ORIGINAL ARTICLE

Decoding the influence of field surface, tactical positioning, and field zone on tactical networks in youth football

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ABSTRACT

This study investigates the impact of different field surfaces on passing networks and tactical performance of youth football teams. Using observational analysis, tactical positioning data were collected, and passing networks were constructed. The results suggest differences in network metrics based on the surface type: average shortest path length $F(2.052) = 6.099$; $p < .006$, $\eta^2 = 0.289$; betweenness centrality $F(2.001) = 7.294$; $p < .003$, $\eta^2 = 0.327$; closeness centrality $F(2.025) = 5.207$; $p < .011$, $\eta^2 = 0.258$; clustering coefficient $F(2.032) = 23.679$; $p < .001$, $\eta^2 = 0.612$; and radiality $F(2.001) = 6.099$; $p < .006$, $\eta^2 = 0.289$. Closeness centrality varied significantly between tactical positions $F(10.009) = 1.918$, $p < .05$, $\eta^2 = 0.466$. Passing relationships based on field zones also showed significant differences: average shortest path length $F(23.193) = 6.057$; $p < .001$, $\eta^2 = 0.744$; betweenness centrality $F(23.002) = 5.103$; $p < .001$, $\eta^2 = 0.710$; closeness centrality $F(23.015) = 6.835$; $p < .001$, $\eta^2 = 0.766$; degree $F(23.592) = 5.298$; $p < .001$, $\eta^2 = 0.717$; radiality $F(23.001) = 8.366$; $p < .001$, $\eta^2 = .800$; and stress $F(23.773) = 5.302$; $p < .001$, $\eta^2 = 0.718$. This study provides valuable insights for coaches and analysts on optimizing youth soccer performance, highlighting the importance of considering field surface in tactical planning and training strategies.

Keywords: Performance analysis, Youth football, Passing networks, Field surfaces, Tactical performance, Network metrics.

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INTRODUCTION

In recent years, the analysis of passing networks has emerged as an innovative and effective approach to understanding the dynamics of football. These networks provide a visual and quantitative representation of player interactions, offering valuable insights into team organization and game strategy (Alves et al., 2022; Clemente et al., 2015; Pina et al., 2017; Gonçalves et al., 2017). The application of network analysis techniques in team sports, particularly football, has gained prominence in the scientific literature, standing out as a crucial tool for coaches, analysts, and researchers. Various network metrics can be used to provide a comprehensive view of the structure and functionality of passing networks, offering a detailed and informative analysis (Assunção et al., 2022; Clemente et al., 2020; Mendes et al., 2028; Sarmento et al., 2014). However, the type of field surface on which games are played can significantly influence these dynamics.

For example, Bartlett et al. (2012) examined the use of network analysis in the study of the collective behaviour of football teams, demonstrating how these techniques can identify tactical and movement patterns. Passos et al. (2011) used network analysis to explore the dynamics of interaction between players in elite games, demonstrating the relevance of these techniques for understanding cooperation and coordination on the field.

Furthermore, Clemente et al. (2015) investigated the application of network analysis to assess team centrality and cohesion, emphasizing the importance of these metrics in evaluating collective performance. The study by Peña and Touchette (2012) reinforced the utility of passing networks for understanding the fluidity and efficiency of offensive transitions in football, providing insights into the tactical organization of teams.

More recently, the work of Ribeiro et al. (2020) highlighted how network analysis can be used to identify key players and evaluate the tactical structure of teams in different competitive contexts, demonstrating the evolution and sophistication of these techniques in performance analysis in football.

It is expected that the type of playing surface can significantly influence these dynamics. The influence of the type of field surface on the performance of players and teams has been the subject of numerous studies over the years, revealing significant variations in game characteristics according to the surface. According to Vaeyens et al. (2008) the type of field can affect not only the physical performance of players but also the strategy adopted by teams.

Artificial turf, natural grass, and clay football field have distinct characteristics that can alter ball speed, traction, and the physical wear on athletes. Artificial turf, a more uniform surface developed to simulate the conditions of natural grass, has particularities that, according to Andersson et al. (2008), can lead to a higher risk of injuries due to increased resistance and traction. Additionally, artificial turf tends to be faster, influencing the dynamics of the game and how passes are executed. On the other hand, natural grass fields are widely preferred by players and coaches due to their softness and lower impact on athletes' joints. According to Ekstrand et al. (2011), natural grass offers a more traditional game with a lower risk of serious injuries, although it requires more maintenance, leading to variations in surface quality throughout the season. Regarding clay football fields, although less common in high-level competitions, they are still used in various regions and contexts. This type of surface is harder and more irregular, which can affect the accuracy of passes and ball control, consequently impacting the game's fluidity. According to Brito et al. (2017), clay football field influence running activity and players' technical actions. Additionally, Mendiguchia and Buchheit (2016) suggest that nature of the playing surface can significantly influence the athletes´ risk of injury, demonstrating that uneven field conditions or those with less traction can increase physical wear and tear and the likelihood of trauma, especially those related to falls and twists.

