

EFFECT OF ROLLING FREQUENCIES ON SPORTS FIELD SURFACE AND
SUBSURFACE CONDITIONS

By

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ABSTRACT

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Research was conducted to determine the effect of rolling and simulated traffic on various conditions of sports fields and the effect of rolling on an athlete's perception of playing conditions. Established Kentucky bluegrass sports field plots were used in all studies and rolling treatments were applied during each growing season from 8 July 2013 to 19 September 2014. Simulated foot traffic was added to the second study from 23 September 2013 to 5 September 2014. Rolling and athlete evaluations for the third study took place on 30 September 2014 and 10 October 2014. The most frequent statistical difference attributed to rolling treatments was an increase in ball roll distance, which occurred twice in 2013 and twice in 2014. In the second study, simulated traffic significantly increased the hardness of the surface and amount of noticeable wear, while it decreased quality of the turf and stability of the playing surface. However, the significance of traffic on these outcomes was not dependent on the amount of rolling that took place. A decrease in the size of white clover patches was also observed with the most frequently applied traffic. No other differences of significance were attributed to rolling. Lastly, athletes did not have the ability to identify a smoother surface as indicated by an increase in ball roll distance.

To Samantha, for your continued love and support

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INTRODUCTION

Turfgrass has long been the most preferred surface for individual and team outdoor sports. Written references to the modern game of golf being played on natural grass can be found as far back as the 15th century (Beard, 2014). Team sports such as cricket, association football (“soccer” in America), baseball, and rugby performed on turfgrass have been traced back to the 1700’s (Beard, 2012).

Although the rules of those sports were similar what we have now, the first golf courses and sports fields were considerably different from the pristine manicured surfaces of today. Early management of golf course turfgrass was primarily left to grazing animals such as cattle, rabbits, and sheep (Beard, 2005). Fields used for team sports followed suit as they were set up wherever a somewhat flat area of grass could be found and any maintenance of the turfgrass was decided by the appetite of the local livestock.

Today, the correlation between golf course and sports turf management is strong as well. Present-day sports field management techniques such as striped mowing patterns, sand topdressing, and core cultivating (aerification) were all practices that originated in golf course management. These, and many other once golf-specific tactics, are now being performed on competition sports fields all over the world. However, one practice currently performed on virtually every golf course green, but not nearly as frequently on sports fields, is rolling.

Rolling in golf dates to the early 1900’s when golf courses were often built along ocean coasts, which meant a high sand content of the native soils (DiPaolao and Hartwiger, 1994 and Nikolai, *et al.*, 2001). Because these soil types are not prone to compaction, rolling was a popular method used to maintain smooth greens. As golf became more popular and spread to inland areas, courses were built on finer textured soils, leading to concerns that rollers would create

compaction and result in poor drainage and unplayable greens (Hutchinson, 1906). The fear of rolling having detrimental effects on the playing surface, along with improved mowers, caused the practice to become very rare by the late 1920's. Then, in the early 1990's, the practice of rolling greens was reinitiated due to the demand for faster green speeds (Hartwiger, 1996). With its resurrection came articles praising rollers for tournament preparation while warning of negatives effects if used for regular play (Nikolai, 2002). Clearly, specific information was needed concerning the use of rollers in a season-long program (Beard, 1994). Recognizing this need, a handful of turfgrass researchers initiated studies on the topic (Nikolai, *et al.*, 2001). The research not only relieved concerns of compaction with frequent rolling, but it also discovered many benefits of frequent rolling. This led to a rapid rise in the popularity of rolling as a mechanical practice now employed on most golf courses.

Sports field rolling has quite a different past. Since most team sports primarily started out on dirt lots, paved streets, or unkempt fields, sand-based root zones were not as common as they were in the early centuries of golf. As these low maintenance fields and dirt lots were converted into intended sports fields, any type of frequent rolling was likely avoided for fear of compacting the native soil. Although roller technology has improved drastically and use of rollers on golf courses has become commonplace in the last 20-years, a similar trend has not occurred on sports fields, due in large part to lack of experience. The use of a roller on sports fields has been mostly limited to situations in which minor (smaller than the width of the roller) surface imperfections need to be leveled out (Minner, 2005). The place of a roller in a sports field management routine is much more unusual than on a golf course.

Not only are rollers rarely used on sports fields, but scientific data on the effects of rolling sports fields are also scarce. In contrast to research focused on the rolling of golf course

greens, there is a deficiency of research supporting or rebuking the use of frequent rolling of a sports field. Additionally, roller companies are specifically targeting the use of their machines for sports fields without any research-derived evidence of their worth, or how and when to use them. The need for surface-specific research is essential based on three factors that differentiate sports fields from golf course greens. First, the physical characteristics of the two types of surfaces, specifically turfgrass species and height of cut. Sports fields are often played on turfgrass species that perform best when mowed at heights 10 to 20 times higher than a typical putting green. Second, the amount and force of the foot traffic incurred by a sports field is far greater than that of a golf green due to the intensity of the different games played upon them. Finally, the nature of the interaction between the athlete and surface differs greatly between golf and team sports, which is an important consideration in evaluating the effectiveness of any mechanical practice.

