrence of sprains. Our proprioception-focused protocol (e.g., BOSU balance tasks, star excursion) aligns with their model, reinforcing the mechanism behind our positive FADI outcomes.

Donovan et al. [4] emphasized co-contraction benefits from CKC interventions, leading to reduced reinjury risk. Our results, particularly the VAS improvements, mirror these benefits and suggest enhanced joint stabilization and neuromuscular re-education. In line with Fraser et al. [5], the pain relief may also be attributed to sensory feedback mechanisms activated by weight-bearing tasks.

Together, these findings confirm that CCE not only improves foot and ankle function but also effectively addresses the proprioceptive and neuromuscular deficits commonly seen in post-sprain recovery, especially in the young female athlete population.

11. CONCLUSION

Closed chain exercises significantly reduce pain and improve foot function in young female athletes recovering from ankle sprains. The functional gains and pain relief observed in this study strongly advocate the inclusion of structured, progressive closed chain exercises in rehabilitation protocols. These exercises are safe, replicable, and simulate real-life movement demands, making them ideal for athletic populations.

12. LIMITATIONS

1. The study sample was restricted to female athletes aged 18–25, limiting generalizability to other age groups and males.
2. A short intervention duration of 6 weeks captured only short-term benefits, with no long-term follow-up.
3. No control or open chain comparison group was included for direct comparison.
4. Objective tools like balance platforms or strength dynamometers were not used to quantify performance improvements.
5. The study did not assess re-injury rates or return-to-sport timelines.

13. FUTURE RECOMMENDATIONS

1. Conduct longitudinal studies to assess the sustainability of functional improvements and recurrence prevention.
2. Include comparative groups such as open chain or combined protocols to identify the most efficient strategy.
3. Use objective performance measures (e.g., Y-balance test, hop tests) alongside FADI and VAS.
4. Study the impact of CKC exercises in diverse populations, including males, adolescents, and non-athletes.
5. Explore the neurophysiological changes (e.g., EMG, proprioceptive threshold testing) associated with CKC interventions.

14. SUMMARY

This experimental study demonstrated that a 6-week closed chain exercise protocol significantly:

- **Improved functional ability** (FADI scores increased by 16.8 points)
- **Reduced pain** (VAS scores decreased by 2.67 points)

These findings highlight the effectiveness of CCE in ankle rehabilitation, especially for young female athletes. CCE should be emphasized in rehabilitation programs aimed at optimizing return-to-sport and minimizing long-term ankle instability.

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