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Effect of Foot Core Strengthening Protocol on Sports Performance in Recreational Football Players

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1. INTRODUCTION

Football is the most popular ball game in the world. Played almost anywhere, from official football fields (pitches) to gymnasiums, school playgrounds, streets, parks, or beaches, football is a simple sport with few fundamental rules and minimal equipment [1,2]. Football players place great demands on their neuromuscular control, agility, and concentric and eccentric muscle activity. Football performance consists of technical, physiological, tactical, and mental components. Due to the intense physical demands of actual football matches, physical fitness is a significant determinant of football performance [3]. Specifically, football involves a combination of explosive accelerations, sudden decelerations, changes in direction, and jumps—all of which require optimal foot function and stability to minimize injury risk and maximize performance.

The foot is essential for supporting body weight, responding to ground reaction forces, and enabling a range of athletic movements, including sprinting, jumping, landing, changing direction, lateral displacements, and shooting. Several studies show that an athlete's risk of injury increases when they repeatedly perform sport-specific movements incorrectly, particularly in the presence of abnormal foot types [4].

Foot Core

The human foot is an extremely complicated structure that enables it to perform a wide range of functions. It serves as a base of support while standing. During the foot strike and push-off phases of gait, the foot should be stable, but during the mid-support phase, the foot should attenuate loads and function as a mobile adaptor. Additionally, it has spring-like properties that store and release energy with every foot strike. This is achieved by deformation of the arch, which is governed by the intrinsic and extrinsic muscles of the foot [5]. The medial longitudinal arch is the structure that compresses and recoils. The elastic elements of the plantar fascia, or aponeurosis, provide this spring mechanism, which works through the windlass system to improve stiffness and may contribute 8–17% of the mechanical energy needed for a stride. Normal foot function depends on the stability of this arch, which is hypothesized to be the fundamental “core” of the foot [6].

The foot core system consists of three subsystems: the passive subsystem, the active subsystem, and the neural subsystem. The foot core system is functionally related to the lumbopelvic–hip core stability concept.

Biomechanical Implications in Football Performance

When engaging in exercise, humans typically adopt an upright, bipedal stance. In this position, we perform various movements at different speeds, including walking, kicking, jumping, and running. The feet are integral to these processes, serving as shock absorbers, weight-bearing structures, and essential components for locomotion. Current studies suggest that training the strength of toe flexors and grip force can lead to notable improvements in walking speed and dynamic balance, along with a reduced risk of falls [7].

Strength is a crucial factor that influences football performance, serving as a key element of physical capacity and a primary regulator of essential football-specific tasks. In a football game, brief sprints usually take place every 90 seconds. These sprints last two to four seconds each, and they usually begin with a quick change in direction [8]. Short foot exercises enhance the function of the abductor hallucis muscle, which assists in propulsion during the push-off phase. Additionally, the flexor hallucis brevis muscle helps maintain the medial longitudinal arch during the terminal stance phase of gait, contributing to overall foot stability. By stabilizing the arch, lowering peak load reflexes, and enhancing leg stability, foot core training greatly improves dynamic balance and eventually produces dynamic biomechanical consequences [4,9].

Agility is an essential component of optimal football performance. Strength, balance, speed, and coordination are all vital elements that define agility [10]. Strengthening the foot core muscles enhances balance, strength, and stability in the feet, ultimately contributing to improved agility. Intrinsic foot muscle strengthening significantly improves strength, balance, motor performance, and sensory function [11].

A study reported that in healthy recreational runners, a foot core strengthening program increased the cross-sectional area of the intrinsic muscles of the foot and enhanced propulsive impulse while running. Another study showed that ankle-foot kinematic patterns may also be altered by foot core strength training. Since running is the most important component of football, it requires coordination among body parts, along with strength, flexibility, and adaptability, which are important for creating a movement pattern that is both practical and effective [9,12].

We frequently overlook strengthening the intrinsic foot muscles in the management of lower limb injuries as well as in routine training. Therefore, the present study aims to train the intrinsic foot muscles to investigate their effects on balance, muscular endurance, foot strength development, and overall football performance.

2. MATERIALS AND METHODOLOGY

The study included a sample of 52 male recreational football players from Karad, aged 18 to 25 years. Written informed consent was obtained from all participants before the commencement of the study. Of the 52 enrolled participants, one was lost to follow-up due to personal reasons.

