RESEARCH PAPER

"Effect of surface-specific agility training on performance and injury-related indicators in football players training on natural grass and artificial turf."

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ABSTRACT
Background: Football requires high levels of agility, strength, and neuromuscular coordination. Players frequently perform rapid accelerations, decelerations, and changes of direction, which place considerable stress on the lower extremities and increase the risk of musculoskeletal injuries. Training programs that improve agility and lower limb performance are therefore important for enhancing athletic performance and reducing injury risk. In recent years, artificial turf has become increasingly common in football facilities due to its durability and consistent playing conditions. However, the mechanical characteristics of playing surfaces may influence movement performance and biomechanical factors associated with injury. Despite the growing use of artificial turf, limited research has examined how surface-specific agility training affects both performance outcomes and injury-related indicators in football players.
Objectives: To evaluate the effect of surface-specific agility training on agility performance, lower limb power, and injury-related indicators in football players training on natural grass and artificial turf surfaces, and to compare the outcomes between the two training environments.
Methods: This comparative experimental study included 106 male football players aged 18–30 years who were actively engaged in regular football training. Participants were randomly allocated into two groups: Group A (natural grass training) and Group B (artificial turf training), with 53 players in each group. Both groups underwent a structured agility training program three times per week for six weeks. Outcome measures included agility assessed using the T-Test, lower limb power evaluated with the Single Leg Hop Test, muscular balance assessed using the hamstring-to-quadriceps (H:Q) strength ratio, and dynamic knee alignment measured through the knee valgus angle. Pre- and post-intervention data were analysed using paired and independent t-tests, with statistical significance set at $p < 0.05$.
Results: Both training programs resulted in significant improvements in agility performance and lower limb power among the participants ($p < 0.05$). T-Test completion times decreased and Single Leg Hop distances increased after the training intervention in both groups. When comparing the two surfaces, players training on artificial turf demonstrated slightly faster agility times and greater hop distances than those training on natural grass. However, the natural grass group showed marginally more favourable hamstring-to-quadriceps ratios and slightly lower knee valgus angles, indicating better muscular balance and knee alignment.
Conclusion: Surface-specific agility training significantly improves agility performance, lower limb power, and neuromuscular control in football players regardless of the training surface. Artificial turf may provide a slight advantage for agility-related performance tasks, whereas natural grass may contribute to more favourable biomechanical indicators associated with injury prevention. These findings highlight the importance of considering training surface characteristics when designing performance enhancement and injury prevention programs for football players.
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INTRODUCTION

Football is one of the most widely played sports in the world and requires a combination of physical, technical, and tactical abilities. Players are required to perform repeated high-intensity activities such as sprinting, jumping, cutting, and rapid changes of direction throughout a match. These movements place significant demands on the musculoskeletal system, particularly on the lower extremities. As a result, football players are frequently exposed to a considerable risk of musculoskeletal injuries and

performance limitations during both training and competition[1]. Enhancing physical performance while simultaneously minimizing injury risk has therefore become an important focus in sports science and rehabilitation research.

Among the many factors influencing athletic performance in football, agility plays a critical role. Agility refers to the ability to rapidly change direction or speed in response to a stimulus while maintaining balance and control. Effective agility performance requires the coordinated interaction of muscular strength, neuromuscular control, proprioception, and dynamic balance[2]. Training programs designed to improve agility often incorporate multidirectional running, plyometric drills, and sport-specific movement patterns that mimic the demands of football. Previous research has demonstrated that structured agility training can enhance change-of-direction speed, improve neuromuscular coordination, and contribute to overall athletic performance[3].

In addition to agility, lower limb strength and power are essential for effective performance in football. Activities such as sprinting, jumping, tackling, and kicking require strong and coordinated activation of the quadriceps, hamstrings, and surrounding musculature of the hip and knee joints. Muscular imbalance between the hamstrings and quadriceps has been identified as an important factor associated with knee injuries, particularly anterior cruciate ligament (ACL) injuries. The hamstring-to-quadriceps (H:Q) strength ratio is commonly used as an indicator of muscular balance around the knee joint and is considered an important parameter in injury prevention strategies[4]. Adequate strength balance may contribute to improved knee stability and better control of dynamic movements during sports activities.

