Surface traction properties affect agility performance and perception in female soccer players

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Agility | **Performance** | **Perception** | **Player-Surface Interaction** | **Football** | **Soccer**

Headline

Variability among soccer fields arises from different surface types, such as natural grass and artificial turf, and variations within each type (1). Surface characteristics, influenced by factors like climate, maintenance and field usage, affect player-surface interactions and performance (2,3). Understanding these interactions is crucial for sport performance coaches to make informed training and match play decisions, improving game quality and reducing injury risk. This pilot study aims to assess performance and perception differences on three surfaces with distinct traction characteristics.

Aim

This pilot study aims to specifically determine the differences in total performance and locomotor intensity during a maximal agility test in female soccer players on three surfaces with different traction characteristics and assess their perceptions about their interaction with the surface.

Athletes

Seven young female soccer players (Mean ± SD: age: 20.6 ± 4.2 years, height: 167.4 ± 5.7 cm) from a Belgian first division club's development squad volunteered to participate in this experimental pilot study. All players were injury-free and in full team participation (6h training per week) for at least three months prior to data collection. Furthermore, all players indicated their right foot as their dominant one. There was a clear variety of profiles and preferred playing positions within the group of participants. Written consent was obtained from all participants or at least one parent/guardian prior to data collection.

Table 1. Demographic data participants

	Mean	SD	Min	Max
Age (years)	20.6	4.2	16.1	28.4
Height (cm)	167.4	5.7	163.0	177.0

Design

A randomized cross-over design was used for performing the agility tests on three surfaces, each with distinct differences in stud force or rotational traction. Surface, performance and perception data were all collected on a single day of testing.

Methodology

Three surfaces on the club's training grounds were used for the agility tests: a 4G artificial turf field with cork infill (field A), a natural grass field with dense grass coverage (field B), and a worn warm-up area with low grass coverage (field C). An experienced certified tester objectively measured each field using a rotational traction device (RTT - Raw Traction Tester V3, Raw Stadia Ltd., UK). The surface properties measured were *stud force* (bar) and *rotational traction*. Stud force is the pressure per stud needed for the outsole to fully penetrate the soil and engage with the surface, and rotational traction (Nm) is the peak torque under which a studded footplate shears through the surface in a circular motion. Translational traction (N) is the force required to linearly shear through the surface, but was not assessed to prevent surface damage, consistent with previous research (4). Data was collected on six locations per field to represent the overall traction properties to be assessed in line with the recommendations of the FIFA Quality Programmes for natural and artificial playing surfaces (5).

Players were randomly divided into three groups, each group starting on a different field. After having performed each stage the active groups transitioned to the next field until every subject performed the agility tests on each of the fields (Figure 2). Participants were familiarized with the agility test one week prior to data collection. At least 24 h prior to the test day, strenuous activity was avoided. Participants were allowed to select one pair of soccer boots for all surfaces. A standardized 10-minute warm-up was given by the team's head coach followed by a refamiliarization of the test on submaximal intensity.

The test protocol used was a modified agility T-test that consists of three phases (Figure 3). Phase 1: a 10m sprint from cone 1 to decelerate and cut behind cone 2 initiating a 5m sideway shuffle to cut and turn behind cone 3. Phase 2: a 10m sprint from cone 3 to perform another 90° cut at cone 4. Phase 3: a 5m shuffle facing cone 1 behind cone 2 and a 10m sprint to finish. Each phase included one peak acceleration (A), maximum speed (M), and peak deceleration (D). The third phase deceleration (D3) was excluded as subjects were not required to perform a maximal stop to ensure a maximal finish. Participants performed the test twice on each surface, one to each side.

Each participant was equipped with an advanced Electronic Performance and Tracking Systems (EPTS) with 10 Hz sampling to measure performance quality and intensity throughout the agility drill (Apex Pro, STATSports, Newry, Ireland). To ensure reliable data collection, the unit is firmly placed inside a vest on the upper back between the scapulae (6). The performed drill time was recorded by handheld stopwatch. EPTS-data were processed with STATSports' Sonra software (V.4.4.17, macOS), showing speed and kinematic load parameters (Figure 4) Participants completed a VAS-questionnaire on their perception of ’comfort’, ’overall fatigue’, ’peripheral fatigue in the legs’, and ’push-off’ quality after each surface test. Slips or errors resulted in a retake after a minimum of two-minute rest to avoid acute fatigue. A 30-second window was given for each trial, resulting in three-and-a-half-minute rest periods between trials with an additional minute when transitioning fields to ensure consistent recovery and avoid accumulating fatigue.