Consequently, given the scarcity of studies that have investigated the dynamics and efficiency of passing networks on different field surfaces, it becomes relevant to assess the effect of the field surface on the passing relationships established by players. The choice of field type has direct implications on team performance and the analysis of passing networks. Understanding the physical and mechanical characteristics of each type of surface is essential for adopting effective game strategies.

To analyse the structure and functionality of passing networks in football, we can use several network analysis metrics, each offering specific insights into the dynamics and efficiency of the network. The degree metric is used to identify important nodes (hubs) in the network, while Closeness Centrality measures how close a node is to all other nodes in the network, highlighting strategic nodes in the spread of the ball. Betweenness Centrality evaluates how often a node appears on the shortest paths between other nodes, identifying crucial players in the mediation and transition of the game. The Clustering Coefficient analyses the formation of clusters or communities within the network, reflecting tactical and organizational cohesion. Average Shortest Path Length evaluates the overall efficiency of the network by measuring the average distance of the shortest paths between all pairs of nodes, indicating faster and more efficient ball transfer. Additionally, Stress measures a node's load, providing additional insights into the player's importance and influence in the network, while Radiality analyses a node's position relative to the network periphery, offering insight into efficiency.

Therefore, the objective of this study is to investigate how different field surfaces (artificial grass, natural grass and clay football field) influence the structure and functionality of passing networks in football. Specifically, the study aims to: (i) Evaluate how the centrality of players in the passing networks varies depending on the field surface, the tactical positioning of the players and the zone field, using metrics such as Degree, Closeness Centrality and Betweenness Centrality; (ii) Measure the tactical cohesion of teams on different field surfaces through the Clustering Coefficient and the Average Shortest Path Length; (iii) Determine the efficiency of pass networks in terms of speed and accuracy, considering the Stress and Radiality variables; (iv) and Identify and compare movement patterns and strategies adopted by teams on different field surfaces, observing differences in game dynamics and passing execution.

With this study, it is expected to provide an in-depth understanding of the implications of different field surfaces in football, contributing to the optimization of game strategies and improved team performance.

METHODS

Participants

Sixty male (under-14) football players (age: 13.4 ± 0.5; height: 161.82 ± 7.52; weight: 50.79 ± 7.22) with the same competitive level (playing and training 3.5 ± 1.4 years). All players and their guardians were informed about the research procedures, requirements, benefits and risks, and, in writing, consented to participate. The study protocol followed the guidelines established in the Declaration of Helsinki and was approved by the local Ethics Committee.

Experimental design

During three weeks, always on Sunday, the games were performed in the following conditions: week (1): 3 games on artificial turf; week (2): 3 games on natural grass; week (3): 3 games on clay football field. The

teams and players who participated in the study were always the same and all football matches were played using 1-4-3-3 tactical structure, the most frequent in Portuguese youth teams (Rebelo et al., 2014). The players were classified according to their tactical position: 1 = goalkeeper (GK); 2 = right back (RB); 3 = right centre back (RCB); 4 = left centre back (LCB); 5 = left back (LB); 6 = central defensive midfielder (CDM); 7 = right centre midfielder (RCM); 8 = left centre midfielder (LCM); 9 = sticker (ST); 10 = right winger (RW); 11 = left winger (LW). The matches were played according to football rules, except match duration (30min, without breaks) and players' substitution (not allowed). The pitch size was adjusted to standardize the measure for all conditions (length: 100 m, width: 64 m). All matches were proceeded by a planned, standardised warm up of 15 min comprising running activities, small-sided games and stretching. Following this period, the players simulated a match during two periods of 2 min, interspersed by 1 min of passive recovery. All games were played between 9 and 11 a.m., with purpose of controlling the effects of circadian variations (Dellal et al., 2012).
The distribution of corridors and sectors can be visualized through the field diagram in Figure 1.