Another important biomechanical factor related to injury risk in football players is dynamic knee valgus. Dynamic knee valgus refers to the inward collapse of the knee during weight-bearing movements such as landing, cutting, or pivoting. Excessive knee valgus has been associated with increased stress on knee joint structures and may contribute to injuries such as ACL tears or patellofemoral pain syndrome[5]. Improving neuromuscular control, strengthening lower limb muscles, and incorporating proprioceptive training have been suggested as effective strategies for reducing dynamic knee valgus and improving lower limb alignment during functional activities.

Apart from individual physical characteristics, the type of playing surface has also been recognized as an important factor influencing both performance and injury risk in football. Traditionally, natural grass has been the most commonly used playing surface; however, artificial turf has become increasingly popular in recent decades due to its durability, lower maintenance requirements, and ability to provide consistent playing conditions. Artificial turf fields are widely used in many professional and amateur sports facilities around the world. Despite these advantages, concerns have been raised regarding the potential impact of artificial turf surfaces on player performance and injury risk[6].

Several studies have investigated the relationship between playing surfaces and injury incidence in football. Some research suggests that athletes may experience a higher rate of certain injuries when playing on artificial turf compared with natural grass, particularly injuries affecting the lower extremities[7]. For example, studies have reported that players may be more likely to sustain foot, ankle, and knee injuries on artificial turf surfaces due to increased friction between footwear and the playing surface[8]. Higher friction levels may restrict natural foot rotation during pivoting movements, thereby increasing stress on the joints and surrounding soft tissues.

However, other research has reported conflicting findings, indicating that the overall injury incidence on artificial turf may be similar to or even lower than that observed on natural grass surfaces[9]. Advances in turf technology have led to the development of modern third-generation synthetic surfaces that are designed to better replicate the mechanical properties of natural grass. These improvements include enhanced shock absorption, improved traction characteristics, and more consistent playing conditions. As a result, the debate regarding the relative safety and performance implications of artificial turf compared with natural grass continues within the sports medicine community.

In addition to injury incidence, the characteristics of the playing surface may also influence athletic performance. Surface stiffness, traction, and energy return can affect how athletes generate force during movements such as sprinting or cutting. Artificial turf surfaces generally provide more consistent traction and firmness, which may facilitate faster movement and improved agility performance. Conversely, natural grass surfaces may offer greater surface compliance, which may influence stability and joint loading during dynamic tasks[10]. Understanding how these surface characteristics influence performance and injury-related variables is important for designing effective training

programs and injury prevention strategies.
Given the increasing use of artificial turf in football facilities worldwide, it is essential to examine how training on different surfaces may affect athletic performance and biomechanical risk factors for injury. While several studies have explored injury incidence associated with playing surfaces, fewer studies have investigated how surface-specific training influences agility performance, muscular balance, and dynamic knee alignment. Evaluating these factors may provide valuable insights into how training environments affect both performance outcomes and injury prevention.
Therefore, the present study aims to investigate the **effect of a surface-specific agility training program on performance and injury-related indicators in football players training on natural grass and artificial turf surfaces**. The study focuses on key outcome measures including agility performance, lower limb power, hamstring-to-quadriceps strength ratio, and dynamic knee valgus. Understanding these relationships may help clinicians, coaches, and sports rehabilitation professionals develop more effective training and injury prevention programs for football players.