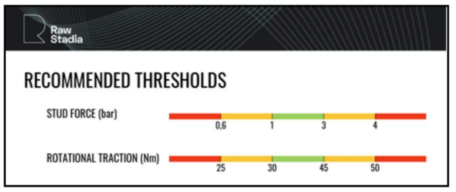

Fig. 1. Recommended thresholds with traffic light system provided by Raw Stadia Ltd

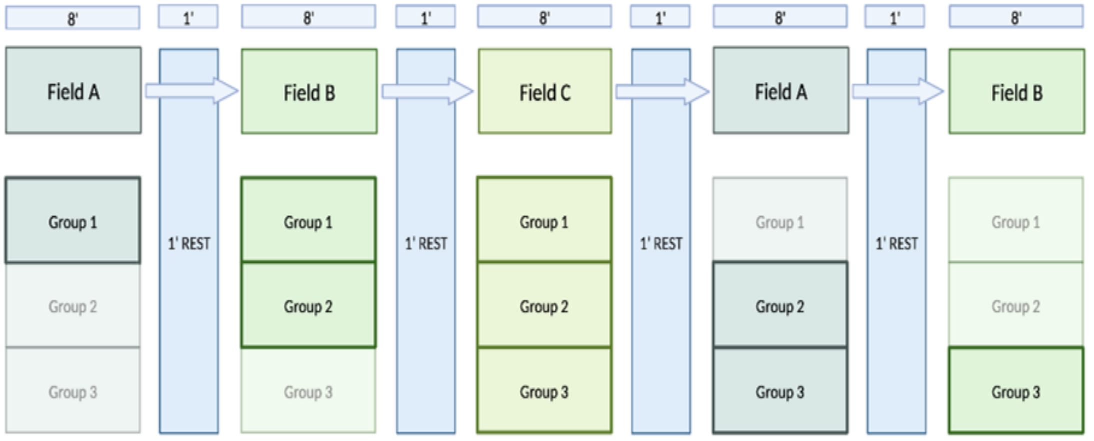

Fig. 2. Study cross-over design: The groups commence with their first tests on different fields and transition through

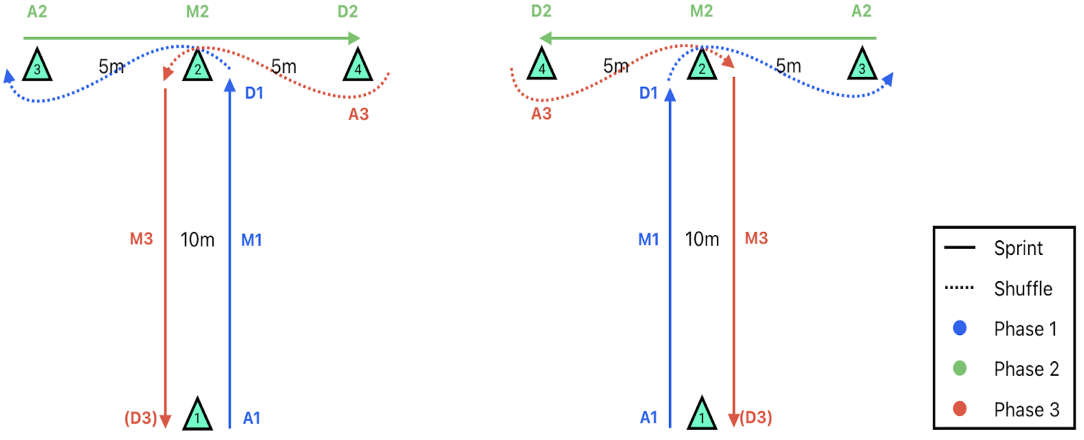

Fig. 3. Set-up of the modified agility T-test protocol: green triangles represent cones of 0.5m in height, full lines represent straight line sprinting, dashed lines represent sideways shuffling. A: accelerations, D: decelerations, M: maximum speed

Fig. 4. Example EPTS-output from the STATSports Sonra platform - Blue area: acute speed, Green boxes: accelerations (m/s^2) (A1, A2, A3), Yellow boxes: decelerations (m/s^2) (D1, D2, D3), Pink boxes: high metabolic load efforts peaking at maximal speed in each phase (m/s) (M1, M2, M3).