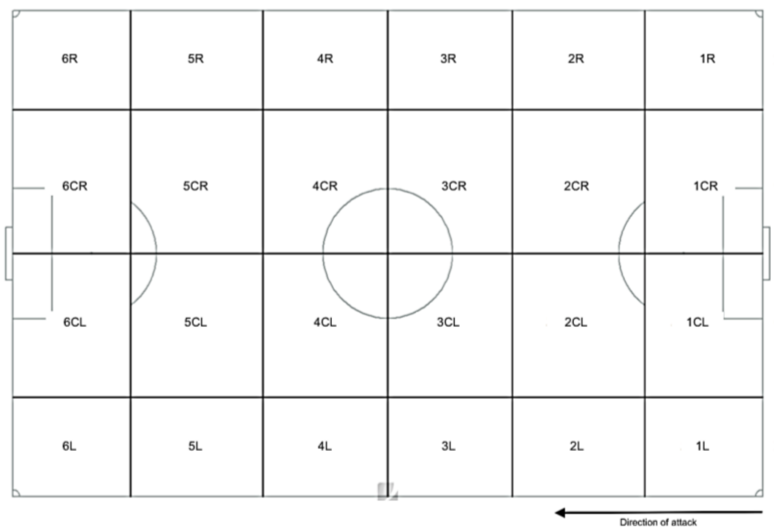


Figure 1. Field diagram (adapted from Amisco).

Data collection

The data were collected from football matches played on different field surfaces: artificial turf, natural grass, and clay football field. Each match was analysed to extract passing network metrics such as Degree, Closeness Centrality, Betweenness Centrality, Clustering Coefficient, Average Shortest Path Length, Radiality, and Stress.
The matches were recorded with a digital camera (Sony Handycam DCR-SR210) used to capture the passing actions performed by the players, as well as the zone field where they took place. The camera was mounted on a tripod (Sony VCT-R6400) positioned at the centre of the fields, with an elevation of 6 and 20 meters from the field. The footage was transferred to a computer via USB and analysed with Windows Media Player (Microsoft Corporation, USA). All data were recorded in Microsoft Office Excel (Microsoft Corporation, USA) and subsequently exported to SPSS Statistics, version 32.0 (SPSS Inc., Chicago, USA), as well as to Cytoscape software (3.10.2).

Data analysis

A successful network connection was considered whenever the ball was passed from one player to another on the same team, reaching the intended player accurately and in control, without interference from the opponent, contributing to the continuity of the play and strategic advancement on the field. The following steps were followed: (i) the data were imported and reviewed to ensure consistency and accuracy; (ii) network metrics were calculated using specific formulas as described in the literature (Duch & Amaral, 2010; Yamamoto & Yokoyama, 2011; Passos et al., 2011; Clemente et al., 2016; Gonçalves et al., 2017).

The inter-observer agreement level for identifying passing relationships was (Kappa = 0.84). Reliability was assessed by the authors coding three randomly selected matches, with the data being compared among themselves.

Statistical analysis

The results are presented as means ± standard deviations (SD). The normality of the data was assessed using the Kolmogorov-Smirnov test, along with skewness and kurtosis coefficients, and through visual inspection of box plots, normal quantile-quantile (QQ) plots, and histograms. The dependent variables, including playing surfaces, players' tactical positions, and field zones, were analysed using a two-factor repeated measures analysis of variance (ANOVA).