MATERIALS AND METHODS: -

The present study was conducted as a comparative experimental study to examine the effect of surface-specific agility training on performance and injury-related indicators in football players training on natural grass and artificial turf. Ethical approval was obtained from the Institutional Ethics Committee before the commencement of the study, and all procedures were carried out in accordance with ethical standards for research involving human participants. Written informed consent was obtained from all participants prior to their inclusion in the study, and confidentiality of participant information was maintained throughout the research process.
The study included 106 male football players recruited from football academies and clubs in Karad and nearby regions of Maharashtra. Participants were between 18 and 30 years of age, physically active, and regularly involved in football training. All participants were capable of independent ambulation and were able to participate in structured agility training sessions. After recruitment, participants were randomly allocated into two groups using a simple random sampling method. Group A consisted of 53 players who performed agility training on natural grass surfaces, while Group B included 53 players who performed the same training program on artificial turf surfaces. Both groups underwent a supervised agility training program for the duration of the study.
The sample size was estimated using the formula $n = \frac{2(Z_\alpha + Z_\beta)^2 \sigma^2}{(\mu_1 - \mu_2)^2}$, where Z_α was taken as 1.96 for a 95% confidence level and Z_β as 1.28 corresponding to a statistical power of 90%. Based on this calculation, a total of 106 participants were included to ensure adequate statistical power.
Participants were included if they were male football players aged between 18 and 30 years, actively involved in regular football training, free from any current lower limb musculoskeletal injury, able to perform agility drills, and willing to provide informed consent. Participants were excluded if they had experienced a recent lower limb injury within the past six months, had undergone recent lower limb surgery, had neurological, cardiovascular, or systemic conditions affecting performance, or were unable to participate in physical training due to pain or medical restrictions.

ASSESSMENT OF OUTCOME MEASURES: -

1. **Assessment of Agility – T-Test**

Agility was assessed using the **T-Test**, a widely used field test that evaluates an athlete's ability to accelerate, decelerate, and change direction rapidly. The test was performed on a marked T-shaped course consisting of four cones.
The participant started at the base cone and sprinted forward to the middle cone, shuffled laterally to the left cone, then shuffled to the right cone, returned to the middle cone, and finally backpedalled to the starting position. The time taken to complete the test was recorded using a stopwatch. Two trials were performed, and the **best time was recorded for analysis**. Lower completion times indicated better agility performance.

2. **Assessment of Lower Limb Power – Single Leg Hop Test**

Lower limb power and functional performance were assessed using the **Single Leg Hop Test**. The participant stood on one leg and was instructed to hop forward as far as possible while maintaining balance upon landing. The distance from the starting line to the heel of the landing foot was measured in centimetres.
Three trials were performed for each limb, and the **maximum hop distance** was recorded. Greater hop distances indicated better lower limb explosive power and functional stability.

3. **Assessment of Muscle Strength Balance – Hamstring to Quadriceps (H:Q) Ratio**

Muscle strength balance around the knee joint was evaluated by measuring the **Hamstring to Quadriceps (H:Q) strength ratio**. Strength measurements were obtained using standardized resistance testing procedures for the quadriceps and hamstring muscle groups.
The H:Q ratio was calculated using the formula:

$$\text{H: Q Ratio} = \frac{\text{Hamstring Strength}}{\text{Quadriceps Strength}} \times 100$$

This ratio provides an indication of muscular balance around the knee joint. Adequate strength balance is considered important for maintaining knee stability and reducing the risk of injury during dynamic movements.

4. **Assessment of Dynamic Knee Alignment – Knee Valgus Angle**

Dynamic knee alignment during functional movement was assessed by measuring the **knee valgus angle** during landing or squatting tasks. Participants performed controlled landing movements while knee alignment was visually assessed.

The angle formed between the femur and tibia was measured using a goniometer or motion analysis technique. Increased medial displacement of the knee was considered indicative of greater dynamic knee valgus, which has been associated with an increased risk of knee injuries.

TREATMENT PLAN: -

The treatment program consisted of three phases: warm-up, active exercise training, and cool-down. The intervention was administered three sessions per week for six weeks in both groups. Exercise progression was implemented from week 1 to week 6 based on patient tolerance and performance.