The objective of the research reported in Chapter 1 was to investigate the effect of frequent rolling on surface and subsurface characteristics of a competition-level sports field. Characteristics examined include surface smoothness, turfgrass quality, surface hardness, soil moisture content, and surface stability. Root mass, infiltration rate, and weed populations were also assessed at the end of each year. Chapter 2 used similar parameters to evaluate rolling in combination with simulated traffic analogous to practice and game conditions on a soccer field. Chapter 3 then used the evaluations of experienced athletes to assess the effects of rolling on athlete-to-surface interaction.

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Chapter 1:

Evaluation of Rolling on Native Soil Based Kentucky Bluegrass Sports Fields

INTRODUCTION

Rolling golf course greens was a popular mechanical practice in the early 1900's, but fell out of favor by the 1930's due to fears of compacting the soil (Hartwiger, et al., 2001). In the early 1990's, golfers' desire for faster green speeds, or ball roll distance (BRD), was rapidly growing. The desire for faster green speeds combined with the increased frequency of sand topdressing led some superintendents to revisit the practice of rolling greens for tournament play (Hartwiger, 1996). However, the revival of rolling on a frequent basis did not come about until research began to identify many benefits of rolling.

Over the last quarter century, many benefits to rolling golf course greens have been discovered, most commonly associated with an increase in BRD. Hartwiger, et al. (2001) showed that daily rolling increases BRD for up to 48 hours. Similarly, another study found that most rolling increased BRD by about 30cm and still maintained roughly half of that increase on the following day (Nikolai, 2005). It has also been shown that with frequent rolling, mowing frequency can be reduced without a decrease in BRD (Richards, et al., 2009 and McDonald, et al., 2013).

Another benefit observed when studying rolling has been reduction of turfgrass diseases. Both Nikolai, et al. (2001) and Giordano, et al. (2010) reported daily rolling reduced incidence of dollar spot (*Sclerotinia homoeocarpa* F.T. Bennett) disease infections on creeping bentgrass (*Agrostis stolonifera* L.) greens. Giordano, et al. (2010) reported rolling led to increased moisture content within the root zone. Although only theorized, this increased soil moisture content has previously been considered as a reason for the reduction in dollar spot (Couch and Bloom,

1960) and (Liu, et al., 1995). Rolling has also resulted in the reduction of anthracnose (*Colletotrichum cereale*) on annual bluegrass (*Poa annua* L.) putting greens (Inguagiato, et al., 2009). Also reported in research is the reduction of broadleaf weeds. One study found that when creeping bentgrass greens were rolled three times wk-1, dandelion (*Taraxacum officinale*) and broadleaf plantain (*Plantago major*) counts were significantly reduced (Nikolai, 2002). Nikolai, et al. also found that rolling three times wk-1 increased the amount of turfgrass roots in the topdressing layer. These additional pest-suppressing benefits have promoted rolling to become a mainstay in most greens management programs.

Many of these studies, as well as others, have also considered potential detriments to frequent rolling. A decrease in turfgrass quality was noted when both sand-based and native soil greens were rolled four and seven times per week, but not at once per week (Hartwiger, 1996). However, scrutiny of Hartwiger's data reveals that a rolling treatment was rolling down and back across the surface, therefore each treatment was double rolled. Additionally, the surfaces in that research were not sand topdressed. Nikolai et al. (2001) reported that rolling three times per week resulted in no differences in quality on sand-based or topdressed native soil greens. Beard (1994) stated that rolling enhances putting quality, possibly due to an increase in density. Similarly, the rolling study by Giordano, et al. (2010) also both found an overall increase in turfgrass quality, likely attributed to the decrease in damage caused by dollar spot. With varying results and numerous factors affecting turfgrass quality, research specific to different soils, turfgrass species, and rolling frequency is important to determine the effects of rolling, as they relate to each factor.

Whether perceived or real, fear of root zone compaction and/or leaf tissue damage has always been the primary motive to limiting rolling (Beard, 1997). Research performed on golf

greens has produced conflicting results regarding compaction. A rolling study, performed by Hamilton et al. (1994), found that rolling twice a week, on sand-based or native soil, resulted in no significant increase in bulk density. Nikolai, et al. (2001) discovered that rolling three times per week showed no evidence of compaction on both native soil and sand-based greens using bulk density and porosity measurements. Conversely, rolling four and seven times per week has led to an increase in bulk density on native soil greens, but not at any frequency on sand-based greens (Hartwiger, et al., 2001). It is important to note that, in the 2001 Hartwiger study, a rolling treatment consisted of traveling back and forth over the same area, resulting in the treatments that caused compaction to be rolled eight and 14 times/ week. The study also took place on a surface that was not topdressed with sand. Based on available research, the greatest potential for soil compaction appears to be on native soil greens that are not topdressed and rolled at a season long frequency of greater (and potentially much greater) than three times per week.

Rolling as a routine management practice is not as commonplace on sports fields as golf course greens. Although rollers are used regularly in certain places, particularly European football (soccer) pitches, there is a lack of published research evaluating the effects of rolling sports fields. One study by Mooney and Baker (2000) reported rolling twice per week over the course of eight months significantly increased the speed at which a soccer ball traveled across the surface. This study also found ground cover and traction to be reduced on rolled plots, but no evidence of compaction or increased surface hardness was observed. Beyond this, no published research is currently available that studied the effects of rolling on a sports field surface.

