



Penn State's

**Center for
Sports Surface Research**

The Effect of Irrigation on Synthetic Turf Characteristics

Surface Temperature, Soccer Ball Roll, and Traction

Progress Report

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The Effect of Irrigation on Synthetic Turf Characteristics

Surface Temperature

Researchers have found that the surface temperatures of synthetic turf playing surfaces are significantly higher than natural turf surfaces when exposed to sunlight (Buskirk et al., 1971; Koon et al., 1971; and Kandelin et al. 1976, Devitt et al, 2007, McNitt et al., 2007). For example, surface temperatures over 160° F have been reported on infilled synthetic turf (Devitt et al, 2007,) while natural turf surfaces tend to remain below 100° F during similar conditions (McNitt et al., 2007).

Surface temperatures tend to be highest during clear, sunny conditions. A clear, sunny day with an air temperature around 80 F often produces higher surface temperatures than a hazy, humid day with higher air temperatures and filtered sunlight (Penn State Center for Sports Surface Research, 2012).

Irrigation of synthetic turf is a common technique to attempt to reduce surface temperature. Previous research has shown that cooling effects from irrigation are significantly reduced in a short period of time, often within less than one hour (McNitt et al., 2007).

In this study, the effects of various irrigation regimes on the surface temperature of FieldTurf Revolution were evaluated. In addition to surface temperature, air temperatures at heights approximately 2 ft. and 5 ft. above the surface were recorded.

This study was conducted at Penn State's Center for Sports Surface Research in University Park, PA on June 24, 2015. The FieldTurf Revolution plot used for testing was installed in 2012. All temperature data was collected using an infrared thermometer (Scheduler Model 2 LiCor Corporation). In addition to collecting surface temperature, the data collection unit also recorded air temperature and was used for the 2 and 5 ft. height measurements.

Conditions during testing were mostly sunny, breezy, with a thin cloud layer beginning at approximately 3:00 PM and lasting for the duration of data collection. Data collection began at 11:55 AM and ended at 5:00 PM. Irrigation treatments were applied at 12:00 PM and 1:30 PM, depending on treatment. Irrigation was applied using hand-held irrigation.

Treatments

- **Heavy Water 2x** – Irrigation (approximately 0.75”) applied at both 12:00 PM and 1:30 PM
- **Heavy Water 1x** – Irrigation (approximately 0.75”) applied at 12:00 PM
- **Light Water 2x** – Irrigation (approximately 0.10”) applied at both 12:00 PM and 1:30 PM
- **Control** – No irrigation
- **Natural Turf** – Perennial ryegrass (*Lolium perenne*), no irrigation

The 2x treatments were chosen to simulate irrigating a field at halftime of an event.

Results

Surface temperature results are shown in Figure 1 and Table 1. Air temperature and solar radiation levels are also shown in Table 1.

The effects of the irrigation treatments are apparent at the 12:00 and 1:45 PM temperature readings. Surface temperatures immediately after the first irrigation treatment were well below 100° F. However, temperatures rebounded fairly quickly, with temperatures returning to above 120 F after 45 minutes for the Light Water 2x treatment and one hour and 15 minutes after the Heavy Water treatments.

While irrigation reduced surface temperature by as much as 20° F one hour and 30 minutes after irrigation compared to the control, surface temperatures were still over 130° F for all treatments at the 1:30 PM temperature reading. Irrigation effects produced by the second irrigation cycle (1:30 PM) lasted for a longer period of time compared to the initial irrigation. This was likely due to reduced solar radiation from both increasing thin cloud cover and the time of day.

The amount of water applied also affected surface temperature. Results show temperatures did not rebound as quickly when a higher amount of water was applied compared to a lighter amount. For example, after both the 12:00 and 1:30 PM irrigation treatments, temperatures for the Light Water 2x treatment increased more rapidly than the Heavy Water 2x treatment.

The highest surface temperature measured on natural grass was 95.4° F, which was 60.3° F cooler than the highest temperature measured on synthetic turf (155.7° F).