The research was conducted at Chhatrapati Shivaji Stadium, various football academies, and Krishna College of Physiotherapy, all located in Karad. Before enrolment, all subjects were provided with necessary information about the study protocol, their rights, and any potential risks involved. Ethical approval for the study involving human participants was obtained from the Institutional Ethics Committee of Krishna Vishwa Vidyapeeth (Deemed to be University), Karad. The sample size of 52 participants was calculated using the formula $n = Z^2 \times SD^2 / (M \times E)^2$, where Z is the standard normal variate for the desired confidence level, SD is the standard deviation, M is the mean difference, and E is the precision.

Inclusion Criteria: Participants were recreational male football players aged between 18 to 25 years. Only individuals without a history of foot injuries were considered eligible. All participants reported engaging in football training for an average of 8 hours per week.

Participants were selected according to the inclusion criteria. Exclusion criteria included a history of recent lower limb injuries or surgery, active foot pathologies within the past six months, or any congenital deformity of the foot. Each participant signed a written informed consent form, and demographic information was recorded on the first day of the study.

Assessments of the outcome measures were conducted before and after the exercise protocol. A comprehensive data sheet was prepared to compile all relevant information. Data were statistically analysed using IBM SPSS Statistics (Version 26), from which the results were derived.

Outcome measure assessment

A toe dynamometer was employed to evaluate intrinsic foot muscle strength. This device is specifically designed to assess toe flexor muscle strength. Dynamic balance was assessed using the Y-Balance Test – Lower Quarter (YBT-LQ). Muscular endurance was evaluated with the Square Hop Test, while football-specific skill performance, specifically shooting ability, was measured using a standardized shooting test.

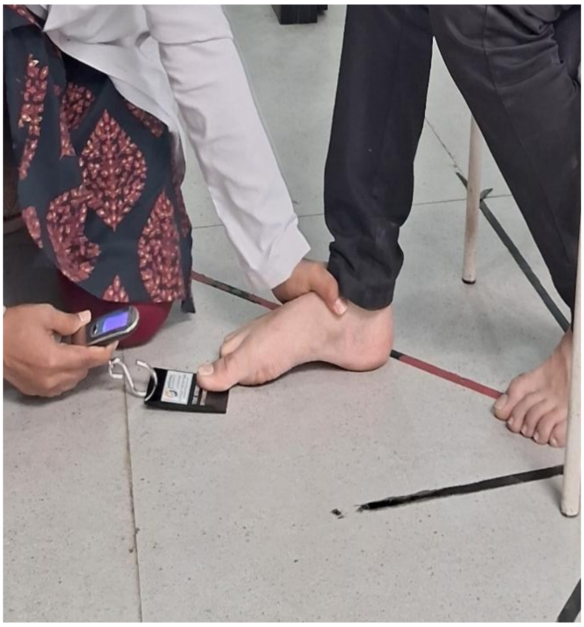

Fig 1. Toe dynamometer

Intervention

Participants selected on the basis of inclusion criteria received six weeks of training focused on the foot-ankle muscles, which involved warm-ups, stretching, and resistance exercises progressing weekly in volume and difficulty. Participants received weekly training sessions from a physical therapist and were instructed to practice the exercises independently twice a week for a total of six weeks.

Week	Focus	Exercises	Progressions
Week 1	Mobility & Intrinsic Activation	Toe flexor & extensor stretching	15 sec hold x 3
		Ankle dorsiflexion & plantarflexion drills	10 reps x 2
		Active toe flexion & extension	10 reps x 2
		Toe yoga	10 reps x 2
		Towel curls	10 reps x 2
		Short foot (sitting)	10 sec hold 5 reps x 2
Week 2	Intrinsic Strengthening	Toe abduction with towel/pen	10 sec hold 5 reps x 2
		Toe abduction without aid	10 reps x 2
		Short foot: standing, single-leg	10 sec hold 5 reps x 2
		Big toe flexion isometric (double-leg, incline)	10 sec hold 5 reps x 2
		Foot bridge + short foot (double-leg, block)	10 sec hold 5 reps x 2
Week 3	Extrinsic Strengthening	Resisted plantarflexion	10 reps x 2