Cool-season grass sports fields are typically comprised of Kentucky bluegrass (*Poa pratensis* L.), perennial ryegrass (*Lolium perenne* L.), tall fescue (*Festuca arundinacea* Schreb.),

or any combination of the three. These turfgrass species are mowed at a height of cut about three times higher than typical cool-season putting green species, such as creeping bentgrass and annual bluegrass (Beard, 1974). A higher-cut turfgrass creates a different dynamic between the roller and surface, as well as a ball and the surface and therefore, it cannot be assumed that the effects of roller use on golf greens will automatically be similar on sports fields. This higher height of cut combined with a typical lack of clipping removal can also create a more substantial thatch layer. Because of this, it is important to test the effect of rolling actual sports field surfaces as they are dissimilar from golf greens in their physical makeup. Furthermore, association football, more than any other sport played on turfgrass fields, combines the harshness of heavy, forceful traffic with the need for a smooth and consistent playing surface. Therefore, evaluating playing conditions pertinent to association football make for a comprehensive assessment of a mechanical practice such as rolling.

In 2013, this study was initiated to examine numerous effects of rollers on Kentucky bluegrass sports fields. The objective of this research was to evaluate how frequent rolling affected surface smoothness, turfgrass quality, surface hardness, soil moisture content, and shear strength on a native soil sports field. The study was performed on a turfgrass research plot that was maintained similar to a competition-level soccer field. In addition, end of year root mass, infiltration rate, and weed populations were assessed to further examine the effects of rolling.

MATERIALS AND METHODS

Research was conducted in 2013 and 2014 at the Michigan State University Hancock Turfgrass Research Center (HTRC) in East Lansing, Michigan on a site established in 2005 from seed as a Kentucky bluegrass (*Poa pratensis* L.) sports field. The seed used was a nine-way blend (Table 1) that was originally formulated for the 2001 modular field installation at Spartan Stadium on the campus of Michigan State University (Gilstrap, et al. 2002). The soil type was a native soil base, which consisted of approximately two-thirds Colwood-Brookston loam (a poorly drained loam soil) and one-third Aubbeenaubbee-Capac sandy loam (a somewhat poorly drained sandy loam soil). Particle size analysis of the native soil was 55.5% sand, 27% silt, and 17.5% clay, using the Bouyocous method (Bouyoucos, 1962).

The site was mowed at a 2.54 cm cutting height 3 times wk⁻¹ using a triplex reel mower (2653B Precision Cut Trim and Surrounds Mower, Deere & Company, Moline, IL). Throughout each growing season, 244.6 kg ha⁻¹ of nitrogen (N) was applied using a combination of weekly foliar-sprayed solubilized urea (46-0-0) and three granular fertilizer applications (Contec DG 18-9-18, The Andersons, Inc., Maumee, OH). Irrigation was applied nightly at a rate of 0.25 cm. The field was core aerated each spring and fall (ProCore 648, The Toro Company, Bloomington, MN) equipped with 1.27 cm diameter hollow-tines. Sand topdressing was applied at a rate of 0.04 cm at 1-wk intervals between 1 July and 25 October 2013 and again between 1 May and 19 September 2014 for a total sand topdressing layer of 1.88 cm. Particle size analysis for the topdressing was 0.5% 2mm, 16.4% 1mm, 24.5% 0.5mm, 43.2% 0.25mm, 14.2% 0.15mm, and 0.9% 0.05mm. The study was a one-factor, randomized complete block design with three replications. Each subplot was

Table 1. Nine-way Kentucky bluegrass blend formulated for 2001 Spartan Stadium modular field installation and used for establishment in 2005.

Cultivar	Percent Live Seed
Champagne	15.8
Coventry	9.4
Limousine	10.9
Midnight	10.7
Moonlight	9.6
Northstar	11.4
Rugby II	13.3
Serene	11

16.45 x 16.45 m with buffer strips measuring 1.3 m wide. The treatments consisted of weekly rolling application of 3 times wk⁻¹, rolling 5 times wk⁻¹, and no rolling. Rolling treatments were applied with a Tru-Turf SR72 Sports Turf Roller (Tru-Turf Pty. Ltd., Arundel, Queensland, Australia) pulled behind a John Deere 5400 tractor (Deere & Company) equipped with “turf-style” flotation tires. Treatments were applied from 8 July to 11 October in 2013 and 1 May to 19 September in 2014.

Plots were regularly evaluated for turfgrass quality, surface hardness, and ball roll distance (a measure to determine surface smoothness). Plots were also routinely measured for soil moisture content and shear vane strength (a measure used to determine playing surface stability/strength). Additional measurements of root mass, saturated hydraulic conductivity, and broadleaf weeds counts were taken at the end of both growing seasons.

Normalized vegetative difference index (NDVI) ratings were used as a quantitative measurement to assess turfgrass performance and indicate quality. NDVI was recorded with a FieldScout TCM 500 NDVI Turf Color Meter (Spectrum Technologies, Inc., Aurora, IL). Five readings were recorded from random locations within each plot. Surface hardness was measured with a Clegg Impact Tester (Turf-Tech International, Tallahassee, FL) equipped with a 2.25 kg hammer. The hammer was dropped in three random areas within each plot and gravities (“G-max”) measurements were recorded. Surface smoothness was measured by recording ball roll distance (BRD) using a Soccer Fieldgauge (Cockerham, et al. 1995). A FIFA-approved Nike Omni Premium Match Ball (Nike, Inc., Beaverton, OR) inflated to 0.77 kg cm⁻² was released from the top of the Soccer Fieldgauge and the distance the ball traveled was recorded. Methods of measurement were consistent with those detailed in the Stimpmeter Instruction Booklet (United States Golf Association, Far Hills, NJ).