Air temperatures at 2 and 5 ft. above the surface were generally the same for all treatments and were approximately 5° F higher than the air temperature measured at the local weather station.

Summary

Under the conditions of this trial, frequent, heavy irrigation (0.75”) is the most effective regime for irrigating synthetic turf for surface temperature reduction. However, surfaces temperatures can be expected to rebound quickly during the period of most intense solar radiation.

The temperature of synthetic turf surfaces depends on numerous variables including weather conditions, location, and especially solar radiation. The benefit of surface cooling through irrigation will vary depending on conditions.

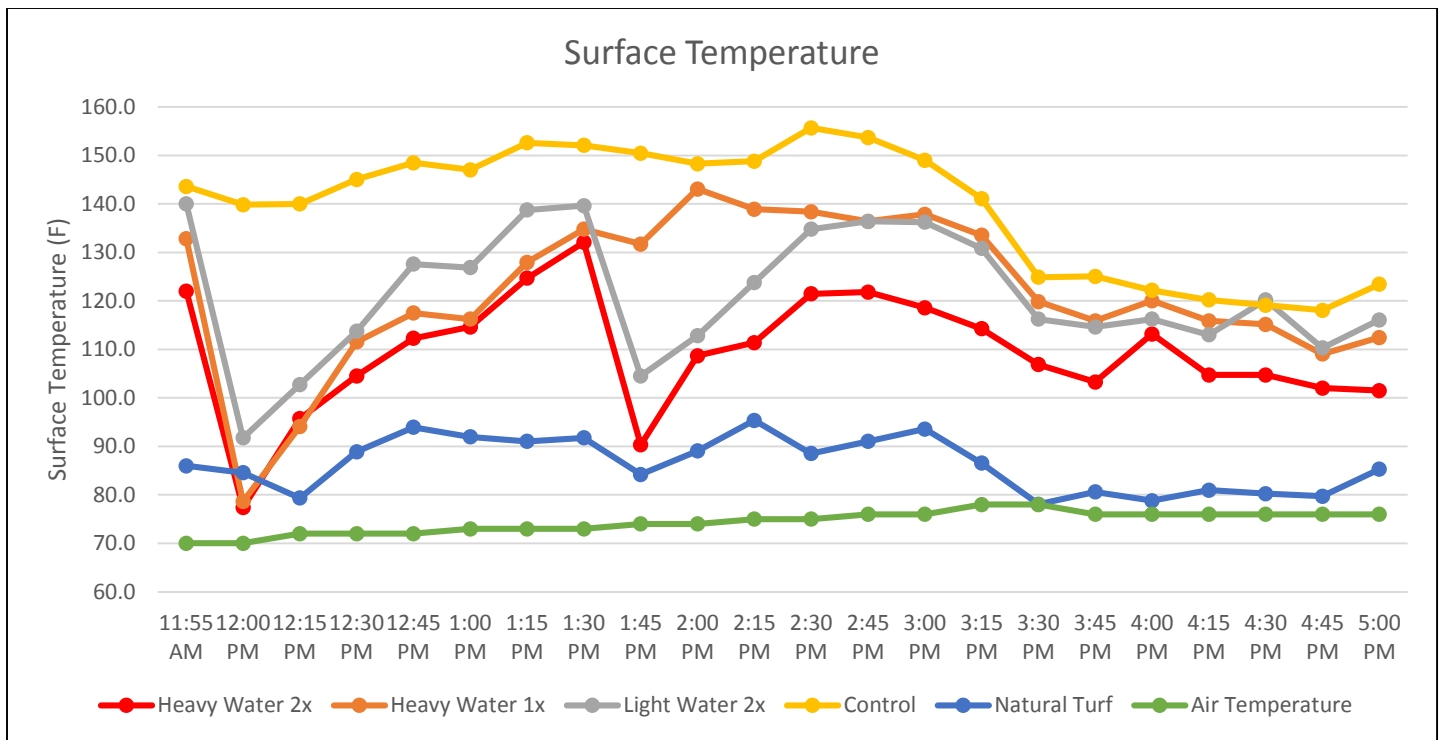


Figure 1. Surface temperatures for each treatment.