	Phase 1	Resisted dorsiflexion	10 reps x 2
		Resisted inversion & eversion (bands)	10 reps x 2
		Heel raises (double → single leg)	10 reps x 2
		Big toe flexion with band (long sitting)	10 reps x 2
Week 4	Extrinsic + Weighted + Proprioception	Foot bridge: weighted single-leg	10 reps x 2
		Heel raises on inclined board	10 reps x 2
		Big toe flexion isometric (single leg on incline)	10 sec hold 5 reps x 2
		Resisted big toe flexion: standing → block	10 reps x 2
		Short foot during squats & lunges	10 reps x 2
Week 5	Plyometric Training – Double Leg	Rebound jumps (double leg): in place, side-to-side, forward-back	10 reps x 2
		Vertical jumps: double leg (sub-max → max)	10 reps x 2
		Horizontal jumps: double leg (sub-max)	10 reps x 2
Week 6	Plyometric Training – Single Leg	Rebound jumps (single leg): in place, side-to-side	10 reps x 2
		Vertical jumps: single leg (sub-max → max)	10 reps x 2
		Horizontal jumps: single leg (sub-max → max)	10 reps x 2
		Penguin marches	10 reps x 2

Table 1: Six-Week Foot Core Strengthening Program for Recreational Football Players

Statistical analysis

IBM SPSS Statistics (Version 26) was used for data analysis. To evaluate changes before and after the intervention, a paired sample t-test was applied to determine statistically significant differences in the outcome measures. For each parameter, mean values and corresponding standard deviations (SD) were calculated to summarize central tendency and variability. The mean was obtained by dividing the total sum of all individual measurements by the number of participants.

3. RESULTS

Table 2 presents the participants' demographic details, including gender, age group, and BMI, which are descriptively correlated with the study population. The study included a total of 52 male recreational football players, all of whom met the inclusion criteria. The majority of participants were aged 21–23 years, 28 (54%), followed by 19 (36%) in the 18–20 years group and 5 (10%) in the 24–25 years group, indicating a predominantly young adult population engaged in football training. Regarding body mass index (BMI), most participants, 36 (69%), fell within the normal BMI range (17–24.9 kg/m²), while 16 (31%) were in the overweight category (25–31.9 kg/m²). These values suggest that the sample largely consisted of individuals with a healthy body composition, appropriate for active sports participation.

Parameters	Frequency (percentage)
Age group, years	
18-20	19 (36%)
21-23	28(54%)
24-25	5 (10%)
Gender	
Male	52 (100%)
BMI, kg/m^2	
17-24.9	36 (69%)
25-31.9	16 (31%)

Table 2: Demographic details of the participants

BMI- body mass index

Table 3 shows the dynamic balance score measured using the Y balance test. For the right limb, the mean composite score showed a slight improvement from 91.37 ± 9.02 (pre-test) to 91.80 ± 9.04 (post-test). Although the numerical change appears small, the p-value of 0.0041 indicates that this change is statistically very significant, suggesting a meaningful improvement in dynamic balance on the right side. For the left limb, a more noticeable improvement was observed, with scores increasing from 89.96 ± 8.84 to 90.45 ± 8.84. The corresponding p-value of 0.0002 indicates a highly significant difference, highlighting a substantial enhancement in dynamic balance for the left side.

	Pre test (Mean±SD)	Post test (Mean±SD)	P value	T value	Level of significance
Right	91.37±9.02	91.80±9.04	0.0041	3.006	**Very significant**
Left	89.96±8.84	90.45±8.84	0.0002	3.6977	**Extremely significant**

Table 3 Comparison of pre- and post-test measures: Y balance test of right and left leg, analyzed using a paired t-test.

Table 4 outlines the pre-test and post-test measurements of intrinsic toe flexor muscle strength (Mean ± SD), evaluated using a toe dynamometer for both the right and left feet, specifically the Great Toe (GT) and Lesser Toes (LT). In the right foot, GT muscle strength improved from 5.01 ± 1.26 to 5.53 ± 1.20, with $p < 0.0001$, denoting a highly significant increase. LT strength rose from 2.88 ± 1.09 to 3.86 ± 1.05, also with $p < 0.0001$, indicating a highly significant enhancement. In the left foot, GT strength increased from 4.09 ± 1.42 to 5.05 ± 1.44 ($p < 0.0001$), and LT strength improved from 2.66 ± 1.08 to 3.57 ± 1.19 ($p < 0.0001$), both showing highly significant gains.

