"TEARING UP THE TURF": HOW NATURAL GRASS RESPONDS TO REPEATED TRACTIONAL TRIALS FOR SOCCER BOOT ANALYSIS

Danyon Loud[1], Paul Grimshaw[1,2], Richard Kelso[1], William Robertson[1]

[1] School of Mechanical Engineering, The University of Adelaide, Australia
[2] College of Health and Life Sciences, Hamad Bin Khalifa University, Qatar

ABSTRACT: The shoe-surface interaction carries both performance and health-based implications for soccer players. As soccer is often played on natural grass surfaces, previous mechanical tests observing shoe-surface traction have examined the interaction on natural grass and reported averaged traction coefficient values. The aim for this study was to explore spatial changes within the playing surface, as well as examine if degradation over the testing period can alter these values. Through translational testing on a custom apparatus, this study showed that the average maximum traction coefficient on the same location of the playing surface was significantly lower than results reported at different locations (2.66 vs 3.05). The influence of the initial trial, however, was highlighted. Isolating and reporting this trial, as well the average result that excluded the first trial, presented traction data that accurately reflected the maximum traction of the playing surface as well as tractional changes over the entire trial.

KEYWORDS: soccer, traction analysis, ACL injury, natural grass.

INTRODUCTION: Natural grasses are often utilised as playing surfaces for a variety of sports. From youth rugby to elite level soccer, there is a wide variation among the quality and consistency of pitches based on the needs of their sport as well as financial investment into each pitch. The mechanical properties of these pitches can have a major impact in terms of player performance or injury risk due to surface composition (Griffith et al. 2022). The primary interaction between a player and the playing surface is through their boots, often equipped with studs to enhance traction and increase player performance (Sterzing et al. 2009). Traction occurs as rotational, translational, or a combination of both, and it is often defined by a traction coefficient (TC) relating a vertical force to a horizontal force (translational traction) or by a torque about an axis (rotational traction). Shoe-surface TC is also linked to lower limb injuries (Wannop et al. 2012). Zanetti et al. (2013) describe several methods for contextualising the traction coefficient (TC). In terms of injury risk, the maximum TC value should be observed as the point of highest loading (Zanetti et al. 2013). Lower limb injuries, particularly to the knee and ankle, are frequent amongst soccer players, with a majority occurring in non-contact situations.

A variety of surface types are utilised for all levels of soccer, with high-thatch forming grasses such as Perennial Rye, Kikuyu and Kentucky Bluegrass chosen for their impact absorption properties (Griffith et al. 2022). While high-thatch grasses provide protection from impact, they often incur a higher rate of non-contact, fixation-related injuries, as players' boots become caught in the build-up of stolons, and they are unable to free themselves when performing sharp movements (Orchard et al. 2005). While different grass varieties exhibit different mechanical properties, there are often within-field variations with pitches of the same grass species due to differences in growth, maintenance and wear of grass and thatch layers. Kent et al. (2015) suggest that the thatch layers act as an initial barrier for the movement of studs along the surface, providing higher levels of traction. At a high enough level of traction, however, the thatch layer tears under load, thus altering the mechanical properties of that area of the pitch. Due to the popularity of grass sports such as soccer, as well as the severity of lower limb injuries, the extent of this shoe-surface interaction has been well researched using mechanical tests with custom apparatus (Sterzing et al. 2009; Wannop et al. 2012).

When performing these mechanical tests, average results are often taken to minimise the impact of errors between samples. It is the average value that is then reported and compared despite the potential for the mechanical behaviour of the surface, specifically natural grass, to change between each trial. The aim for this study is to examine how the TC of a natural grass pitch changes over the testing period; and, assuming there is a change in mechanical properties, to report a method for accurate representation with minimal error

METHODS:

In line with other literature, a portable testing apparatus was constructed to observe the traction properties of the different playing surfaces (Kent et al. 2015). The device, Figure 1, consisted of an aluminium frame with two linear bearings attached to a sliding table. This sliding table was secured to a mounting platform via a four-bar linkage to ensure it remained level to the playing surface. A 3D printed, polylactic acid footform was fixed to the mounting platform and a Nike Tiempo Legend Elite soft ground boot was fitted to the footform. Once the apparatus was level, it was secured to the playing surface and added weights applied a normal force of 100N as this ensured full stud penetration. The sliding table was then pulled along the surface by a PA250D electric winch, at a constant rate of 4m/min to align with methods in literature (Wannop et al. 2012). Between the winch and sliding table, a SunScale STS 500kg load cell measured the tension force applied by the winch to calculate the TC. The signal from the load cell was read by a Measurement Computing USB1616FS data acquisition (DAQ) device. The testing apparatus was calibrated by calculating the dynamic TC of mild steel sliding on aluminium and determining a value of 0.46.

A natural grass surface consisted of a Kikuyu base with Ryegrass support with a moderate thatch layer. Data was recorded at 44 different locations in 15m square as shown in Figure 1. The playing surface is currently used by a soccer club competing in the top division in South Australia and undergoes regular maintenance by ground staff. The moisture content remained between 13 and 15 percent during the testing period.

The testing apparatus was used to translate the footform medially along the playing surface 10 times at the same location. Each test lasted 8 seconds recording at 250Hz. To observe the spatial differences in natural grass, the testing procedure was then repeated at 10 different locations on the playing surface 1 time to observe the initial characteristics of the playing surface on an untested location. This process was repeated for lateral, posterior, and anterior movements. A custom Matlab code was created to transform the electrical signal obtained from the DAQ to force data, through a moving average filter over three time intervals.

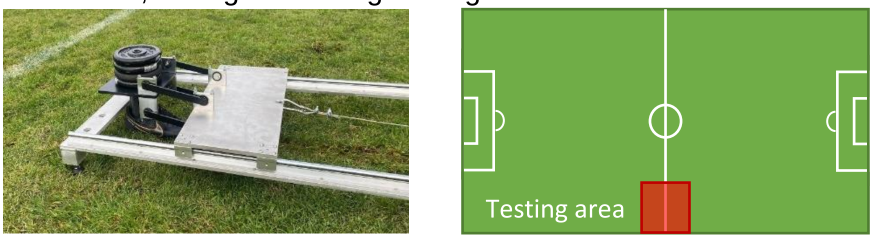

Figure 1: The testing apparatus used (left) and the testing area (highlighted) in relation to a soccer pitch (right).

RESULTS:

The results for each test were then calculated over the testing interval as shown in Figure 2. From Figure 2, it can be observed that the initial TC for the same location data (left) is larger than measured in the remaining 9 tests, all of which appear to have a closer fit to the mean value compared to test 1. The different-location trial (right), however, appears to follow no consistent trend, highlighting levels of variation amongst different locations within the same playing surface as suggested by Wannop et al. (2012). The maximum TC value for each test was compared for the medial movement on both testing scenarios on natural grass. The average value for the test maxima, and standard deviation are reported in Table 1.

	Averaged Maximum Traction Coefficient (Standard Deviation)			
	Surface Condition			
Movement Type	*Same Location (Trials 1-10)*	*Same Location (Trials 2-10)*	*Different Locations*	*Trial 1 (Same Location)*
Medial	2.66 (0.44)	2.01 (0.25)	3.05 (0.38)	3.03

Table 1: Comparison between the averaged maximum TC values on different surfaces.