Table 1. Surface temperature for each treatment

Time	Heavy Water 2x	Heavy Water 1x	Light Water 2x	Control	Natural Turf	Air Temp.	Solar Radiation
	Temperature (F)						(W/m ²)
11:55 AM	122.0	132.8	140.0	143.6	86.0	70	932.0
12:00 PM	77.4	78.6	91.8	139.8	84.6	70	932.6
12:15 PM	95.7	94.1	102.7	140.0	79.3	72	749.8
12:30 PM	104.5	111.6	113.7	145.0	88.9	72	936.4
12:45 PM	112.3	117.5	127.6	148.5	93.9	72	979.9
1:00 PM	114.6	116.2	126.9	147.0	91.9	73	1055.2
1:15 PM	124.7	127.9	138.7	152.6	91.0	73	966.6
1:30 PM	132.1	134.8	139.6	152.1	91.8	73	958.6
1:45 PM	90.3	131.7	104.5	150.4	84.2	74	985.3
2:00 PM	108.7	143.1	112.8	148.3	89.1	74	949.0
2:15 PM	111.4	138.9	123.8	148.8	95.4	75	948.9
2:30 PM	121.5	138.4	134.8	155.7	88.5	75	1039.7
2:45 PM	121.8	136.4	136.4	153.7	91.0	76	899.3
3:00 PM	118.6	137.8	136.2	149.0	93.6	76	669.8
3:15 PM	114.3	133.5	130.8	141.1	86.5	78	828.9
3:30 PM	106.9	119.8	116.2	124.9	78.1	78	428.9
3:45 PM	103.3	115.9	114.6	125.1	80.6	76	721.2
4:00 PM	113.2	120.0	116.2	122.2	78.8	76	678.0
4:15 PM	104.7	115.9	113.0	120.2	81.0	76	620.3
4:30 PM	104.7	115.2	120.2	119.1	80.2	76	738.0
4:45 PM	102.0	109.0	110.3	118.0	79.7	76	454.1
5:00 PM	101.5	112.5	116.1	123.4	85.3	76	539.1