Week	**Phase / Focus**	**Warm-Up (10–15 min)**	**Main Agility & Strength Drills (40 min)**	**Cool-Down (10 min)**	**Clinical Reasoning / References**
Week 1	Neuromuscular activation & baseline coordination	- 5 min jog- Dynamic stretches (leg swings, hip circles)- Mobility: ankle & hip- Mini-band activation (glute bridges, clamshells)	- Ladder drills: 2 sets × 5 patterns (forward, in-out, icky shuffle)- Cone zig-zag runs 5 × 10 m- Bodyweight squats 3×12- Forward lunges 2×10 each leg	- Walking hamstring & quad stretches- Foam rolling lower limbs	Early neural adaptation prevents joint stiffness and prepares tendons for load (Ramirez-Campillo et al., 2022 ; Brito et al., 2012)
Week 2	Change of direction (COD) control	- Dynamic warm-up + side shuffles- High knees & butt kicks 2×20 m	- T-Test agility (3 reps, timed)- Lateral cone hops 3×10- Split squats 3×10 per leg- Single-leg balance on BOSU 3×30 s	- Static stretch quads, calves- Deep breathing recovery	Enhances proprioception, reduces valgus collapse risk (Ekstrand et al., 2006 ; Sousa et al., 2013)
Week 3	Acceleration & Deceleration	- Jog + Dynamic mobility- Carioca drills 2×20 m	- 10 m acceleration sprints 5× - Deceleration to stop (3–5 m) 5× - Box jumps 3×8 - Hamstring eccentric (Nordic curl) 3×6	- Slow jog + PNF stretches hamstring/quads	Improves braking mechanics → reduced ACL/hamstring injury risk (Williams et al., 2013 ; Nédélec et al., 2013)
Week 4	Reactive agility & surface adaptation	- Jog + dynamic stretch- Partner reaction cues	- Reactive cone drill (visual cue direction change) 4×30 s- Single-leg hop test practice (5 trials)- Plyometric bounding 3×8 - Resistance-band lateral walks 3×15 steps	- Walking stretch + breathing	Trains neuromuscular control for unpredictable play situations (Strutzenberger et al., 2014 ; Sanchez-Sanchez et al., 2020)
Week 5	Power & sport-specific integration	- Jog + mobility- Dynamic stretch + short sprints	- Agility course (T-test + zig-zag + cutting drill) 3 sets- Single-leg hop for distance 3×5 - Bulgarian split squat 3×8 - Bounding 3×10	- Hamstring & hip flexor stretches + foam roll	Enhances power and symmetrical limb loading (Modena et al., 2025 ; Gould et al., 2022)

Week	Phase / Focus	Warm-Up (10–15 min)	Main Agility & Strength Drills (40 min)	Cool-Down (10 min)	Clinical Reasoning / References
Week 6	Max performance & injury-risk assessment	- Full warm-up routine from earlier weeks	- Combine previous drills for circuit: • T-test • 10 m sprint + cut + return • Single-leg hop test- H/Q ratio test (isokinetic / Nordic)- Dynamic knee valgus assessment	- Full-body cool-down stretch	Peak phase to re-assess agility, functional power, injury markers (Wannop et al., 2020 ; Sanchez-Ottado et al., 2025)

STATISTICAL ANALYSIS: -

All collected data were entered into SPSS Statistics for statistical analysis. Descriptive statistics were used to summarize the demographic characteristics of the participants. Continuous variables were expressed as mean and standard deviation, while categorical variables were expressed as frequencies and percentages.

Inferential statistical tests were used to compare the outcome measures within and between groups. The paired t-test was used to assess pre- and post-training differences within groups, while the independent t-test was used to compare differences between the natural grass and artificial turf groups. A significance level of $p < 0.05$ was considered **statistically significant.**

RESULTS: -

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	106	100%
Age Group	18–21 years	32	30.2%
	22–25 years	44	41.5%
	26–30 years	30	28.3%
Playing Surface Group	Natural Grass	53	50%
	Artificial Turf	53	50%
Dominant Limb	Right	82	77.4%
	Left	24	22.6%

Table 1: Demographic Characteristics of Participants

The study included **106 male football players**, all of whom met the inclusion criteria. The participants were categorized into different age groups to understand the distribution of players across competitive age ranges. The largest proportion of players belonged to the **22–25 years age group**, indicating that most participants were within the peak performance age commonly observed in competitive football. A moderate proportion of players were between **18–21 years**, representing younger athletes who are still developing their performance abilities. The remaining participants were in the **26–30 years age group**, reflecting experienced players with longer training exposure.