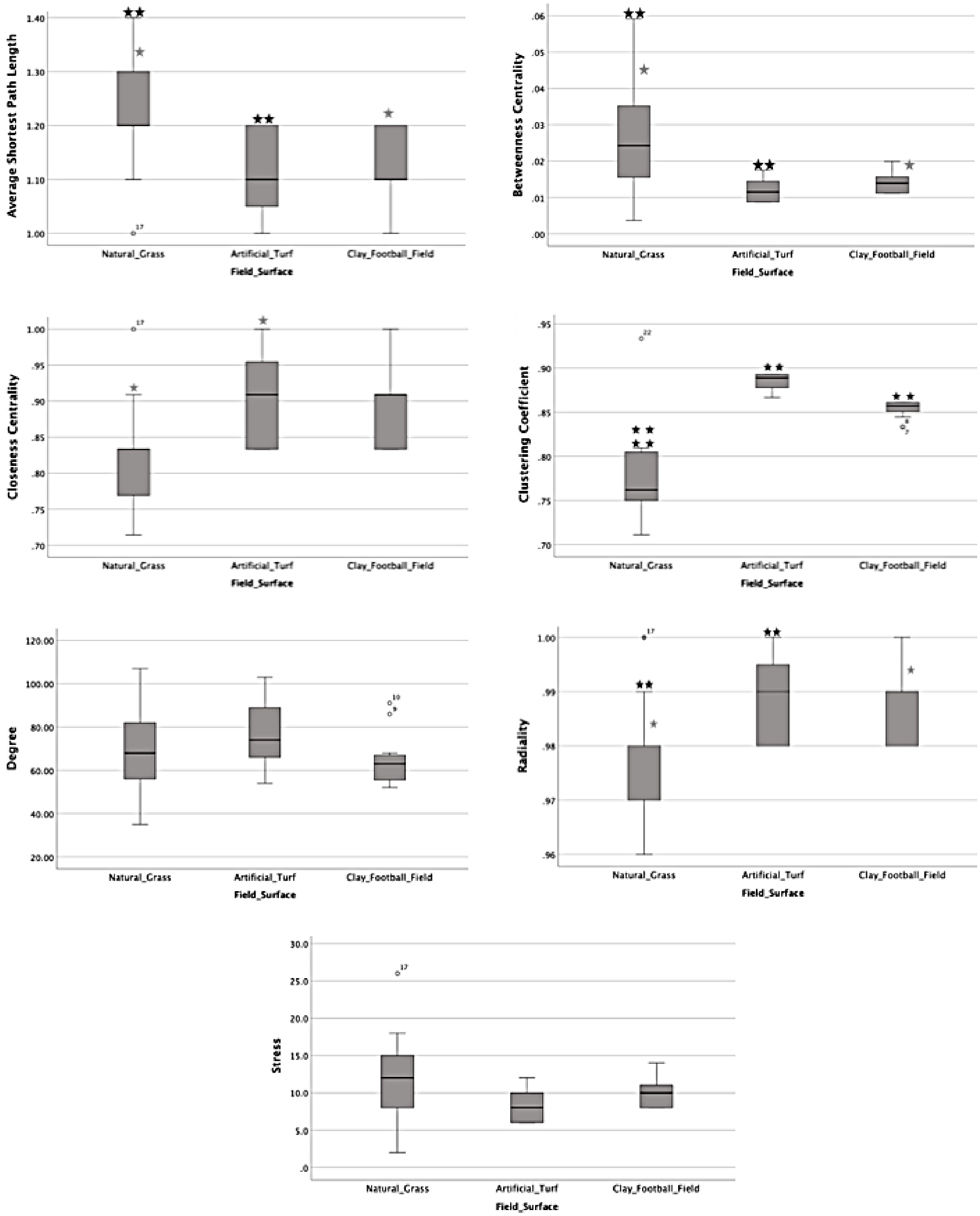
Effect sizes were reported as partial eta squared (η^2) obtained from the ANOVAs, following Cohen's guidelines (Cohen, 2013): (i) $0.01 \leq \eta^2 < 0.06$ – small effect; (ii) $0.06 \leq \eta^2 < 0.14$ – moderate effect; and (iii) $\eta^2 \geq 0.14$ – large effect. Significant main effects of each factor were followed up with Bonferroni-corrected post hoc multiple comparisons tests. All statistical analyses were conducted using SPSS Statistical Analysis software (SPSS Inc., Chicago, USA) version 32.0 for Windows. Significance was defined as $p \leq .05$, consistent with conventional thresholds for statistical significance.

RESULTS

The results are presented in terms of network metrics calculated for each field surface type. Figure 2 shows the main differences found in passing relationships established by players according to the field surface: (i) average shortest path length $F(2,052) = 6.099$; $p < .006$, $\eta^2 = 0.289$; (ii) betweenness centrality $F(2,001) = 7.294$; $p < .003$, $\eta^2 = 0.327$; (iii) closeness centrality $F(2,025) = 5.207$; $p < .011$, $\eta^2 = 0.258$; (iv) clustering coefficient $F(2,032) = 23.679$; $p < .001$, $\eta^2 = 0.612$; and (v) radiality $F(2,001) = 6.099$; $p < .006$, $\eta^2 = 0.289$.