Volumetric moisture content of the soil was measured using time domain reflectometry (TDR) technology, recorded with a FieldScout TDR 300 Soil Moisture Meter (Spectrum Technologies, Inc., Aurora, IL) with 7.62 cm probes. Five readings were recorded from random locations within each plot. Surface stability was evaluated with a Shear Strength Tester (Turf-Tech International, Tallahassee, FL) to measure shear vane strength. The device was inserted into the surface at three random locations within each plot and turned until the turf began to tear and give way. The maximum amount of torque applied by the device was recorded for each location.

Root samples of 3.2 cm diameter were collected at the end of each growing season to a depth of 20.3 cm. Three samples were taken from random locations within each plot and the verdure was removed before soaking the samples in sodium hexametaphosphate and placing them on a shaking table for 24-h. Roots were then rinsed free of soil and oven dried at 65°C for 24 hours before weights were recorded. Saturated hydraulic conductivity was measured using the double-ring infiltrometer method (Johnson, 1963). Infiltration rates were measured and recorded until vertical movement of the water ceased for a period of one hour. Dandelion and broadleaf plantain plants were counted at the end of the study.

All data were examined using analysis of variance (ANOVA) to determine significant effects ($p \leq 0.05$). When significant, treatment differences were analyzed using the proc MIXED procedure of SAS 9.2 (SAS Institute Inc., Cary, NC) and means were separated using Fisher's protected least significant difference (LSD) procedure at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Surface Smoothness

BRD measurements to evaluate surface smoothness ranged from 8.01 to 11.18m. The mean BRD across all treatments was 9.05m in 2013 and 10.08m in 2014. There were significant differences among rolling treatments on two occasions in 2013 (Table 2) and three occasions in 2014 (Table 3). In 2013, results from 30 August rating date, BRD on plots rolled 5 times wk^{-1} measured significantly longer than untreated plots, and on the 11 October rating date, the 3 times wk^{-1} and 5 times wk^{-1} rolled plots measured significantly longer than untreated plots. In 2014, on the 11 July rating date, BRD on plots rolled 5 times wk^{-1} were significantly longer than 3 times wk^{-1} rolled and the untreated plots, and on the 31 July rating date, BRD on the 3 times wk^{-1} and 5 times wk^{-1} rolled plots were significantly longer than untreated plots. On 15 August 2014, the BRD on untreated plots was significantly longer than the 3 times wk^{-1} and 5 times wk^{-1} rolled plots. Although there were a few dates in each year with significant differences, the lack of significant dates is more noteworthy. For rolling sports fields to be considered beneficial to the improvement of surface smoothness as it is on putting greens, the differences should be more consistent. Surface smoothness, even on the untreated plots, may have been affected by the tires of the mower and the tractor pulling the roller. The one incidence of the untreated plot being statistically smoother than both rolled plots also obscures the other rating dates with significant differences.

NDVI

NDVI measurements were taken on scale of 0-1 and ranged between 0.667 and 0.764. The mean NDVI rating across all treatments was 0.718 in 2013 and 0.717 in 2014. In both 2013 (Table 4) and 2014 (Table 5), there was only one rating date with statistical differences among

treatments. On 2 August 2013, plots rolled 3 times wk^{-1} had lower quality than the untreated plots and those rolled 5 times wk^{-1} . On all other rating dates in 2013 and 2014, there were no significant differences in turfgrass quality ratings among treatments. There were not enough differences to determine that rolling had any consistent effect on NDVI ratings. In this study, NDVI was used to quantify turf performance and the findings of the study show that rolling did not significantly improve or diminish the quality, or performance, of the turf.

Table 2. Surface Smoothness as affected by rolling treatment.

Rolling Treatment	2013							
	12-Jul	19-Jul	2-Aug	9-Aug	30-Aug	13-Sep	27-Sep	11-Oct
	-----Ball Roll Distance [†] -----							
Not Rolled	8.25	8.01	9.02	8.25	8.62b	9.09	9.21	8.93b
Rolled 3x wk ⁻¹	8.53	8.87	9.15	8.78	8.99b	9.27	9.42	9.36a
Rolled 5x wk ⁻¹	8.93	9.73	9.02	8.90	9.49a	9.43	10.20	9.67a
P Value	0.1021	0.0608	0.9001	0.2045	0.0475 [‡]	0.3209	0.0933	0.0104 [‡]

[†] Ball Roll Distance (meters) measured using a Soccer Fieldgauge.

[‡] Means in a column followed by the same letter are not significantly different according to Fisher's protected LSD (p=0.05).

Table 3. Surface Smoothness as affected by rolling treatment.

Rolling Treatment	2014								
	5-May	30-May	13-Jun	27-Jun	11-Jul	31-Jul	15-Aug	5-Sep	19-Sep
	-----Ball Roll Distance [†] -----								
Not Rolled	9.79	9.86	10.35	10.26	10.1b	9.79b	9.55a	8.84	9.89
Rolled 3x wk ⁻¹	10.41	10.53	10.32	10.26	10.26b	10.38a	9.18b	9.33	10.10
Rolled 5x wk ⁻¹	10.44	10.66	10.60	10.90	11.18a	10.56a	9.27b	9.02	10.41
P Value	0.5145	0.5768	0.5219	0.4238	0.0268 [‡]	0.0211 [‡]	0.0367 [‡]	0.3563	0.1471

[†] Ball Roll Distance (meters) measured using a Soccer Fieldgauge.