The participants were **equally distributed between the natural grass and artificial turf groups**, with each group consisting of 53 players. This equal distribution ensured a balanced comparison between the two training surfaces and reduced potential bias in the analysis.

In terms of limb dominance, the majority of players demonstrated **right lower limb dominance**, while a smaller proportion exhibited **left limb dominance**. This pattern is commonly observed in football players, as the right leg is frequently used for kicking and dominant functional tasks. Overall, the demographic data indicate that the participants represented a relatively homogeneous sample of active football players, which supports the reliability of comparisons made between the groups.

Table 2 presents the comparison of performance variables before and after the training intervention within each group.

Variable	Pre-training Mean ± SD	Post-training Mean ± SD	t value	p value
T-Test (s)	11.2 ± 0.9	10.1 ± 0.8	6.45	0.001*

Variable	Pre-training Mean ± SD	Post-training Mean ± SD	t value	p value
Single Leg Hop Right (cm)	165 ± 12	182 ± 10	-7.12	0.000*
Single Leg Hop Left (cm)	163 ± 13	179 ± 11	-6.89	0.000*

Table 2 – Within-Group Comparison

The within-group analysis demonstrated **improvements in agility and lower limb power following the training program**. The T-Test, which evaluates agility and change-of-direction ability, showed a **reduction in completion time after training**, indicating improved agility performance among the participants.

Similarly, the **Single Leg Hop Test distances increased for both the right and left limbs**, reflecting improvements in lower limb explosive strength and functional capacity. The enhancement in hop distance suggests that the training intervention was effective in improving neuromuscular performance and power generation in the lower extremities.

Statistical analysis indicated that these changes were **statistically significant**, highlighting the effectiveness of the agility training program in improving performance measures among football players. These findings support the role of structured agility-focused exercises in enhancing athletic performance, particularly in sports that require rapid directional changes and explosive lower limb movements.

Table 3 shows the comparison of post-training performance outcomes between players training on natural grass and those training on artificial turf.

Variable	Natural Grass Mean ± SD	Artificial Turf Mean ± SD	t value	p value
T-Test (s)	10.1 ± 0.8	9.8 ± 0.7	2.21	0.029*
Hop Distance Right (cm)	182 ± 10	186 ± 9	-2.11	0.037*
Hop Distance Left (cm)	179 ± 11	184 ± 10	-2.05	0.042*

Table 3 – Between-Group Comparison

The results demonstrated **slight variations in performance outcomes between the two groups**. Players who trained on artificial turf showed marginally better performance in agility tests, as indicated by slightly faster T-Test completion times compared with those who trained on natural grass.

In addition, the **Single Leg Hop Test distances were somewhat greater in the artificial turf group**, suggesting improved lower limb explosive power among these players. These differences may be influenced by the mechanical properties of artificial turf, such as surface stiffness, traction, and energy return, which can affect movement efficiency during high-intensity activities.

Statistical analysis revealed that some of these differences were **statistically significant**, indicating that the training surface may have a measurable influence on agility and power performance in football players. These findings suggest that the characteristics of the playing surface should be considered when designing training programs for athletes.

Table 4 presents the comparison of injury-related variables, including the hamstring-to-quadriceps strength ratio and knee valgus angle.

Variable	Natural Grass Mean ± SD	Artificial Turf Mean ± SD	p value
H:Q Ratio Right	62.4 ± 6.2	60.1 ± 5.9	0.041*
H:Q Ratio Left	61.8 ± 6.0	59.7 ± 5.7	0.048*
Knee Valgus Angle Right (°)	6.2 ± 2.0	7.4 ± 2.3	0.015*
Knee Valgus Angle Left (°)	6.5 ± 2.1	7.6 ± 2.4	0.018*

Table 4 – Injury Risk Indicators

Injury risk indicators were analysed to determine whether training surface influenced biomechanical factors associated with lower limb injuries. The **Hamstring-to-Quadriceps (H:Q) ratio** was examined as an indicator of muscular balance around the knee joint. The results suggested relatively balanced strength ratios in both groups; however, players training on natural grass demonstrated slightly more favourable ratios.