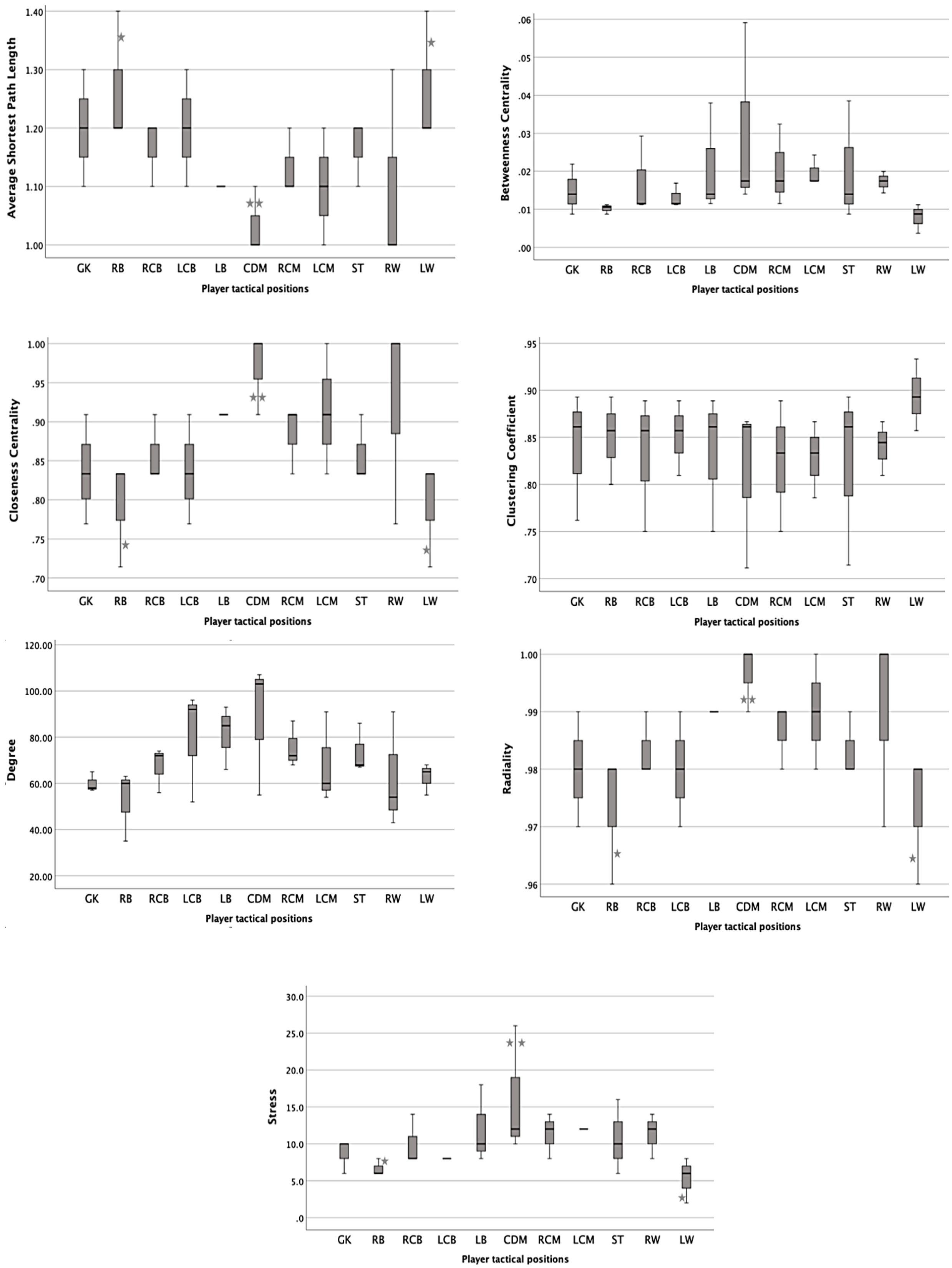
The results showed that artificial turf tends to exhibit higher values of Closeness Centrality and Radiality, reflecting greater fluidity in ball distribution. Natural grass presents a balance in the metrics, with moderate values in Degree, Closeness Centrality, and Clustering Coefficient, suggesting a more balanced tactical cohesion. Clay football fields show higher values of Stress and Betweenness Centrality, indicating a greater load on players in terms of transition and ball control. Figure 3 shows the main differences found in network metrics related to players' tactical positioning.

Closeness centrality varied significantly across tactical positions, $F(10.009) = 1.918$, $p < .05$, $\eta^2 = 0.466$. On artificial turf, attackers exhibited higher closeness centrality, reflecting a more effective penetration ability. In contrast, on clay football field, midfielders showed the highest closeness centrality, suggesting a need for more constant support during transitions. The analysis of passing networks (Figure 4) reveals that natural grass surfaces reflect a high density of connections, with many links between players, suggesting a playing style based on short and frequent passes, facilitating a fluid and dynamic game. Concomitantly, centrality on natural grass presents a strong central core, namely the connections of central midfielders and defenders, suggesting that they are key players in maintaining possession and distributing the ball.