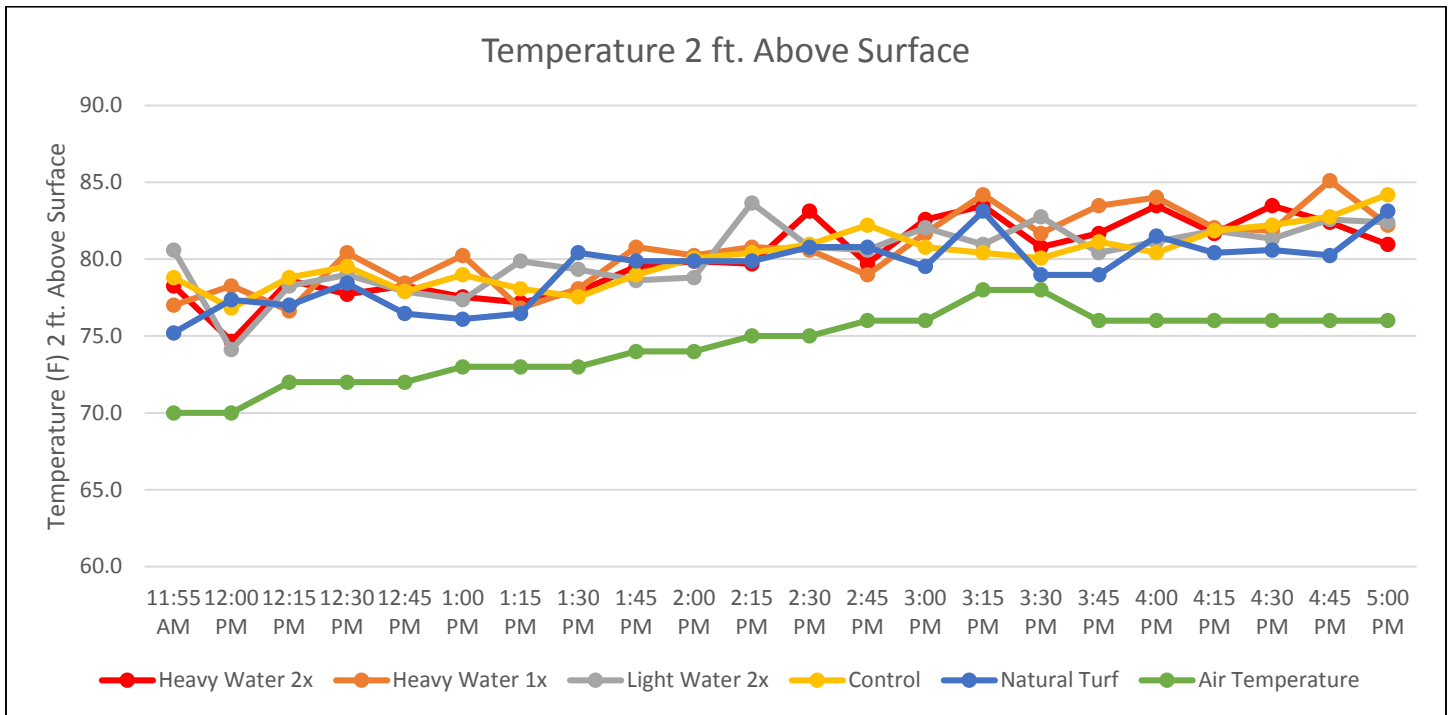


Figure 3. Temperatures 2 ft. above the surface for each treatment

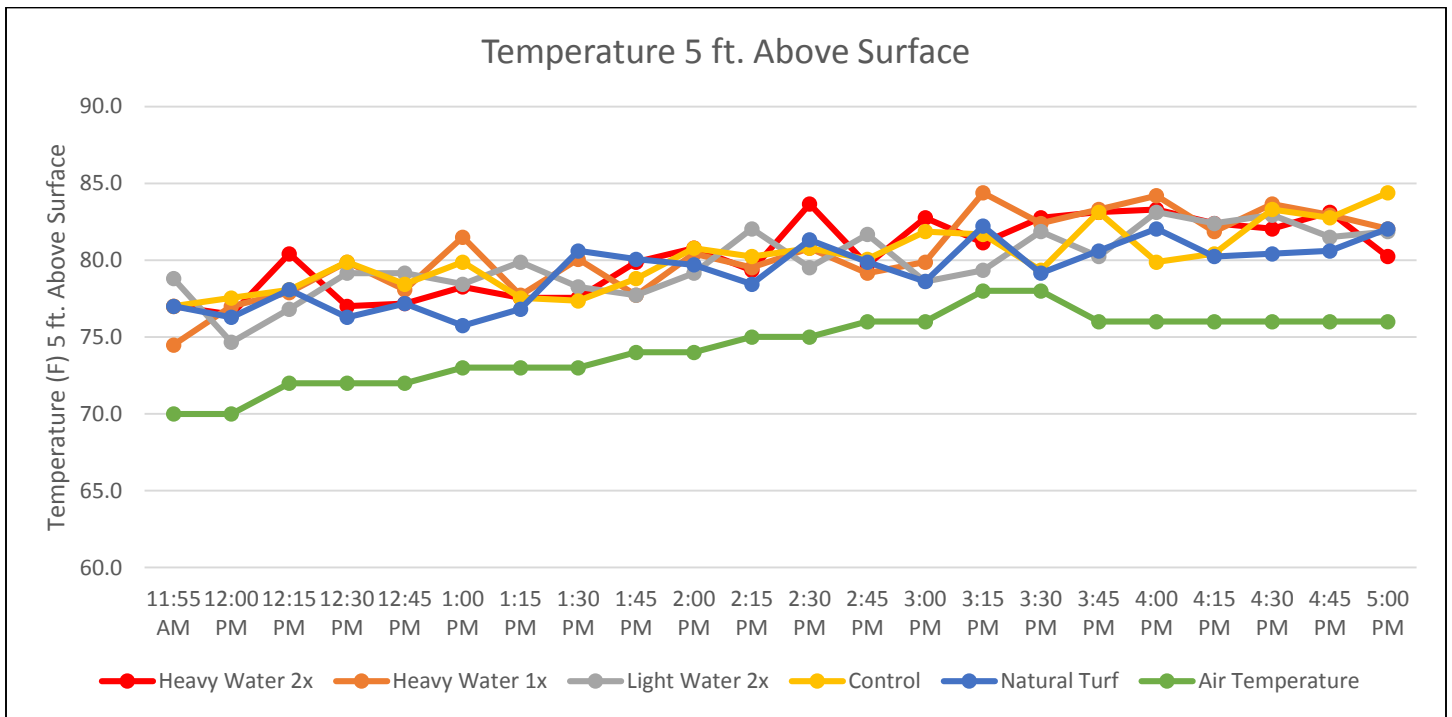


Figure 4. Temperatures 5 ft. above the surface for each treatment

The Effect of Irrigation on Synthetic Turf Characteristics

Soccer Ball Roll

Soccer ball roll testing was conducted on wet and dry FieldTurf Revolution (installed 2012). The same testing was also conducted on Kentucky bluegrass (*Poa pratensis*) and perennial ryegrass (*Lolium perenne*) for comparison. Ball roll distance was tested using the method described in the FIFA Quality Concept, Handbook of Test Methods for Football Turf (FIFA, 2012a). The distance a ball travels is an indicator of the “speed” of a field (FIFA, 2012b).

For these tests, the FieldTurf Revolution area tested had a 2.5 inch pile height and an infill depth of 43 mm. The mowing height for the Kentucky bluegrass was 1.25 inches. The mowing height for the perennial ryegrass was 1.5 inches. For wet testing, each surface was irrigated to ensure the surface of each test area was wet. Wet and dry testing was conducted on the same day.

Results

Ball roll differences under wet conditions were 0.4 m (perennial ryegrass) and 0.3 m (Kentucky bluegrass and FieldTurf) longer than under dry conditions (Table 2).

Table 2. Ball roll distance on FieldTurf Revolution and natural turf (wet and dry)

