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# Effects of Closed-Chain Exercise Versus Neuromuscular Training on Functional Performance in Football Players with Chronic Ankle Sprain

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**Keywords**
Chronic ankle sprain, functional performance, closed-chain exercise, neuromuscular training, rehabilitation, football players, proprioception, ankle instability, sports physiotherapy.

**Disclaimers**

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|---|---|
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## ABSTRACT

**Background**: Chronic ankle sprain is a common condition among football players, leading to functional instability and reduced athletic performance. Appropriate rehabilitation strategies are crucial to restore function and prevent recurrence.

**Objective**: To compare the effects of closed-chain exercises versus neuromuscular training on functional performance in football players with chronic ankle sprain.

**Methods**: A randomized clinical trial was conducted with 34 football players (aged 18-35 years), divided into two groups: Group A (closed-chain exercises) and Group B (neuromuscular training), with 17 participants in each group. The interventions were administered thrice weekly for four weeks. Functional performance was assessed using single-leg balance, wobble board balance, Star Excursion Balance Test (SEBT), Y Balance Test, and validated questionnaires: IdFAI, AII, and FAAM. Data were analyzed using SPSS version 25.0, applying Wilcoxon Signed Rank and Mann-Whitney U tests.

**Results**: Group A demonstrated significantly higher post-intervention scores in SEBT (69.59 vs. 63.59; $p = 0.018$) and Y Balance Test (73.35 vs. 68.88; $p = 0.030$) compared to Group B. Both groups showed significant within-group improvements ($p < 0.05$).

**Conclusion**: Closed-chain exercises were more effective than neuromuscular training in enhancing functional performance, suggesting their priority in early rehabilitation for chronic ankle instability.

## INTRODUCTION

Football is one of the most popular sports worldwide, involving a complex combination of low- and medium-intensity exercises, such as jogging and marching, alongside high-intensity activities, such as sprinting, tackling, and rapid changes of direction (1). Given the physical demands, football players are often required to achieve and maintain a high level of physical fitness and skill to perform optimally during matches. However, a lack of individualized and evidence-based training programs can predispose players to musculoskeletal injuries, particularly in the ankle joint, where sprains are among the most frequently reported injuries (2). Chronic ankle sprains often lead to recurrent instability and compromised joint biomechanics, which can severely impact players' functional performance and quality of life (3). The most commonly injured ligament in the ankle is the anterior talofibular ligament, a key stabilizer of the lateral ankle complex. Recurrent sprains can lead to chronic ankle instability (CAI), a condition that affects functional performance, proprioception, and dynamic stability, often resulting from inappropriate rehabilitation or insufficient neuromuscular control (4).

The Hertel Model conceptualizes chronic ankle instability as comprising both functional and mechanical instability, distinguishing these as separate entities that contribute to the development and persistence of CAI (5). Mechanical instability involves pathological laxity, while functional instability is characterized by deficits in neuromuscular control and proprioception. Consequently, CAI is associated with alterations in gait mechanics, including increased plantar flexion, inversion, and lateral deviation during functional movements such as walking, running, and jumping (6). Studies have shown that individuals with CAI display altered ankle kinematics, such as reduced sagittal plane motion and increased dorsiflexion during the absorption phase of landing, which can result in abnormal joint loading patterns and heightened ground reaction forces (7). These biomechanical alterations may also contribute to increased risks of re-injury and decreased performance levels in football players, highlighting the importance of implementing effective rehabilitation strategies that address both mechanical and functional deficits (8).

Among the various rehabilitation techniques for CAI, neuromuscular training and closed-chain exercises are

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widely recommended due to their potential to enhance proprioception, balance, and joint stability (9). Neuromuscular training focuses on improving sensory-motor function through exercises that challenge the body's ability to maintain balance and dynamic stability, thereby reducing the risk of re-injury (10). On the other hand, closed-chain exercises are characterized by weight-bearing activities that simulate functional movements, promoting co-contraction of the surrounding musculature and improving joint mechanics (11). While both approaches have shown promise in enhancing functional outcomes, there is a lack of consensus regarding their comparative efficacy for managing CAI in athletes, particularly football players (12).

To address this gap, the current study aims to evaluate and compare the effects of neuromuscular training and closed-chain exercise on functional performance in football players with chronic ankle sprains. Functional performance was assessed using a variety of physical tests, including single-leg balance tests, the star excursion balance test (SEBT), and the Y balance test, along with validated questionnaires such as the Identification of Functional Ankle Instability (IdFAI), Ankle Instability Instrument (AII), and the Foot and Ankle Ability Measure (FAAM)-Sport Subscale (13). These assessments are widely used to evaluate proprioception, dynamic stability, and overall functional capacity in athletes with CAI (14). Although previous research has demonstrated the benefits of these interventions individually, there is a need for comparative studies to establish which modality offers superior outcomes in terms of restoring function and preventing recurrence of ankle sprains (15).