*Note. Significant difference between conditions; *(p < .05) and **(p < .001).*

Figure 2. Metrics relating to passing relationships established by players depending on the pitch surface(mean ± SD).



*Note. Significant difference between conditions; *(p < .05) and **(p < .001).*

Figure 3. Metrics related to the tactical positioning of players (mean ± SD).

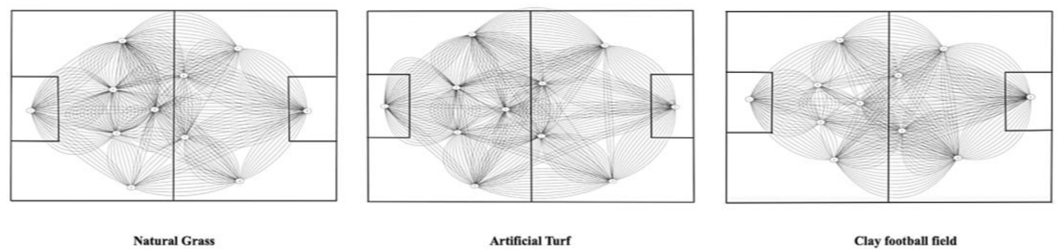
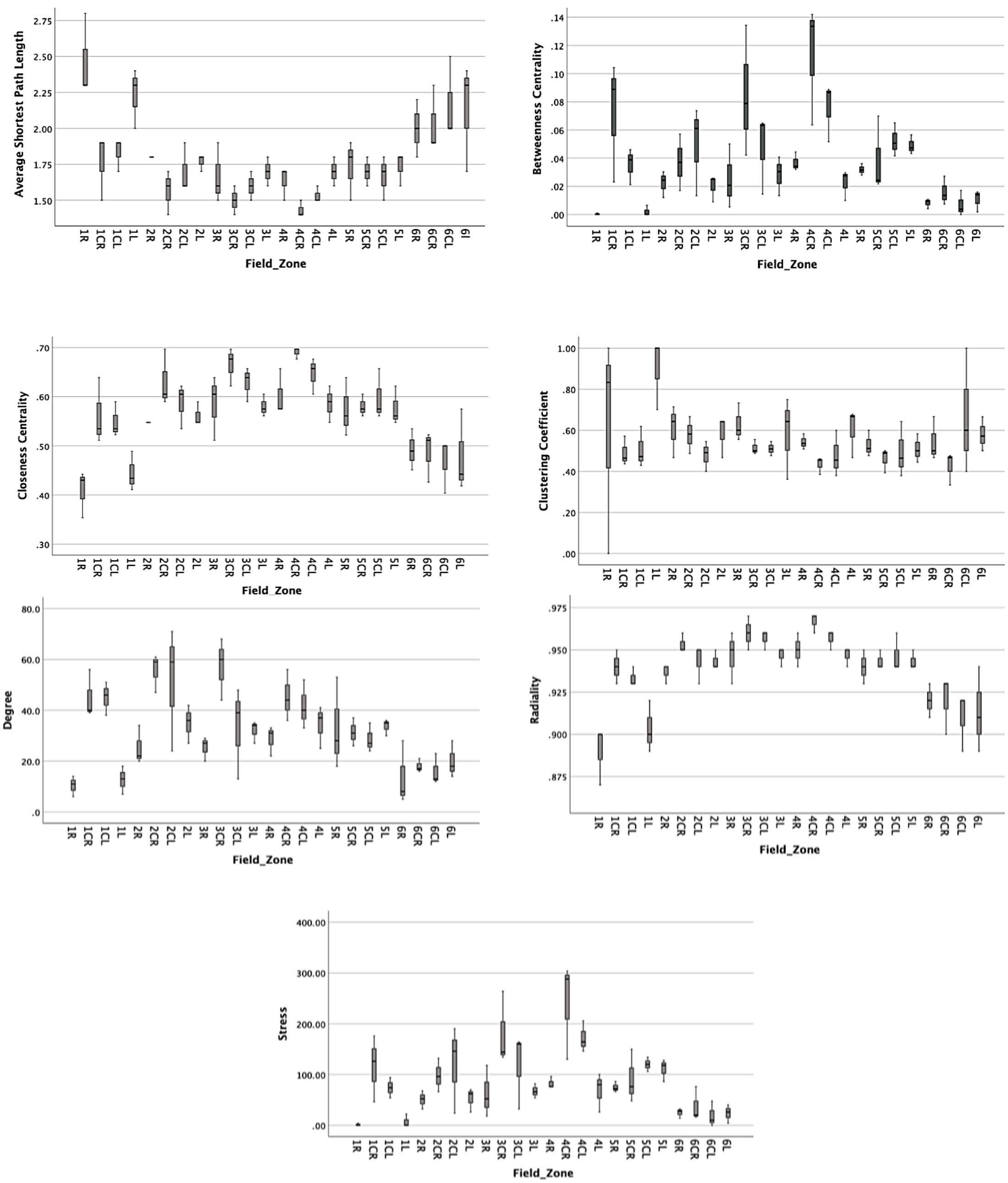