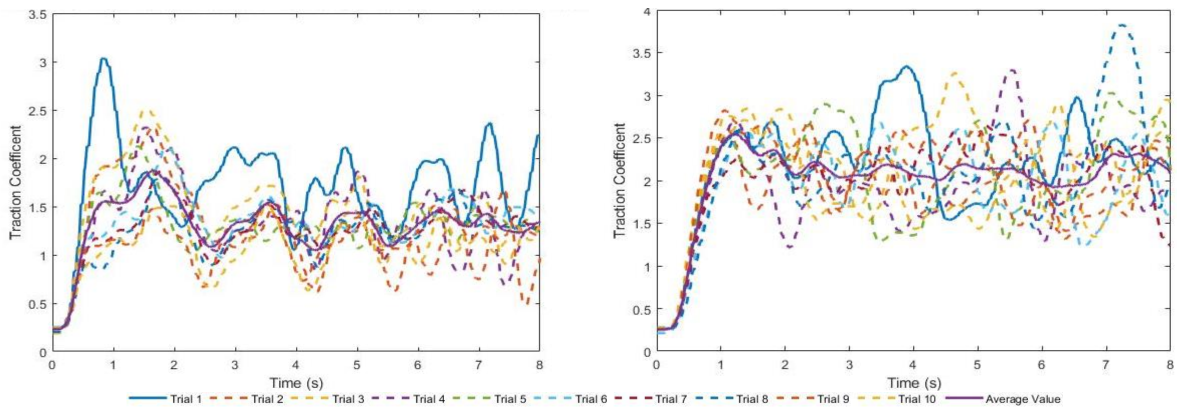

Figure 2: The traction coefficient of Soft Ground boots moving medially on natural grass in the same location (left) and different locations (right).

While Table 1 shows there is approximately a 20-25% variation of the maximum TC across the loading conditions, other temporal variations in the data were observed. The reliability of the TC profile over the entire trial duration to examine fatigue or localised wear points is important (Zanetti et al. 2013). To measure this profile, the average TC was recorded at 1 second intervals, as well as standard deviation and coefficient of variation, across the 10 tests for both testing parameters. While these times did not align with the maxima, a standardized approach was needed to investigate the data trends. These points were recorded on natural grass at the same location for all tests and then tests 2-10 as well as different locations (Table 2).

Table 2: Details of the TC for medial movement at different time intervals on different surfaces.

	Average Traction Coefficient			***Standard Deviation***			***Coefficient of Variation***		
Time (s)	*Same Location (1-10)*	*Same Location (2-10)*	*Different Locations*	*Same Location (1-10)*	*Same Location (2-10)*	*Different Locations*	*Same Location (1-10)*	*Same Location (2-10)*	*Different Locations*
1	1.55	1.42	2.40	0.52	0.33	0.25	0.34	0.23	0.10
2	1.66	1.69	2.19	0.33	0.33	0.38	0.20	0.20	0.17
3	1.33	1.24	2.05	0.31	0.15	0.33	0.23	0.12	0.16
4	1.16	1.17	2.07	0.20	0.20	0.58	0.17	0.17	0.28
5	1.43	1.41	2.14	0.25	0.25	0.44	0.18	0.18	0.21
6	1.33	1.26	1.97	0.28	0.20	0.38	0.21	0.16	0.19
7	1.38	1.32	2.24	0.32	0.26	0.59	0.23	0.19	0.26
8	1.35	1.25	2.08	0.34	0.13	0.47	0.25	0.10	0.22

An analysis of covariance (ANCOVA) was conducted in SPSS Statistics to observe the impact of location type. The data was slightly non-normal, failing the Levene's test of homogeneity with a significance of 0.036. The results from the ANCOVA, however, showed a significant difference ($p<0.001$) between the TC obtained with different location types with a partial eta squared value of 0.515, indicating a large effect that was consistent across movements.

DISCUSSION:

The shoe-surface interaction has significant performance and health-based implications for players; thus, an accurate and reliable testing mechanism is paramount to ensure consistent results. As observed in Figure 2, there is a large variation in the traction data on natural grass surfaces due to uneven wear and maintenance within the playing surface. Zanetti et al. (2013) highlights the importance of the maximum TC value, especially when examining injury risk, suggesting that a higher maximum TC value leads to an increased risk of foot fixation on the playing surface, leading to an increased likelihood of non-contact lower limb injury. Table 1, however, indicates that there are significant differences when reporting the maximum value of the TC for different testing parameters on the same playing surface. For all movement types, testing at different locations on the same playing surface yielded a higher average maximum TC value than testing on the same location repetitively. This suggests that, to observe the TC value most relevant to injury risk, tests must occur at different locations, or an alternative approach to reporting same location data is needed.