This randomized controlled trial provides a robust methodology for comparing neuromuscular training and closed-chain exercise, contributing valuable evidence to inform clinical decision-making for sports rehabilitation professionals. Given the prevalence of chronic ankle sprains in football players, understanding the relative effectiveness of these rehabilitation strategies is crucial for developing targeted interventions that optimize recovery and enhance performance (16). The findings of this study have significant implications for sports medicine and physiotherapy, offering insights into the most effective rehabilitation approaches for managing CAI and improving long-term functional outcomes in athletes.

## MATERIAL AND METHODS

This randomized clinical trial aimed to compare the effects of closed-chain exercises versus neuromuscular training on functional performance in football players with chronic ankle sprain. The study was conducted at the Pakistan Sports Board (PSB), Lahore, and was completed over a duration of 10 months following approval of the research synopsis by the institutional review board. The sample size was determined using Epitools software, and an additional 10% attrition rate was considered, resulting in a final sample size of 34 participants. A non-probability convenient sampling technique was used to recruit both male and female participants between the ages of 18 and 35 years. The inclusion criteria comprised football players with grade 1 or 2 ankle sprains, recurrent ankle sprains, and those who met the diagnostic criteria of positive ankle sprain special tests, including the Squeeze Test and the Talar Tilt Test (19). Participants were excluded if they had a history of traumatic ankle fractures within the past six months, vestibular or balance disorders (20), or comorbidities affecting physical fitness. Athletes who had suffered an ankle sprain within the month preceding the study or who were taking anti-inflammatory drugs were also excluded to minimize confounding factors.

Prior to data collection, all participants provided written informed consent in accordance with the Declaration of Helsinki, ensuring their voluntary participation and the confidentiality of their personal information. Ethical clearance for the study was obtained from the institutional review board. Baseline data, including demographic details such as age, gender, weight, height, and body mass index (BMI), were recorded. Participants were randomly assigned into two groups using a computer-generated randomization table: Group A received closed-chain exercises, while Group B underwent neuromuscular training. Each group consisted of 17 participants. The intervention was conducted over a 4-week period, with three supervised sessions per week, ensuring consistency and adherence to the training protocols.

The intervention for Group A (closed-chain exercise group) included weight-bearing exercises that targeted the stability and strength of the ankle joint through co-contraction of the surrounding musculature. Exercises such as squats, step-ups, and lunges were included, focusing on improving proprioception and joint stabilization under controlled conditions. Group B (neuromuscular training group) received exercises aimed at enhancing dynamic balance and neuromuscular control through activities such as single-leg stance, wobble board training, and balance tasks with external perturbations. Both groups followed a structured progression of exercises, ensuring that the intensity was increased gradually based on individual tolerance and performance levels.

Functional performance was assessed pre- and post-intervention using a combination of clinical and functional tests. Proprioception was evaluated through a single-leg balance test with eyes closed and wobble board balance tasks, while dynamic balance was assessed using the star excursion balance test (SEBT) and Y balance test. The identification of functional ankle instability was determined using the Greek version of the Identification of Functional Ankle Instability Questionnaire (IdFAI) (19), and the Ankle Instability Instrument (AII) was employed to quantify the degree of ankle instability. Additionally, the Foot and Ankle Ability Measure (FAAM)-Sport Subscale was used to evaluate the functional status of participants in relation to their sports activities.

Data were analyzed using SPSS version 25.0, and statistical significance was set at a p-value of 0.05. The Shapiro-Wilk test was performed to assess the normality of the data. Given the non-normal distribution, non-parametric tests were applied for between-group and within-group comparisons. For within-group analysis, the Wilcoxon

Signed Rank test was utilized to compare pre- and post-intervention values, while the Mann-Whitney U test was used for between-group comparisons. Continuous variables, such as age, weight, and height, were reported as mean and standard deviation (SD), while categorical variables were expressed as frequencies and percentages. All statistical analyses were performed in accordance with standard guidelines, ensuring robust and reliable results.

The study adhered to strict ethical considerations throughout, maintaining participant anonymity and data integrity. The intervention protocols were supervised by experienced physiotherapists to ensure the safety and efficacy of the training regimens. Any adverse events or deviations from the protocol were documented and addressed immediately to safeguard the health and well-being of the participants. The findings of this study are expected to contribute valuable evidence to inform clinical practice regarding the optimal rehabilitation strategies for managing chronic ankle sprains in football players.