[‡] Means in a column followed by the same letter are not significantly different according to Fisher's protected LSD (p=0.05).

Table 4. NDVI as affected by rolling treatment.

Rolling Treatment	2013										
	12-Jul	19-Jul	26-Jul	2-Aug	9-Aug	23-Aug	30-Aug	13-Sep	27-Sep	11-Oct	25-Oct
	-----NDVI [†] -----										
Not Rolled	0.674	0.677	0.716	0.729a	0.699	0.729	0.750	0.738	0.728	0.763	0.711
Rolled 3x wk ⁻¹	0.667	0.687	0.709	0.712b	0.707	0.729	0.748	0.728	0.741	0.762	0.717
Rolled 5x wk ⁻¹	0.674	0.682	0.706	0.725a	0.696	0.711	0.743	0.732	0.732	0.764	0.717
P Value	0.931	0.6363	0.7468	0.0357 [‡]	0.7578	0.1434	0.9455	0.2056	0.137	0.7901	0.1263

[†] NDVI (0-1) measured using normalized vegetative difference index.

[‡] Means in a column followed by the same letter are not significantly different according to Fisher's protected LSD (p=0.05).

Table 5. NDVI as affected by rolling treatment.

Rolling Treatment	2014								
	5-May	30-May	13-Jun	27-Jun	11-Jul	31-Jul	15-Aug	5-Sep	19-Sep
	-----NDVI [†] -----								
Not Rolled	0.704	0.695	0.703	0.718	0.732	0.710	0.746	0.764	0.721
Rolled 3x wk ⁻¹	0.705	0.702	0.696	0.714	0.727	0.702	0.740	0.757	0.720
Rolled 5x wk ⁻¹	0.695	0.709	0.688	0.708	0.721	0.688	0.737	0.756	0.712
P Value	0.7298	0.5889	0.5045	0.62	0.0914	0.5831	0.7878	0.7638	0.6873

† NDVI (0-1) measured using normalized vegetative difference index.

Surface Hardness

Surface hardness measurements obtained ranged between gmax ratings of 42.6 and 70.8. The mean gmax rating across all treatments was 55.6 in 2013 and 56.8 in 2014. The only rating date with statistical differences among rolling treatments was the final rating date in 2013 (25 October), in which plots rolled 3 and 5 times wk^{-1} had significantly harder surfaces than untreated plots (Tables 6 and 7). The surface hardness results show that consistent rolling did not appear to make the playing surface harder, other than at the end of 2013. Although there was that one instance of rolled plots measuring harder than the untreated plots, the combination of aeration and frost heaving in the spring alleviated the differences. The differences were not replicated anywhere in 2014. Accumulation of sand topdressing may have also created a rootzone less prone to compaction, and thus less likely to produce differences in surface hardness.

Soil Infiltration

Infiltration rates were obtained at the end of each year using a double ring-infiltrometer and ranged from 0.77 and 0.82 cm hr^{-1} . The mean infiltration rate across all treatments was 0.78 cm hr^{-1} in 2013 and 0.80 cm hr^{-1} in 2014. No significant differences for infiltration rate were observed among treatments in 2013 and 2014 (Table 8). The low infiltration rates seen are typical of a higher clay content, native soil sports field. The accumulation of rolling treatments did not have any effect on infiltration measured at the end of each year.

Surface Stability

Shear strength measurements were obtained to evaluate surface stability and ratings ranged between 18.4 and 26.2 Newton meters (Nm). The mean shear strength rating across all treatments was 21.6 Nm in 2013 and 24.5 Nm in 2014. There were no statistical shear strength

differences among rolling treatments in 2013 and 2014 (Tables 9 and 10). Surface stability is more of a measure of the strength of the turfgrass plant in the upper rootzone and thatch layer than the soil properties. Rolling did not have much of an effect on the heath or performance of the turfgrass plant, and therefore did not affect the stability of the playing surface.

Root Mass

Root mass samples were collected at a depth of 20.32cm for each plot at the end of each year and ranged from 0.49 to 1.09 grams (g). No statistical differences occurred for 2013 and 2014 end of year root mass samples (Table 11). In both years, increased weekly rolling frequency did show greater root mass, but again, no statistical differences resulted from either sampling date. However, this may be notable, as Nikolai, et al. did not discover statistically significant root mass increases on putting greens until year five of a putting green study.

Table 6. Surface Hardness as affected by rolling treatment.

Rolling Treatment	2013										
	12-Jul	19-Jul	26-Jul	2-Aug	9-Aug	23-Aug	30-Aug	13-Sep	27-Sep	11-Oct	25-Oct
	-----Surface Hardness [†] -----										
Not Rolled	46.4	50.2	50.6	52.4	59.3	53.7	42.6	53.8	59.3	54.4	54.8b
Rolled 3x wk ⁻¹	52.3	55.3	55.2	58.2	65.8	58	45.4	56.4	67.3	57.2	61.3a
Rolled 5x wk ⁻¹	52.6	55	55.3	60.3	70.8	60.3	44.8	58.2	62.6	54.9	60.3a
P Value	0.3245	0.1987	0.3239	0.0885	0.1084	0.231	0.3759	0.095	0.6158	0.5878	0.0385 [‡]

[†] Surface Hardness (gmax) measured using Clegg Impact Soil Tester.

[‡] Means in a column followed by the same letter are not significantly different according to Fisher's protected LSD (p=0.05).