Statistical Analysis

All collected data was processed in Excel (v. 16.64) to then be imported in JASP (v. 0.16.2 (Intel)) to perform the statistical analyses. To present the subjects demographic data and the surface data, descriptive statistics were performed and reported as mean and standard deviation (Mean ± StD). Assumption checks on homogeneity (Levene's test) and sphericity (Mauchly's W) were performed on every data subset. A one-way repeated measures ANOVA was conducted to test for differences in ***performance*** (performed drill time and kinematic load parameters), and ***perception*** on player-surface interaction. If a within-subjects main effect was present ($p < 0.05$), a Bonferroni post-hoc pairwise comparison was conducted to compare fields individually. Cohen's d was calculated to determine the surface's effect size. Effect sizes are classified as negligible (<0.2); small (0.2-0.5); medium (0.5-0.8); large (0.8-1.2); very large (0.8-1.2) and huge (>2.0).

Results

The three surfaces differed in at least one measured traction property: stud force and rotational traction. Field B showed significantly higher stud force ($p < 0.001$), while field C showed the lowest rotational traction ($p < 0.001$).

For performed drill time, an overall within-subject main effect was found for surface ($p < 0.05$) with a significant difference between field A and field C ($p < 0.05$). On average, players performed best on field A (10.68 s ± 0.33 s) and worst on field C (10.89 s ± 0.53 s), showing a large effect size (ES = -1.0). Kinematic load parameters revealed multiple within-subject differences between fields. Acceleration phases showed significant differences, with both accelerations A1 (+0.29 m/s^2) and A2 (+0.28 m/s^2) higher for field A (respectively, ES = 1.05, 0.96) compared to field B ($p < 0.05$) (Figure 5A, 5B). Deceleration analysis showed an overall within-subject main effect for surface ($p < 0.05$), with significantly higher magnitudes on field A than field C (+0.21 m/s^2) for D2 (ES = 0.53, $p < 0.05$) (Figure 5C). Maximum speed showed an overall within-subject main effect in the second phase ($p < 0.01$). Post-hoc analysis revealed a large effect, with significantly higher M2 on field A (18.9 ± 1.0 km/h) than both field B (+0.49 km/h, ES = 1.23, $p < 0.01$), and field C (+0.38 km/h, ES = 0.95, $p < 0.05$).

Table 2. Surface traction properties: *$p < 0.001$

	Stud Force (bar)		Rotational Traction (Nm)	
	Mean	SD	Mean	SD
Field A	1.8	0.5	33.8	2.2
Field B	5.9*	1.1	36.4	2.3
Field C	2.6	1.0	24.0*	4.4

Perception results, averaged into a 'total score,' showed a significant main effect for surface ($p < 0.01$). Bonferroni post-hoc tests revealed large effect sizes, with field A (63.8% ± 8.9%) was perceived as better than fields B (49.2% ± 6.6%) and C (40.9% ±11.1%). The VAS-questionnaire component '*comfort*' was significantly different between all three fields ($p < 0.01$) with field A (7.36 ± 1.32) scoring best, followed by field B (5.1 ± 1.2) and field C (2.14 ± 1.48). Perception scores for '*push-off*' quality showed a large surface effect, with field A (7.0 ± 2.5) significantly higher than fields B and C (4.1 ± 0.4 and 2.0 ± 1.7, respectively). VAS-scores for both '*overall fatigue*' and '*fatigue in the legs*' showed no significant differences.