	Ball Roll Distance	% Difference when wet
FieldTurf Revolution - Dry	6.2 m	
FieldTurf Revolution - Wet	6.5 m	+ 4.8%
Kentucky bluegrass - Dry	5.3 m	
Kentucky bluegrass - Wet	5.6 m	+ 5.7%
Perennial ryegrass - Dry	4.5 m	
Perennial ryegrass - Wet	4.9 m	+ 8.9%

Summary

These test results show that irrigating the surface increases soccer ball roll distance, and thus speed. Ball roll distances increased by approximately 5 to 10%, depending on the surface.

The Effect of Irrigation on Synthetic Turf Characteristics

Traction

Rotational and linear traction of various cleated shoes was measured under wet and dry conditions on FieldTurf Revolution. Pennfoot (McNitt et al., 1997; Figure. 5) was used for all traction measurements. For comparison, the same measurements were made on Kentucky bluegrass (*Poa Pratensis*) and bermudagrass (*Cynodon dactylon*).



Figure 5. Pennfoot traction tester

The FieldTurf Revolution plot was installed in 2012 and exposed to a total of 200 passes with a Brinkman Wear Machine (Cockerham and Brinkman, 1989) prior to testing. Both the Kentucky bluegrass and bermudagrass plots were unworn and contained healthy turfgrass with 100% coverage grown on USGA-sand rootzones. This study was conducted at Penn State's Center for Sports Surface Research in University Park, PA.

Descriptions of traction measurements are shown below.