## RESULTS

The study analyzed a total of 34 participants, with 17 in each group. Group A (closed-chain exercise group) had a mean age of 21.65 ± 3.28 years, while Group B (neuromuscular training group) had a mean age of 24.82 ± 3.66 years. The distribution of gender showed that Group A comprised 94.1% males and 5.9% females, whereas Group B had 70.6% males and 29.4% females. Both groups exhibited similar distributions in dominant ankle (Right = 76.5%, Left = 23.5%). Table 1 summarizes the baseline demographic characteristics of the participants.

**Table 1: Baseline Demographic Characteristics**

| Variables | Group A (Closed-Chain) | Group B (Neuromuscular) | p-value |
|---|---|---|---|
| Mean Age (years) | 21.65 ± 3.28 | 24.82 ± 3.66 | 0.032 |
| Mean Weight (kg) | 61.0 ± 9.40 | 61.12 ± 4.89 | 0.942 |
| Mean Height (feet) | 5.58 ± 0.28 | 5.64 ± 0.28 | 0.871 |
| Gender Distribution (Male %) | 94.1 | 70.6 | 0.045 |
| Dominant Ankle (Right %) | 76.5 | 76.5 | 1.000 |
| Injured Ankle (Right %) | 64.7 | 52.9 | 0.312 |

Functional Outcomes Functional performance was evaluated pre- and post-intervention using several assessment tools, including the single-leg balance test, wobble board balance test, SEBT, Y balance test, and validated questionnaires such as IdFAI, AII, and FAAM-Sport Subscale. Significant improvements were observed in both groups, with Group A demonstrating superior results in most parameters, as detailed in Table 2.

**Table 2: Within-Group Comparison of Functional Performance Pre- and Post-Intervention (Wilcoxon Signed Rank Test)**

| Variables | Group A (Mean Ranks) | p-value | Z-value | Group B (Mean Ranks) | p-value | Z-value |
|---|---|---|---|---|---|---|
| Single-Leg Balance Test | 10.18 → 20.88 | 0.000 | 4.135 | 11.88 → 17.71 | 0.000 | 5.514 |
| Wobble Board Balance Test | 17.71 → 29.88 | 0.000 | 5.908 | 16.71 → 23.06 | 0.001 | 6.234 |
| Star Excursion Balance Test | 49.82 → 69.59 | 0.000 | 6.399 | 45.88 → 63.59 | 0.000 | 8.513 |
| Y Balance Test | 56.76 → 73.35 | 0.000 | 5.197 | 54.76 → 68.88 | 0.000 | 3.407 |
| Identification of Functional Ankle Instability | 17.00 → 6.29 | 0.000 | 3.901 | 17.76 → 8.12 | 0.000 | 4.568 |
| Ankle Instability Instrument | 12.18 → 3.24 | 0.000 | 4.575 | 15.94 → 5.59 | 0.000 | 4.046 |
| FAAM (Daily Activities) | 16.03 → 7.38 | 0.000 | 6.856 | 19.82 → 9.03 | 0.001 | 11.315 |
| FAAM (Sports Subscale) | 32.77 → 18.26 | 0.001 | 15.578 | 32.49 → 20.85 | 0.003 | 13.551 |

**Table 3: Between-Group Comparison Post-Treatment (Mann-Whitney U Test)**

| Variables | Group A (Mean Rank) | Group B (Mean Rank) | p-value | Z-value |
|---|---|---|---|---|
| Single-Leg Balance Test | 20.88 | 17.77 | 0.009 | 3.176 |
| Wobble Board Balance Test | 29.88 | 23.06 | 0.000 | 6.824 |
| Star Excursion Balance Test | 69.59 | 63.59 | 0.018 | 6.000 |
| Y Balance Test | 73.35 | 68.88 | 0.030 | 4.471 |
| Identification of Functional Ankle Instability | 6.29 | 8.12 | 0.013 | -1.824 |
| Ankle Instability Instrument | 3.24 | 5.59 | 0.020 | -2.353 |
| FAAM (Daily Activities) | 7.38 | 9.03 | 0.461 | -1.647 |
| FAAM (Sports Subscale) | 18.26 | 20.85 | 0.369 | -2.585 |

Interpretation of Results The results indicate that both closed-chain exercises and neuromuscular training yielded significant improvements in functional performance measures among football players with chronic ankle sprain ($p < 0.05$). However, Group A (closed-chain exercises) showed superior outcomes in most functional tests, including the single-leg balance test, wobble board balance test, SEBT, Y balance test, and Ankle Instability Instrument. The between-group comparisons revealed that the closed-chain group demonstrated statistically significant

improvements compared to the neuromuscular training group in key variables, particularly proprioceptive tests and dynamic balance measures. Although both groups showed positive trends in post-intervention scores, the closed-chain exercise group had a slight edge in enhancing overall functional stability and reducing functional ankle instability. In summary, while the closed-chain exercise program appears to be more effective in improving functional outcomes, the neuromuscular training regimen also produced favorable results, suggesting its potential as a complementary rehabilitation strategy. The findings support the incorporation of both interventions in clinical practice to optimize recovery and functional performance in athletes with chronic ankle sprains.