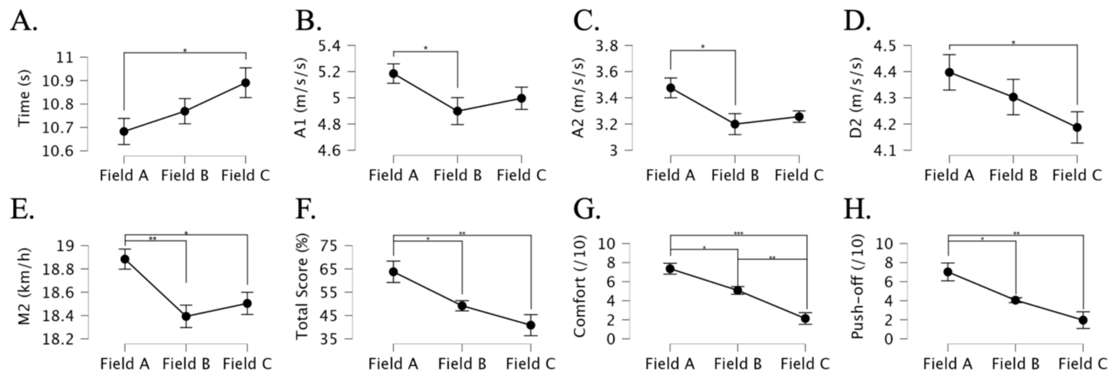

Fig. 5. Total time, kinematic load parameters and perception per playing surface (means with SE): (A) Mean performed drill time (s), (B) A1: peak acceleration phase 1, (C) A2: peak acceleration phase 2, (D) D2: peak deceleration phase 2, (E) M2: maximum speed phase 2, (F) Total score (%), (G) Push-off (score/10), (H) Comfort (score/10). *p $<$ 0.05, **p $<$ 0.01, ***p$<$0.001.

Discussion

This study aimed to examine differences in agility performance and players' perceptions on three different surfaces. The key finding was that performance and perception were best on a surface with recommended stud force and traction levels. Field C however, characterized by its low traction properties, scored the worst on most perception and performance parameters. While fields A and B had similar rotational traction, field B's higher stud force indicated difficulty in penetrating the surface with studs, making it harder for players to fully engage the outsole and utilize available traction effectively (7). Even though the surface would provide adequate traction at full stud penetration, it became more slippery due to the thick and dense top layer. The research team also confirmed a higher amount of slipping occurred on foot contact with participants having to retake the test. Field C's surface testing showed lowest traction values which also indicate a risk of slipping by shearing through the surface. More players slipped on fields B and C due to exceeding available traction, which can be caused by incomplete outsole engagement or low shearing resistance. Players often compensate for poor traction levels by adopting a more upright posture, increasing the vertical force to facilitate penetration of studs into the surface and increase available traction. In doing so, players reduce the horizontal force needed for reacceleration (8,9,10). Kinematic load parameters reflected these expected higher magnitudes for accelerations and decelerations on field A on which less time was needed to execute the agility test compared to the other two surfaces. This finding is consistent with a study that found faster running times with high traction outsoles (11). Players perceived field A as having the best grip and overall comfort. Perception of overall and peripheral fatigue did not reveal differences between the fields, likely due to the short effort bouts and long recovery periods. As cognitive aspects are known to affect a player's decision making and performance (12) it is key for players to feel confident and able to optimally perform. The analysis and assessment of surface data aligned with performance and perception outcomes, suggesting that pre-session surface assessments could inform staff and players, improving decision-making and performance. This study confirms the link between subject-sensory data and performance outcomes, emphasizing the importance of surface conditions on player confidence and performance.

Practical Applications

This pilot study underscores the importance of measuring surface traction properties before sessions to anticipate differences in performance and perception during soccer-specific and agility-based activities. Additionally, the study emphasizes the need to measure stud penetration mechanics to assess surface stability at the shoe-surface interaction, which directly affects player performance and safety. Under unfavorable conditions, players can perceive differences in comfort and grip, hindering their ability to perform optimally. This highlights the necessity of pre-session surface assessments to ensure optimal playing conditions. Since players were not allowed to change footwear, which affects stud penetration and traction, coaches should consider footwear choices based on surface conditions. Coaches and players should assess surface conditions prior to sessions to optimize training, match, and rehabilitation strategies, and to select appropriate footwear, enhancing performance and reducing injury risks. By being informed about the state of the surface and its expected effect on player-surface interaction, they can make better decisions to maximize performance and minimize injuries.

Limitations

- A limited sample of female participants were recruited from a single second division team in Belgium, which may restrict the generalizability of the findings to players from different clubs, levels, or regions.
- The study focused on three specific playing surfaces, which may not capture the full range of playing conditions. Future research could explore more diverse surface types and properties.
- Despite using advanced EPTS-technology, errors may occur. Additionally, total drill times were measured by handheld stopwatch. Future studies would benefit from the latest on-field movement analysis tools for more detailed kinetics and kinematics.
- Participants were familiarized with the playing surfaces as the study was conducted at their own training ground. As perception is well-known to be influenced by knowledge or previous experiences, outcomes measures could be biased.

Conflicts of Interest

The authors were paid employees or consultants for Raw Stadia BV over the course of the study. Additionally, the corresponding author was active as teamcoach at the club where participants were recruited.

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