1. **Rotational Traction** – Rotational traction refers to the traction that resists rotation of the shoe during pivoting movements. For an athlete, high rotational traction equates to a greater tendency for foot fixation during changes of direction and low rotational traction means the shoe tends to release from the surface more easily. There are currently no safety thresholds associated with rotational traction; however, it is useful to compare surfaces and shoe types. In general, a lower rotational traction value is preferred over a higher value. Rotational traction was measured using Pennfoot in a toe-only stance with 45° rotation with a loading weight of 240 lbs. Three traction measurements were

obtained with each shoe on each plot under wet and dry conditions. Shoes used for testing are shown in Figure 6.

2. **Linear Traction – Static** – Static linear traction is the resistance to sliding or pivoting when there is no movement between the shoe and the surface. Static traction forces tend to resist the initiation of sliding or pivoting. Because linear traction is primarily associated with athlete performance, in general, a higher static linear traction value is preferred over a lower value. Static linear traction was also measured with Pennfoot. Three traction measurements were obtained with each shoe on each plot under wet and dry conditions. Shoes used for testing are shown in Figure 6.
3. **Linear Traction – Dynamic** – Dynamic linear traction is the resistance that occurs during a sliding or pivoting motion. Dynamic traction forces tend to resist or decelerate pivoting motions. Because linear traction is primarily associated with athlete performance, in general, a higher dynamic linear traction value is preferred over a lower value. Dynamic linear traction was also measured with Pennfoot. Three traction measurements were obtained with each shoe on each plot under wet and dry conditions. Shoes used for testing are shown in Figure 6.

A total of six shoes were used for testing rotational traction and four shoes were used to measure linear traction. The shoes used in testing are shown in Figure 6.



Figure 6. The shoes used in the traction testing were (from left to right) Adidas CrazyQuick Mid (hybrid), Under Armour Highlight MC (hybrid), Nike Air Destroyer 5/8 (molded nubs), Adidas Scorch Thrill FieldTurf (hybrid), Nike Air Zoom Alpha Talon (12-stud peripheral with toe cleat), and Nike Air Zoom Blade D (seven-stud screw-in)

Wet and Dry Testing Conditions

For “dry” traction testing, all surfaces were free of surface moisture and were tested mid-day, under full sunlight. For “wet” traction testing, plots were irrigated prior to testing and the surface remained wet throughout testing. Irrigation (approximately 0.75” of water) was applied to the FieldTurf Revolution plot. The volumetric soil water contents of the natural turf plots during wet and dry testing are shown in Table 3.

Table 3. Volumetric water contents for K. bluegrass and bermudagrass plots

Surface	Water Content	
	Dry	Wet
K. bluegrass	22.6%	30.9%
Bermudagrass	17.7%	32.9%

Results - Rotational Traction

Rotational traction values on each surface under wet and dry conditions are shown in Table 4. On FieldTurf, rotational traction increased by 14% under wet conditions. For the natural turf surfaces, rotational traction slightly decreased under wet conditions.

Table 4. Rotational traction values on wet and dry surfaces

Surface	Rotational Traction (Nm)		% change from dry to wet
	Dry	Wet	
FieldTurf Revolution	52.8	60.2	+14.0%
K. Bluegrass	61.2	58.9	-3.8%
Bermudagrass	63.1	61.6	-2.4%

Rotational traction values for each shoe on each surface are shown in Table 5. On FieldTurf, all shoes, with the exception of the Nike Air Destroyer 5/8 (nub-style cleats), produced higher rotational traction under wet conditions compared to dry conditions. The Nike Air Zoom Blade D (screw-in cleat) showed the largest increase in traction under wet conditions on FieldTurf (58.8%).

The largest reduction in traction when going from dry to wet conditions was the Nike Air Destroyer 5/8 on Kentucky bluegrass (12.8%).