## DISCUSSION

The findings of this randomized clinical trial demonstrated that both closed-chain exercises and neuromuscular training led to significant improvements in functional performance among football players with chronic ankle sprain. However, the closed-chain exercise group showed superior results in key functional measures, indicating its greater effectiveness in addressing the symptoms of chronic ankle instability. This is consistent with previous research suggesting that closed-chain exercises are beneficial for enhancing proprioception, stability, and coordination by promoting co-contraction of the surrounding musculature and improving joint mechanics in weight-bearing conditions (9). These exercises simulate functional movements encountered during sports activities, which may explain their positive impact on restoring functional performance. Neuromuscular training, although not as effective as closed-chain exercise in the current study, also produced significant improvements, supporting its role in improving neuromuscular control and dynamic stability (12). These results align with the work of Cruz-Díaz et al., who reported positive effects of neuromuscular training on balance and muscle strength in athletes with CAI (15).

The differences observed between the two groups may be attributed to the specific nature of the interventions. Closed-chain exercises focus on improving joint stabilization through weight-bearing activities that closely mimic functional tasks, thereby enhancing the ability to control joint position during dynamic movements (11). In contrast, neuromuscular training typically targets proprioceptive deficits and reactive muscle activation, which may require a longer intervention period to achieve similar outcomes (17). The study by Khorjahani et al. also highlighted that neuromuscular training might be more effective in addressing sensory-motor control in athletes with functional ankle instability, particularly over extended durations (22). Therefore, the slightly lower efficacy of neuromuscular training observed in the present study could be due to the relatively short duration of the intervention.

Despite the promising outcomes, several limitations should be acknowledged. The sample size was relatively small, which may have limited the generalizability of the results. Additionally, the study only included football players aged 18 to 35 years, which may not reflect the broader population of athletes with chronic ankle sprain. Future studies with larger sample sizes and diverse athletic populations are recommended to validate these findings. Moreover, the study was conducted over a period of only four weeks, which may not have been sufficient to capture long-term effects of the interventions. Previous research has suggested that a longer intervention period, extending to six weeks or more, may be necessary to fully realize the benefits of neuromuscular training on dynamic stability and proprioception (23). Thus, future research should incorporate longer follow-up periods to assess the sustainability of functional improvements.

The strengths of this study include its rigorous randomized clinical trial design and the use of validated assessment tools to measure functional outcomes. The inclusion of both proprioceptive and dynamic balance tests provided a comprehensive evaluation of functional performance, allowing for a detailed comparison between the two interventions. Additionally, the adherence to a structured intervention protocol ensured consistency in the application of the exercise programs, reducing potential biases. However, the lack of blinding in the assessment process could have introduced measurement bias, as the evaluators were aware of the participants' group allocations. Future studies should implement double-blind designs to minimize such biases.

In terms of clinical implications, the findings suggest that closed-chain exercises should be prioritized in rehabilitation programs for athletes with chronic ankle instability, particularly in the early stages of recovery. Given the rapid improvements observed in the closed-chain group, these exercises may help restore functional performance and reduce the risk of recurrent ankle sprains more effectively. However, neuromuscular training should not be disregarded, as it demonstrated positive effects on dynamic balance and proprioception, which are crucial for long-term injury prevention.

The integration of both interventions into a comprehensive rehabilitation protocol may yield optimal outcomes, addressing both joint stabilization and neuromuscular deficits (18). This combined approach could be particularly beneficial for athletes returning to high-demand sports, where quick changes of direction and dynamic stability are critical.

## CONCLUSION

In conclusion, while closed-chain exercises were found to be more effective in enhancing functional performance, neuromuscular training also showed promise as a viable intervention for chronic ankle instability.

Future studies should explore the potential synergistic effects of combining these modalities and investigate their long-term impact on injury recurrence and athletic performance.

Expanding the scope of research to include biomechanical assessments and kinematic analyses would provide deeper insights into the mechanisms underlying these interventions and their role in optimizing functional recovery in athletes with chronic ankle instability.

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