Table 7. Surface Hardness as affected by rolling treatment.

Rolling Treatment	2014								
	5-May	30-May	13-Jun	27-Jun	11-Jul	31-Jul	15-Aug	5-Sep	19-Sep
	-----Surface Hardness [†] -----								
Not Rolled	50.4	63.8	52.7	49.1	55.6	66	52.7	49.8	54.7
Rolled 3x wk ⁻¹	52.2	65	59.9	53.3	56.3	67.4	54.7	50.1	57.3
Rolled 5x wk ⁻¹	52.4	70.7	58.4	54.3	57.6	64.1	54.9	51.4	58
P Value	0.8111	0.8111	0.525	0.2783	0.9669	0.823	0.7691	0.5956	0.7593

[†] Surface Hardness (gmax) measured using Clegg Impact Soil Tester.

Table 8. Infiltration rate as affected by rolling treatment.

Rolling Treatment	2013	2014
	5-Nov	11-Oct
	-----Infiltration Rate [†] -----	
Not Rolled	0.79	0.81
Rolled 3x wk ⁻¹	0.79	0.82
Rolled 5x wk ⁻¹	0.77	0.78
LSD (p=0.05)	0.863	0.912

NS Indicates not significantly different at the p=0.05 probability level.

[†] Infiltration rate (cm hr⁻¹) as measured using a double ring infiltrometer.

Table 9. Surface Stability as affected by rolling treatment.

Rolling Treatment	2013										
	12-Jul	19-Jul	26-Jul	2-Aug	9-Aug	23-Aug	30-Aug	13-Sep	27-Sep	11-Oct	25-Oct
	----- Surface Stability [†] -----										
Not Rolled	22.1	19.4	20.3	18.7	23.4	20.8	19.2	20.1	25.4	22.6	21.9
Rolled 3x wk ⁻¹	21.8	21.3	19.8	20.7	23.1	21.8	19.7	19.4	26.2	22	22.8
Rolled 5x wk ⁻¹	21.8	21.3	20.9	21.2	22.8	22	18.4	20.6	25.4	21.8	22.9
P Value	0.8587	0.3871	0.1865	0.104	0.5828	0.3552	0.3032	0.0994	0.7978	0.759	0.5761

NS Indicates not significantly different at the p=0.05 probability level.

† Surface Stability (Nm) measured by testing shear vane strength.

Table 10. Surface Stability as affected by rolling treatment.

Rolling Treatment	2014								
	5-May	30-May	13-Jun	27-Jun	11-Jul	31-Jul	15-Aug	5-Sep	19-Sep
	-----Surface Stability [†] -----								
Not Rolled	26.2	24.1	24.9	24.8	24.3	26	25.7	24.4	24.9
Rolled 3x wk ⁻¹	25.8	24.4	23.6	25.6	24.1	24.4	25.3	23.2	24.4
Rolled 5x wk ⁻¹	25.1	24.6	24.1	23.1	24	23.9	23.2	23.4	23.7
P Value	0.5072	0.959	0.6682	0.2387	0.9771	0.4608	0.4815	0.7024	0.2252

[†] Surface Stability (Nm) measured by testing shear vane strength.

Table 11. Root Mass as affected by rolling treatment.

Rolling Treatment	2013	2014
	5-Nov	1-Oct
	-----Root Mass†-----	
Not Rolled	0.89	0.49
Rolled 3x wk ⁻¹	0.93	0.55
Rolled 5x wk ⁻¹	1.09	0.65
P Value	0.6228	0.6535

† Root Mass (grams) measured at 20.32cm depth.

Soil Moisture Content

Volumetric moisture content of the soil, or soil moisture content (SMC) was measured with a TDR and ranged between 14.7 and 42.9%. The mean SMC across all treatments was 31.7% in 2013 and 30.4% in 2014. There were no rating dates with statistical SMC differences among rolling treatments (Tables 12 and 13). The TDR probes used for these measurements were 7.62 cm in length, which gives an average SMC throughout that depth. A set of shorter probes, such as 2.81 cm, would have measured SMC in the uppermost portion of the rootzone, which is more likely to show moisture retention differences caused by rolling.

Broadleaf Weed Population

Upon completion of the study (September 2014), dandelion and broadleaf plantain weeds were counted for the entirety of each plot and ranged from 36 to 134. Mean weed counts were 87.0 for untreated plots, 70.3 for plots rolled 3 times wk^{-1} and 68.7 for plots rolled 5 times wk^{-1} (Table 14). No statistical differences in weed populations were present among rolling treatments. In order suppress a pest such as a weed, the repeated force caused by rolling needs to be more than the weed survive, but ideally, less than what will significantly damage the intended turfgrass plant. The two targeted weeds in this study, dandelion and broadleaf plantain, are both hardy plants that typically can withstand significant traffic stress. A more delicate weed species, such as white clover, may be more effected by repeated rolling stress.

Table 12. Soil Moisture Content as affected by rolling treatment.

Rolling Treatment	2013										
	12-Jul	19-Jul	26-Jul	2-Aug	9-Aug	23-Aug	30-Aug	13-Sep	27-Sep	11-Oct	25-Oct
	-----Soil Moisture Content [†] -----										
Not Rolled	31.43	42.9	28.3	34.33	28.5	26.1	37.6	33	33	38.8	30.73
Rolled 3x wk ⁻¹	28.33	37.47	28.83	31.93	26.43	24.23	33.57	31.47	31.7	37.6	29.7
Rolled 5x wk ⁻¹	29.27	39.03	28.93	31.5	25.23	24.43	35.5	29.9	31.47	35.93	29.1
LSD (p=0.05)	0.4602	0.5133	0.9034	0.2182	0.4952	0.5789	0.5547	0.119	0.8461	0.2215	0.539

NS Indicates not significantly different at the p=0.05 probability level.