		Pre test (Mean±SD)	Post test (Mean±SD)	P value	T value	Level of significance
Right	**GT**	5.01±1.26	5.53±1.20	<0.0001	6.162	**Extremely significant**
	LT	2.88±1.09	3.86±1.05	<0.0001	12.404	**Extremely significant**
	GT	4.09±1.42	5.05±1.44	<0.0001	11.669	**Extremely significant**

Left	**LT**	2.66±1.08	3.57±1.19	<0.0001	8.301	**Extremely significant**

Table 4: Comparison of pre- and post-test foot flexor strength (right and left leg) using the toe dynamometer; analysed using a paired t-test.

Table 5 presents the pre-test and post-test results of the Square Hop Test, which evaluates muscular endurance in the lower limbs. For the right leg, the average score increased marginally from 35.51 ± 10.35 to 36.25 ± 10.27 after the intervention. However, the p-value of 0.3039 indicates that this change is not statistically significant, suggesting that the improvement may represent variability rather than a consistent training outcome. For the left leg, an increase was observed from 30.96 ± 10.37 to 32.56 ± 10.88. The p-value of 0.0678 suggests the change was not quite significant, indicating a trend toward improvement but not meeting the standard criterion for statistical significance ($p < 0.05$).

	Pre test (Mean±SD)	**Post test** (Mean±SD)	**P value**	**T value**	**Level of significance**
Right	35.51±10.35	36.25±10.27	0.3039	**1.039**	**Not significant**
Left	30.96±10.37	32.56±10.88	0.0678	**1.867**	**Not quite significant**

Table 5 Comparison of pre- and post-test measures of muscular endurance: square hop test, calculated using paired t-test.

Table 6 shows the pre-test and post-test results of the football shooting test, assessing skill performance using the dominant leg. The mean shooting score remained the same before and after the intervention at 2.627, with a slight reduction in standard deviation from ±1.52

	Pre test (Mean±SD)	**Post test (Mean±SD)**	**P value**	**T value**	**Level of significance**
Dominant	2.627±1.52	2.627±1.39	>0.999	**0.000**	**Not significant**

Table 6 Comparison of pre- and post-test measures of football skill with the shooting test of the dominant leg, analyzed using a paired t-test.

4. DISCUSSION

Football demands a mix of explosive accelerations, abrupt stops, directional changes, and jumps. These movements rely heavily on optimal foot function and stability to enhance performance and reduce injury risk. The foot serves a vital function in supporting body weight, absorbing ground reaction forces, and facilitating various athletic actions such as sprinting, jumping, landing, cutting, lateral movements, and shooting. The feet support the body's weight, act as shock absorbers, and enable mobility during all phases of motion; they are essential to human movement [13].

The intrinsic and extrinsic muscles of the foot work together to facilitate efficient movement patterns, preserve the foot's medial arch, and offer stability, which make up the foot core system. Weakness in any element of the foot core system is linked to altered biomechanics, increased risk of injury, and decreased balance and agility. There is a gap in research examining the influence of foot core strengthening on football performance [14].

The study focused on analyzing the effect of foot core strengthening on sports performance in 52 recreational football players. Participants underwent pre- and post-assessments for dynamic balance (Y-Balance Test), muscular endurance (Square Hop Test), intrinsic foot muscle strength (Toe Dynamometer), and football skills (Shooting Test). After a six-week progressive foot core strengthening protocol, results showed significant improvements in intrinsic muscle strength and dynamic balance. Nevertheless, no significant changes were observed in muscular endurance or football skill performance. The results indicate that the protocol effectively enhances foot strength and balance but not endurance or football-specific skills.

Changes in Intrinsic Foot Muscle Strength.

A significant improvement was observed in intrinsic foot muscle strength following the intervention, indicating that targeted foot core training can have a substantial positive impact on the strength of these muscles. Our results are consistent with those of **Takayuki and Keishoku (2014)**, who also reported notable enhancements in intrinsic foot flexor strength after implementing a training program that excluded extrinsic muscle exercises [15]. However, **Fraser and Hertel (2019)** reported contrasting evidence, finding no significant activation of intrinsic foot muscles using ultrasound imaging (USI) after a four-week intrinsic muscle strengthening program [16]. This discrepancy underscores the need for further investigation into optimal assessment tools and training durations for effectively evaluating intrinsic muscle activation and strength gains.

Effect of Foot Core Strengthening on Balance Ability.