Figure 4. Passing networks established by players on different pitch surfaces.



*Notes. Significant difference between conditions; *(p < .05) and **(p < .001).*

Figure 5. Metrics relating to passing relationships established by players depending on the area of the pitch (mean ± SD).

Finally, on clay football field the density of connections shows a more dispersed arrangement in the midfield, suggesting that adapting to the surface may hinder quicker and more accurate passes. The centrality analysis reveals that players seem to have a more equitable involvement in the passing network with less reliance on specific players, suggesting that this surface is less predictable.

Figure 5 provides insights into how passing relationships vary across different zones of the field. Specifically, significant differences were found in: (i) average shortest path length $F(23.193) = 6.057$; $p < .001$, $\eta^2 = 0.744$; (ii) betweenness centrality $F(23.002) = 5.103$; $p < .001$, $\eta^2 = 0.710$; (iii) closeness centrality $F(23.015) = 6.835$; $p < .001$, $\eta^2 = 0.766$; (iv) degree $F(23.592) = 5.298$; $p < .001$, $\eta^2 = 0.717$; (v) radiality $F(23.001) = 8.366$; $p < .001$, $\eta^2 = 0.800$; and (vi) stress $F(23.073) = 5.302$; $p < .001$, $\eta^2 = 0.718$.

Figure 6 shows that the density and complexity of lines vary, suggesting different movement patterns depending on the surface type. Natural grass shows more concentrated movement in the centre.

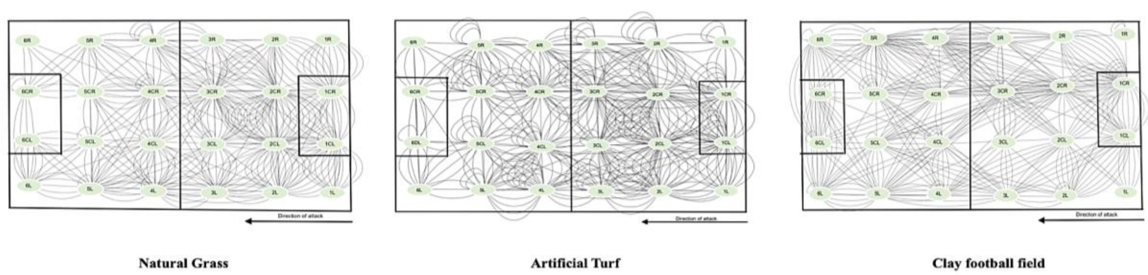


Figure 6. Passing networks established by players in different areas and surfaces of the field.

On the other hand, artificial turf shows a high density of lines across the entire field, suggesting a more balanced distribution across all zones of the field. Regarding the clay football field, although it concentrates the main activity in the central area of the field, it also shows a tendency for longer connections between different zones, suggesting a more direct style of play.

DISCUSSION

This study aimed to investigate how different playing surfaces (artificial turf, natural grass, and clay football field) influence the structure and functionality of passing networks in football. Specifically, the study intended to: (i) Assess how player centrality in passing networks varies according to the playing surface, the tactical positioning of players, and the zone of the field; (ii) Measure the tactical cohesion of teams on different playing surfaces; (iii) Determine the efficiency of passing networks in terms of speed and accuracy; and (iv) Identify and compare the movement patterns and strategies adopted by teams on different playing surfaces, observing differences in game dynamics and passing execution. The study results provide a detailed overview of the game dynamics in youth football on different playing surfaces, using passing network analysis. This discussion will analyse the findings based on the calculated metrics, player tactical positions, and zones of the field, relating them to the existing literature.