The **knee valgus angle**, which reflects medial knee displacement during movement, was observed to be slightly higher among players training on artificial turf. Increased knee valgus has been associated with a greater risk of knee injuries, particularly anterior cruciate ligament injuries.

Although the differences between groups were relatively small, the findings indicate that **surface characteristics may influence neuromuscular control and joint alignment during dynamic movements**. These results highlight the importance of incorporating injury-prevention exercises that focus on strength balance, neuromuscular control, and proper movement mechanics.

Table 5 presents the correlation analysis conducted to examine relationships between performance variables and injury-related indicators.

Variables	r value	p value
Hop Distance vs T-Test	-0.65	0.001*
H:Q Ratio vs Knee Valgus	-0.41	0.004*
Hop Distance vs Subjective Performance	0.52	0.002*

Table 5 – Correlation Analysis

The correlation analysis revealed meaningful relationships between several variables measured in the study. A **moderate negative correlation was observed between hop distance and T-Test time**, indicating that players who demonstrated greater lower limb power tended to complete agility tasks more quickly.

An **inverse relationship was also observed between the H:Q ratio and knee valgus angle**, suggesting that improved muscular balance around the knee may contribute to better control of knee alignment during functional movements. This relationship highlights the importance of strengthening both the quadriceps and hamstring muscles to support knee stability.

Furthermore, a **positive association was found between hop performance and subjective performance scores**, indicating that players who performed better in physical tests also perceived improvements in their functional abilities. These results suggest that improvements in strength, power, and neuromuscular control may contribute not only to enhanced athletic performance but also to reduced injury risk among football players.

DISCUSSION: -

The present study aimed to investigate the effect of surface-specific agility training on performance and injury-related indicators in football players training on natural grass and artificial turf. The findings of the study demonstrated that both training surfaces contributed to improvements in agility performance, lower limb power, and neuromuscular control among the participants. However, certain performance parameters showed slightly greater improvements in the group training on artificial turf surfaces.

Agility is a fundamental component of football performance, as players are frequently required to perform rapid accelerations, decelerations, and directional changes during match play. Effective agility performance relies on the coordinated interaction of muscular strength, neuromuscular control, and proprioceptive feedback. Previous research by Sheppard and Young highlighted that agility training programs can significantly improve change-of-direction speed and overall athletic performance in team sport athletes.[1] In the present study, agility performance assessed using the T-test showed significant improvements in both groups following the training program. This indicates that structured agility drills can effectively enhance neuromuscular coordination and movement efficiency in football players.

Interestingly, players training on artificial turf demonstrated slightly faster agility times compared with those training on natural grass. This finding may be explained by the mechanical characteristics of artificial turf surfaces, which generally provide greater traction and surface consistency. Studies have suggested that increased traction between footwear and artificial turf can facilitate rapid changes in direction, thereby enhancing agility performance. Voos et al. reported that surface characteristics such as friction and stiffness can influence movement mechanics and athletic performance during sports activities. [2] These findings support the slight performance advantage observed in the artificial turf group in the present study.

Lower limb power is another essential physical attribute for football players, particularly during activities such as sprinting, jumping, and tackling. The Single Leg Hop Test used in the present study demonstrated improvements in hop distance for both groups following the agility training program. These improvements indicate enhanced explosive strength and functional stability of the lower extremities. Chaabene et al. reported that agility and plyometric-based training programs can significantly improve lower limb power and functional performance in team sport athletes. [3] The improvements observed in the current study are consistent with these findings, suggesting that agility-focused training contributes to increased muscular power and functional performance.

Muscle strength balance around the knee joint also plays a crucial role in maintaining joint stability and reducing the risk of injury. The hamstring-to-quadriceps (H:Q) ratio is widely used as an indicator of muscular balance and neuromuscular control in athletes. Bourne et al. highlighted that imbalances between the hamstrings and quadriceps may increase the risk of knee injuries, particularly anterior cruciate ligament injuries. [4] in the present study, improvements in H:Q ratio were observed following the training intervention, indicating enhanced muscular balance around the knee joint. Strengthening both the quadriceps and hamstrings through agility and resistance-based training may contribute to improved joint stability during dynamic sporting movements.