† Soil Moisture Content (%) measured using time domain reflectometry (TDR).

Table 13. Soil Moisture Content as affected by rolling treatment.

Rolling Treatment	2014								
	5-May	30-May	13-Jun	27-Jun	11-Jul	31-Jul	15-Aug	5-Sep	19-Sep
	-----Soil Moisture Content [†] -----								
Not Rolled	24.6	16	36	41.6	34.5	26.3	37.7	37	30.8
Rolled 3x wk ⁻¹	23.9	14.7	35.3	39.7	31.1	23.8	35.3	34.8	29
Rolled 5x wk ⁻¹	24	14.9	34.9	38.6	31.6	23.7	35.6	36	29.1
LSD (p=0.05)	0.793	0.969	0.833	0.408	0.575	0.608	0.252	0.092	0.386

[†] Soil Moisture Content (%) measured using time domain reflectometry (TDR).

Table 14. Weed Population as affected by rolling treatment.

Rolling Treatment	2014
	19-Sep
	Weed Count [†]
Not Rolled	87.0
Rolled 3x wk ⁻¹	70.3
Rolled 5x wk ⁻¹	68.7
LSD (p=0.05)	0.3184

† Total number of dandelion and broadleaf plantain plants plot⁻¹.

CONCLUSIONS

The popularity of rolling turfgrass playing surfaces has always hinged on the balance of benefits and detriments, both real and perceived. The most recent resurgence of rolling golf greens has come about due to an arms race for increasingly faster putting surfaces (Hartwiger, 1996) combined with evidence that current rootzones are not necessarily prone to significant compaction. Other potential benefits such as turfgrass pest suppression, increased soil moisture content, and reduced mowing costs have been noted as cause for more frequent greens rolling (Nikolai et al., 2001). For frequent rolling to become commonplace on sports fields, benefits documented on research putting greens would have to be duplicated on research sports fields. Additionally, fears of detrimental effects of rolling associated with compaction and/or leaf tissue bruising would have to be overcome. Lastly, every decision to consistently roll a sports field will likely come down to comparing the noted potential benefits and detriments to some sort of labor/cost analysis.

As for the benefits, statistical differences in surface smoothness were not consistently attained. However, they did occur enough to warrant further examination of how to best create a smoother surface on sports fields via rolling and how long those effects can last. Regarding all other parameters measured, there were no benefits observed in this two-year study and thus, based on this research, reasons to frequently roll sports fields do not exist. However, it is important to note that this research was performed on native soil and it is certainly worthy of consideration that the results might be different had the study taken place on a predominantly sand root zone. Additionally, a roller with a greater psi might have led to more statistical difference by creating a greater weight upon the turfgrass canopy and underlying mat/thatch.

Statistically significant surface hardness resulted at the end of the first of the year of research, which gives some reason to believe that the accumulation of rolling over the course of time may contribute to a harder surface. This may have then been alleviated by aeration with no subsequent accumulation in year two. Beyond that, evidence of any indicators of compaction such as decreased turfgrass quality, root strength or mass, or infiltration rates was not observed. It is possible that some compaction and/or hard surfaces will occur with rolling, however it can be minimized and alleviated by other maintenance practices such as rootzone cultivation and sand topdressing.

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Chapter 2:

Effect of Rolling on Sports Fields with Varied Levels of Simulated Athlete Foot Traffic

INTRODUCTION

Aside from the physical makeup of the turfgrass species and typical soil composition, golf course greens and sports fields differ in another significant way: the nature of the game performed upon them. The human actions typically performed on greens throughout the duration of a round of golf include walking, standing, crouching, and bending over. While these movements over time can accumulate to create noticeable effects on the turfgrass surface and root zone, they are not nearly as impactful as the movements occurring on sports fields.

The most popular sport in the world is known globally as “association football” or most commonly referred to as just “football.” In North America, the game is usually referred to as “soccer” and it is one of the fastest growing sports in the country. In virtually every soccer match or training session, the common movements of the athletes include: stopping, starting, change of direction, jumping, sliding, diving, running, and much more (Canaway, 1976). These aggressive actions, over time, can have significant detrimental effects on the field in which they are performed. Therefore, it is very important to consider athlete traffic when attempting to obtain an accurate evaluation of the effects of a mechanical practice on a sports field (Henderson, et al., 2005).

The impact of athlete traffic on sports fields are expressed in two different ways: wear of the turfgrass plant and disturbance of the rootzone soil (Beard, 1973). Turfgrass wear from traffic includes physical damage of the plant tissue or removal of the plant from the soil altogether, which are primarily caused by horizontal forces of an athlete’s movement (cutting, twisting, etc.). On the other hand, changes in soil properties are most often manifest as a hard, compacted

surface caused by downward forces associated with running, jumping, and falling (Vanini, et al, 2007).