These results support previous research findings that indicate shoe-type plays a large role in rotational traction forces. For example, the Nike Air Destroyer 5/8 has very short cleats that do not penetrate deeply into the playing surface. These results indicate that a wet surface reduces rotational traction on shoes with short cleats on both synthetic and natural turf surfaces. On FieldTurf in particular, more aggressive cleat patterns tended to show a large increase in rotational traction when the surface was wet compared to dry.

For four of the six shoes tested, the largest traction differences between wet and dry conditions were on FieldTurf. Smaller differences were found on the natural turf surfaces.

Table 5. Rotational traction values for each shoe on wet and dry surfaces

Shoe	Surface	Rotational Traction (Nm)		% change from dry to wet
		Dry	Wet	
Adidas CrazyQuick Mid	FieldTurf	43.5	56.1	+29.0%
Adidas CrazyQuick Mid	Bermudagrass	53.9	58.3	+8.2%
Adidas CrazyQuick Mid	K. Bluegrass	56.7	57.7	+1.8%
Adidas Scorch Thrill FT	FieldTurf	51.1	54.2	+6.0%
Adidas Scorch Thrill FT	Bermudagrass	56.1	56.4	+0.5%
Adidas Scorch Thrill FT	K. Bluegrass	54.8	55.8	+1.8%
Nike Air Destroyer 5/8	FieldTurf	69.6	63.9	-8.2%
Nike Air Destroyer 5/8	Bermudagrass	69.0	61.1	-11.4%
Nike Air Destroyer 5/8	K. Bluegrass	65.8	57.4	-12.8%
Nike Air Zoom Alpha Talon	FieldTurf	63.3	64.3	+1.6%
Nike Air Zoom Alpha Talon	Bermudagrass	75.6	71.5	-5.4%
Nike Air Zoom Alpha Talon	K. Bluegrass	69.6	67.1	-3.6%
Nike Air Zoom Blade D	FieldTurf	44.2	70.2	+58.8%
Nike Air Zoom Blade D	Bermudagrass	69.3	65.5	-5.5%
Nike Air Zoom Blade D	K. Bluegrass	64.3	60.2	-7.1%
UnderArmour Highlight MC	FieldTurf	45.4	52.3	+15.2%
UnderArmour Highlight MC	Bermudagrass	54.8	57.0	+4.0%
UnderArmour Highlight MC	K. Bluegrass	56.1	55.2	-1.6%

Results - Linear Traction – Static

Static linear traction values on each surface under wet and dry conditions are shown in Table 6.

Table 6. Static linear traction values on wet and dry surfaces

Surface	Static Ratio		% change from dry to wet
	Dry	Wet	
FieldTurf Revolution	1.69	1.72	+1.8%
K. Bluegrass	1.63	1.63	0%
Bermudagrass	1.74	1.72	-1.1%

Although the majority of differences between wet and dry conditions were less than 5%, two of the shoes produced significantly different wet and dry traction values on Kentucky bluegrass. The static linear traction level of Nike Air Destroyer 5/8 was 30% lower on wet Kentucky bluegrass compared to dry Kentucky bluegrass. Conversely, the Nike Air Zoom Blade D produced a traction value nearly 45% higher under wet conditions on Kentucky bluegrass.

Table 7. Static linear traction values for each shoe on wet and dry surfaces

Shoe	Surface	Static Ratio		% change from dry to wet
		Dry	Wet	
Adidas Scorch Thrill FT	FieldTurf	1.70	1.70	0%
Adidas Scorch Thrill FT	Bermudagrass	1.80	1.74	-3.3%
Adidas Scorch Thrill FT	K. Bluegrass	1.56	1.57	+0.6%
Nike Air Destroyer 5/8	FieldTurf	1.52	1.52	0%
Nike Air Destroyer 5/8	Bermudagrass	1.51	1.46	-3.3%
Nike Air Destroyer 5/8	K. Bluegrass	1.85	1.29	-30.3%
Nike Air Zoom Alpha Talon	FieldTurf	1.72	1.84	+7.0%
Nike Air Zoom Alpha Talon	Bermudagrass	1.80	1.84	+2.2%
Nike Air Zoom Alpha Talon	K. Bluegrass	1.85	1.83	-1.1%
Nike Air Zoom Blade D	FieldTurf	1.83	1.82	-0.5%
Nike Air Zoom Blade D	Bermudagrass	1.83	1.82	-0.5%
Nike Air Zoom Blade D	K. Bluegrass	1.27	1.84	+44.9%