Our findings demonstrated a significant improvement in dynamic balance following the implementation of foot muscle strengthening exercises, highlighting the critical role of intrinsic foot musculature in postural control and stability. These results are reinforced by the findings of **Dong-Roure et al. (2019)**, who implemented a six-week intrinsic foot muscle training protocol in individuals diagnosed with chronic ankle instability. Their study similarly reported notable improvements in both functional performance and dynamic balance, reinforcing the efficacy of targeting the foot core in balance training interventions [17]. Additionally, **Kazunori, Daisuke et al. (2021)** investigated the impact of toe-grasping exercises on balance ability and determined that these exercises might contribute to improvements in balance performance [18]. In a 2022 systematic review, **Zhen Wei et al. (2021)** demonstrated that intrinsic foot muscle (IFM) training has beneficial biomechanical impact on the medial longitudinal arch. Their study further revealed that IFM training enhances lower limb postural balance and serves as an effective strategy for improving foot function and overall stability [19].

A key component of our protocol was the incorporation of progressive short-foot exercises, which are particularly effective in strengthening the medial longitudinal arch (MLA). This approach is substantiated by the findings of **Lynn et al. (2012)**, who compared short foot exercises with towel curls over a four-week period in healthy individuals. Their results demonstrated that a short foot exercise were superior in maintaining MLA height during dynamic balance tasks, underscoring their utility in promoting structural and functional stability of the foot [20].

Effect on Football Performance.

The results showed no significant improvement in shooting ability. While our protocol improved balance, we hypothesize that this enhancement may ultimately support football-specific skills. In contrast to our assumption, **Nurtekin et. al. (2010)** stated that sprinting and acceleration had no correlation with balance performance [21]. In football, the dominant foot is mainly responsible for actions such as passing, ball control, and kicking, whereas the non-dominant leg primarily aids in providing balance and support [22]. **Mazari et al. (2018)** further demonstrated that incorporating balance-focused training significantly enhanced both players' stability and their shooting accuracy. They found that incorporating balance-focused training significantly enhanced both the players' balance and their accuracy in aiming [23].

Effect on Injury Prevention

As recreational football continues to grow in popularity, the physical demands of the sport—particularly the running component—have led to a corresponding rise in running-related injuries (RRIs). Running is a fundamental aspect of football, requiring high levels of endurance, speed, and agility. However, this increased activity brings a heightened risk of injury. RRIs have emerged as a major concern, especially among individuals involved in high-volume running. **Ulisses and Alessandra et al. (2020) and Eneida Yuri Suda (2022)** conducted a study on the effectiveness of foot core training in preventing running-related injuries in recreational runners. They found that participants who followed the foot exercise program experienced a notable reduction in injury risk, with benefits that became evident after 4 to 8 months of consistent training [24, 25].

Even though our research was limited to a six-week duration, making it difficult to observe any injury prevention effects, it is worth mentioning that injury prevention was not among the study's objectives. Nevertheless, foot core strengthening may have potential value as a component of both rehabilitation and prehabilitation programs.

The evaluation of muscular endurance was performed using the square hop test; however, the findings showed no meaningful change following the foot core strengthening protocol. This outcome is likely due to the intervention targeting only the intrinsic and extrinsic muscles of the foot, which are unlikely to influence overall lower extremity muscular endurance. It is possible that including exercises focused on major muscle groups could produce more pronounced endurance benefits.

A limitation of this study is the six-week protocol, which involves moderate repetition levels. This may not have provided sufficient stimulus to produce measurable adaptations in muscular endurance or football-specific outcomes. This short intervention period and submaximal training intensity likely contributed to the absence of significant improvements in these domains. Furthermore, the study did not include long-term follow-up to evaluate sustained effects or performance during actual gameplay.

5. CONCLUSION

The findings of the study suggest that the implementation of a foot core strengthening protocol resulted in significant measurable improvements in dynamic balance, according to the measurements from the Y-Balance Test, and intrinsic foot muscle strength, as assessed using a toe dynamometer. These improvements reflect enhanced neuromuscular control and stabilization capacity of the foot. However, the protocol did not lead to statistically significant changes in muscular endurance or lower limb power, as evaluated by the Square Hop Test, nor in football-specific performance skills, such as shooting accuracy. This suggests that while the protocol is effective in targeting stability and foot-level strength, it may not be sufficient on its own to influence broader athletic performance parameters such as endurance, explosive power, or skill-based tasks.

Conflict of Interest: The authors declare that they have no conflict of interest.

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