Figure 2, though, shows large variation over the trial duration for testing in different locations, and, if the overall profile of the data, is being analysed, as suggested by Zanetti et al. (2013), then this variation poses a problem. Table 2 loosely supports the variations seen in Figure 1 with the different location data having larger standard deviation values than the same location data, aside from the initial time stamp. The coefficient of variation, however, was inconclusive as there were minimal differences between the same location and the different location data.
Kent et al. (2015), however, suggests that the mechanical properties of a natural grass playing surface differ under load as thatch layers are torn, providing less resistance, and lowering the TC. This observation is seen across both Tables. Table 1 shows that the maximum TC value for test 1 of the same location data is significantly larger than the average result for tests 2-10 and closely resembles the data obtained over different locations. Table 2 demonstrates that removing test 1 yields a more consistent result across the entirety of the test with significantly lowered standard deviation and coefficient of variation (aside from the opening 2 seconds). This indicates the thatch layer is torn in test 1, significantly lowering the maximal TC of subsequent tests by creating a less resistive testing surface.
If logistical complications are also considered, then testing on different locations becomes impractical. In their study, Wannop et al. (2012) utilised 106 different pairs of boots, testing each boot 5 times for a total of 530 tests. If it is assumed that the testing apparatus requires 1 square metre to operate, and the playing surface has the dimensions of a typical soccer pitch (100m x 50m), then Wannop et al. (2012) would require an additional 30 square metres of playing surface to complete their study.
Spatial implications, coupled with variation in results over the entirety of the test, suggest that testing at different locations on the same pitch for each trial is not necessary. To report a variety of key TC values, that include the impact of playing surface disruption, the average maxima over the entire data set should be avoided. Instead, it is suggested that research reports the maximum TC from the initial test. Subsequent values, such as the average TC for the same location, can then be recorded from tests 2-10 to draw comparisons regarding fatigue.

CONCLUSION:

Natural grass playing surfaces are organic objects, and thus, have spatial variances throughout sports grounds. When examining the shoe-surface traction properties of these playing surfaces in terms of injury prevention, the traditional method of repeating tests and reporting the average result ultimately skews the data, displaying a lower-than-natural value due to the breakdown of thatch between each test. Thus, this study suggests reporting the absolute maximum traction value, as well as the average result to display the worst-case scenario to most accurately represent the traction properties of a natural grass playing surface

REFERENCES:

Griffith, GG, Brett, AG, Gregory, PG & Heath, PG 2022, 'Playing Surface and Injury Risk: Artificial Turf Vs. Natural Grass', in MDTR Wojda & PS Dr. Stanislaw (eds), *Injury and Sports Medicine*, IntechOpen, Rijeka, p. Ch. 1.
Kent, R, Forman, JL, Lessley, D & Crandall, J 2015, 'The mechanics of American football cleats on natural grass and infill-type artificial playing surfaces with loads relevant to elite athletes', *Sports biomechanics*, vol. 14, no. 2, 2015/04/03, pp. 246-257.
Orchard, JW, Chivers, I, Aldous, D, Bennell, K & Seward, H 2005, 'Rye grass is associated with fewer non-contact anterior cruciate ligament injuries than bermuda grass', *British Journal of Sports Medicine*, vol. 39, no. 10, pp. 704-709.
Sterzing, T, Müller, C, Hennig, EM & Milani, TL 2009, 'Actual and perceived running performance in soccer shoes: A series of eight studies', *Footwear Science*, vol. 1, pp. 5-17.
Wannop, JW, Luo, G & Stefanyshyn, DJ 2012, 'Footwear traction at different areas on artificial and natural grass fields', *Sports engineering*, vol. 15, no. 2, pp. 111-116.
Zanetti, EM, Bignardi, C, Franceschini, G & Audenino, AL 2013, 'Amateur football pitches: Mechanical properties of the natural ground and of different artificial turf infills and their biomechanical implications', *Journal of sports sciences*, vol. 31, no. 7, pp. 767-777