Network metrics by surface type

The analysis of network metrics revealed significant variations among natural grass, artificial turf, and clay football field. On natural grass surfaces, we observed a higher Clustering Coefficient and greater Betweenness Centrality, indicating greater cohesion and collaboration among players. This result suggests that natural grass, due to its more uniform surface, allows for a more integrated and collaborative game, facilitating frequent interactions between players. The literature supports this observation, as highlighted by Andersson et al. (2008), who found greater fluidity and efficiency in plays on natural grass due to the predictability of the surface.

On artificial turf surfaces, metrics indicated a faster and more direct style of play, with a slight increase in Closeness Centrality. This suggests that players tend to adopt a playing style that takes advantage of the lower rolling resistance of the ball, enabling rapid transitions. This characteristic is corroborated by studies such as Impellizeri et al. (2009), who observed an increase in the speed of play on artificial surfaces.

Conversely, clay football fields exhibited lower network efficiency, with a lower Clustering Coefficient and a less centralized ball distribution. This surface suggests significant challenges for maintaining a fluid style of play, reflecting the findings of Mendiguchia and Buchheit (2016), who pointed to difficulties in controlling and accurately passing the ball on irregular terrain.

Metrics related to the tactical positioning of players

Results also indicated tactical differences associated with each surface type. On natural grass, players exhibited greater positional balance, allowing for a uniform distribution of interactions and mutual support, favouring a more structured tactical strategy. This balanced positioning can maximize attacking and defensive opportunities, as discussed by Fernandez-Navarro et al. (2018), who highlight the importance of a cohesive team structure for tactical success.

On artificial turf surfaces, the analysis suggests an increase in transition and counter-attack plays, with players occupying more advanced and aggressive positions. This behaviour may be a response to the surface's ability to support rapid movements, as observed by Di Salvo et al. (2007), who suggest that artificial surfaces encourage a more direct style of play.

On the other hand, clay football field reflected a more defensive and compact positioning, possibly as an adaptation to the difficulty of executing accurate passes. This finding highlights the need to adjust tactical strategies to mitigate the challenges presented by the surface, aligning with the observations of Goto and Okano (2020) who discuss tactical adaptation as a necessary response to adverse playing conditions.

Metrics according to the zone of the field

The analysis of field zones revealed that natural grass facilitated a more balanced and effective use of all zones, with players exhibiting fluid movement between defensive, midfield, and attacking zones. This flexibility is critical for maintaining control of the game and creating scoring opportunities, as discussed by Clemente and Serrani (2016), who highlight the importance of the ability to transition between zones in football.

In contrast, the artificial turf surface demonstrated a greater focus on attacking zones, reflecting an offensive-oriented strategy. This emphasis on advanced zones is consistent with the research of Modric et al. (2023), who associate artificial turf with an increase in attacking opportunities due to the faster pace of the game.

Finally, the clay football field reflected a higher concentration of play in the defensive and midfield zones, suggesting a more cautious approach to defensive positioning. On the other hand, a more aggressive approach to offensive positioning seems visible, probably with the purpose of pressing higher to take advantage of the unevenness of the ground and provoke errors in the opponent, recovering the ball in high areas of the field and quickly approaching the goal in favourable conditions. This is in line with the theory that irregular surfaces limit the effectiveness of game indicators (Andersson et al., 2008).

CONCLUSIONS

This study concludes that the playing surface has a significant impact on the dynamics of the game and the tactical effectiveness of youth soccer teams. Natural grass surfaces provide better conditions for tactical cohesion and passing accuracy, allowing for a more collaborative and structured game. In contrast, clay football field presents substantial challenges for maintaining a fluid playing strategy, resulting in a more defensive and cautious approach. Artificial turf encourages a faster and more direct game, favouring attacking strategies. These findings underscore the importance of adjusting tactical and training strategies according to the field conditions to maximize performance. The study also highlights the value of pass network analysis as a powerful tool for understanding team dynamics and the impact of playing surfaces. Future studies should investigate adaptive training interventions and explore the longitudinal effect of surfaces on the skill development of young players. In summary, understanding the influences of playing surfaces can inform strategic decisions and optimize performance in youth soccer.

Limitations and future research

As limitations of this study include its restriction to a specific age group and the lack of control over external variables such as weather conditions. Future research could explore more diverse samples and consider the use of advanced technology to capture more precise data on the impact of playing surfaces on the game. New investigations could also explore specific training interventions to help players better adapt to the challenging conditions of surfaces like clay and longitudinally analyse how different surfaces affect skill development over time.

AUTHOR CONTRIBUTIONS

Ângelo Brito: Responsible for the conceptualization, study design, data analysis, interpretation of results, and manuscript drafting. Luís Freitas: Contributed to data collection and preprocessing.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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