Results - Linear Traction – Dynamic

Dynamic linear traction values on each surface under wet and dry conditions are shown in Table 8. The largest difference between wet and dry traction was on FieldTurf, which produced nearly 20% lower dynamic traction under wet conditions. Dynamic traction on Kentucky bluegrass was approximately 6% higher under wet conditions and dynamic traction was the same on bermudagrass under wet and dry conditions. It is important to note that not all shoes tested could be moved across the surfaces to a degree that allowed for a dynamic traction measurement. This was due to aggressive cleat patterns and device limitations.

Table 8. Dynamic linear traction values on wet and dry surfaces

Surface	Dynamic Ratio		% change from dry to wet
	Dry	Wet	
FieldTurf Revolution	1.53	1.23	-19.6%
K. Bluegrass	1.12	1.19	+6.3%
Bermudagrass	1.30	1.30	0%

Dynamic linear traction values for shoe-surface combinations under wet and dry conditions are shown in Table 9. There is no dynamic traction data for multiple shoe-surface combinations due to the traction device not being able to produce enough dynamic movement to allow for a dynamic traction measurement. The aggressive cleat pattern of several shoes provided a large amount of resistance to linear movement that was unable to be overcome by the hydraulic forces produced by Pennfoot. While the amount of data is limited, there is an indication that dynamic traction is reduced by approximately 15 – 20% on wet FieldTurf compared to dry FieldTurf for certain shoes.

Table 9. Dynamic linear traction values for each shoe on wet and dry surfaces

Shoe	Surface	Dynamic Ratio		% change from dry to wet
		Dry	Wet	
Adidas Scorch Thrill FT	FieldTurf	1.58	1.28	-19.0%
Adidas Scorch Thrill FT	Bermudagrass	n/a	n/a	n/a
Adidas Scorch Thrill FT	K. Bluegrass	1.19	1.33	+11.8%
Nike Air Destroyer 5/8	FieldTurf	1.39	1.19	-14.4%
Nike Air Destroyer 5/8	Bermudagrass	1.30	1.22	-6.2%
Nike Air Destroyer 5/8	K. Bluegrass	1.05	1.06	+1.0%
Nike Air Zoom Alpha Talon	FieldTurf	n/a	n/a	n/a
Nike Air Zoom Alpha Talon	Bermudagrass	n/a	n/a	n/a
Nike Air Zoom Alpha Talon	K. Bluegrass	n/a	n/a	n/a
Nike Air Zoom Blade D	FieldTurf	1.58	n/a	n/a
Nike Air Zoom Blade D	Bermudagrass	n/a	n/a	n/a
Nike Air Zoom Blade D	K. Bluegrass	n/a	n/a	n/a

Summary

Traction differences between wet and dry conditions were found for nearly all shoe-surface combinations. For rotational traction, the largest traction differences between wet and dry conditions tended to be on FieldTurf, with the highest difference being nearly 60%. Somewhat surprisingly, the majority of shoe-surface combinations showed higher rotational traction during wet conditions compared to dry conditions. Smaller differences were found for static linear traction with the exception of the Nike Air Zoom Blade D and the Nike Air Destroyer 5/8, which each showed substantial differences in static linear traction on dry versus wet Kentucky bluegrass. Given the limited amount of dynamic linear traction data, it is difficult to draw conclusions. However, the data do show a traction reduction of 15 – 20% with two shoes on FieldTurf. These results continue to support the notion that shoe selection has a large influence on traction and that wide ranging conclusions regarding surface characteristics and conditions cannot be made without taking into consideration shoe-type.

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