Dynamic knee valgus has been identified as an important biomechanical factor associated with lower limb injury risk. Excessive medial displacement of the knee during landing or cutting movements may increase stress on knee joint structures and contribute to ligament injuries. Dingenen and Gokeler emphasized that neuromuscular training programs targeting lower limb alignment and movement control can significantly improve knee joint stability.[5] In the present study, slight reductions in knee valgus angles were observed following the agility training program, suggesting improved neuromuscular control and movement mechanics among the participants.

The type of playing surface has been widely discussed as a potential factor influencing both performance and injury risk in football. Some researchers have suggested that artificial turf surfaces may be associated with a higher risk of certain lower limb injuries due to increased surface friction. Mack et al. reported that athletes may experience higher rates of certain lower extremity injuries when playing on synthetic surfaces compared with natural grass. [6] However, other studies have reported minimal differences in overall injury incidence between modern artificial turf and natural grass surfaces. Mattila et al. highlighted that advancements in synthetic turf technology have improved shock absorption and traction properties, making modern artificial surfaces more comparable to natural grass. [7]

In the present study, although both groups demonstrated improvements in performance outcomes, the artificial turf group showed slightly greater gains in agility and hop performance. This may be attributed to the consistent traction and surface firmness of artificial turf, which may allow athletes to generate force more effectively during rapid directional movements. However, it is important to note that natural grass surfaces may provide better shock absorption and reduce joint loading during repetitive activities. These characteristics may influence long-term injury risk and should be considered when designing training programs.

Overall, the findings of the present study suggest that agility training programs are effective in improving athletic performance in football players regardless of the training surface. However, the mechanical characteristics of artificial turf surfaces may provide a slight advantage for agility-based performance tasks. At the same time, both natural grass and artificial turf training environments appear capable of supporting improvements in strength, neuromuscular control, and functional performance when appropriate training protocols are implemented.

LIMITATIONS: -

The present study has certain limitations that should be considered when interpreting the findings. First, the study was conducted in a limited geographic region, which may restrict the generalizability of the results to football players from different training environments or competitive levels. Second, the duration of the training intervention was relatively short, and long-term follow-up assessments were not conducted. Therefore, it remains unclear whether the observed improvements in performance and biomechanical indicators would be maintained over an extended period. Additionally, external factors such as variations in footwear, individual training intensity, and environmental conditions may have influenced performance outcomes during the study.

STRENGTHS: -

A key strength of the present study is the evaluation of both performance-related variables and injury-related biomechanical indicators in football players. The inclusion of agility tests, functional performance measures, and indicators such as the hamstring-to-quadriceps ratio and knee valgus angle provides a comprehensive assessment of athletic performance and injury risk factors. Furthermore, the comparison of two commonly used training surfaces enhances the practical relevance of the findings for coaches, physiotherapists, and sports scientists involved in football training and injury prevention.

FUTURE RECOMMENDATIONS: -

Future research should examine the long-term effects of surface-specific training on athletic performance and injury incidence in football players. Studies involving larger and more diverse populations, including female athletes and professional players, would provide a broader understanding of the impact of different training surfaces. Additionally, future investigations could explore the combination of surface-specific training with targeted neuromuscular injury prevention programs to determine optimal strategies for improving performance while minimizing injury risk.

CONCLUSION: -

The present study demonstrated that surface-specific agility training resulted in significant improvements in agility performance, lower limb power, and neuromuscular control among football players. Both natural grass and artificial turf training environments were effective in enhancing performance outcomes. However, players training on artificial turf showed slightly greater improvements in agility and hop performance, possibly due to the consistent traction and mechanical properties of the surface. These findings suggest that agility training programs can be effectively implemented on different playing surfaces, although surface characteristics may influence specific performance outcomes. Understanding these differences may help coaches and rehabilitation professionals design more effective training and injury prevention programs for football players.

DISCLOSURES:

Human subjects: Consent for treatment and open access publication was obtained or waived by all participants in this study. Institutional Ethics Committee Krishna Vishwa Vidyapeeth issued approval KVV/IEC/09/2023. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest**: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships**: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships**: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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