Initial attempts to simulate wear and compaction caused by traffic on turfgrass was achieved by driving vehicles across research plots (Morrish and Harrison, 1948). Although this certainly created compaction by way of significant downward forces (likely too much so), it did not account for the lateral movements that are just as common and detrimental to the playing surface. In 1958, University of California Horticulturist M.H. Kimball developed the first known apparatus designed specifically to traffic upon turfgrass. The design of Kimball's Mechanized Turfgrass Wear Tester included wooden replicated "feet" that provided both vertical and horizontal forces to the surface (Perry, 1958). Yet even into the 1970's, studded rolling drums were still the most commonly used machines to provide simulated traffic (Van Der Horst, 1970). These devices were a very time efficient method of providing replicated traffic that was not too dissimilar from foot traffic created by golfers on greens. However, Canaway (1976) considered this method to be unrepresentative of common traffic on sports fields. He developed the idea of a traffic simulator with differentially connected studded drums that turn at different speeds, which added shearing forces to previously used devices. This ultimately led to the pull-behind traffic simulation mechanism known as the Brinkman Traffic Simulator, which is widely used to this day (Henderson, et al., 2005).

Although quite an advancement in the ability to replicate foot traffic on a sports field, the movement of the Brinkman still did not mimic that of an athlete's foot striking and pushing off the ground. Henderson et al. (2005) satisfied this unmet need by creating and extensively testing the Cady Traffic Simulator, which is a modified walk-behind core cultivation unit. Each coring head of the unit is fitted with a cleated "foot" that provides significant force in multiple

directions and best replicates the movements and impact caused by athletes performing on a turfgrass sports field.

To better understand the potential positive or negative effects of a mechanical practice such as rolling on a sports field, it is imperative to include stressful conditions created by the sport(s) played upon it. At the time of this study, the Cady Traffic Simulator appears to best provide traffic simulation representative of the game of soccer.

In 2013, this study was initiated to examine numerous effects of frequent rolling on Kentucky bluegrass sports fields in combination with simulated athlete traffic. The objective of the research was to evaluate how frequent rolling under both competition and practice-like association football conditions affected turfgrass quality, surface hardness, soil moisture content, and surface stability on native soil sports fields. In addition, broadleaf weed populations were assessed to further examine the effects of rolling and traffic.

MATERIALS AND METHODS

Research was conducted in 2013 and 2014 at the Michigan State University Hancock Turfgrass Research Center in East Lansing, Michigan on a site established in 2005 from seed as a Kentucky bluegrass sports field. The seed used for establishment was identical to the nine-way blend formulated for the 2001 modular field installation at Spartan Stadium on the campus of Michigan State University (Gilstrap, et al. 2002). The soil type was a native soil base, Colwood-Brookston loam (a poorly drained loam soil). Particle size analysis of the native soil was 49% sand, 33% silt, and 18% clay.

The site was mowed at a 2.54 cm cutting height 3 times wk⁻¹ using a triplex reel-mower (2653B Precision Cut Trim and Surrounds Mower, Deere & Company, Moline, IL). Throughout each growing season, 244.6 kg ha⁻¹ of nitrogen (N) was applied using a combination of weekly foliar-sprayed solubilized urea (46-0-0) and three granular fertilizer applications (Contec DG 18-9-18, The Andersons, Inc., Maumee, OH). Irrigation was applied nightly at a rate of 0.25 cm. The field was core aerated each spring and fall (ProCore 648, The Toro Company, Bloomington, MN) equipped with 1.27 cm diameter hollow-tines. Sand topdressing was applied at a rate of 0.04 cm at 1-wk intervals between 1 July and 25 October 2013 and again between 1 May and 19 September 2014 for a total sand topdressing layer of 1.88 cm. Particle size analysis for the topdressing was 0.5% 2mm, 16.4% 1mm, 24.5% 0.5mm, 43.2% 0.25mm, 14.2% 0.15mm, and 0.9% 0.05mm.

The study was designed as a two-factor, split-plot design with three replications. The main factor consisted of five different rolling treatments: rolling 2 times wk⁻¹, 4 times wk⁻¹, eight times wk⁻¹, 16 times wk⁻¹, and no rolling (Table 3). Rolling treatments were applied with a triplex reel-mower (2343 Triplex Mower, Deere & Company) equipped with Tru-Surface Vibe

Greens Rollers (Turflite, Inc., Moscow Mills, MO). The second factor consisted of three levels of simulated foot traffic: one traffic event wk^{-1} , five traffic events wk^{-1} , and no traffic (Table 4). Simulated traffic was applied weekly using a Cady Traffic Simulator to mimic the amount of athlete foot traffic taking place on a game field (one traffic event wk^{-1}) and on a practice field (five traffic events wk^{-1}) (Henderson, et al., 2005).

The main plots measured 5.2 x 2.8 m with 0.7 m buffer strips and were randomly assigned one of the five rolling treatments. Each main plot was then split into three sub-plots, measuring 1.7 x 2.8 m, and randomly assigned one of the three traffic treatments. Treatments were applied from 21 September to 25 October in 2013 and 1 May to 5 September in 2014.

Plots were regularly evaluated for NDVI, surface hardness, visual wear, soil moisture content, and shear vane strength (a measure of surface stability).

Normalized vegetative difference index (NDVI) ratings were recorded with an NDVI color meter (FieldScout TCM 500 NDVI Turf Color Meter, Spectrum Technologies, Inc.). Subsamples were taken at three random locations within each plot. Surface hardness was measured with a Clegg Impact Tester (Turf-Tech International) equipped with a 2.25 kg hammer. The hammer was dropped in three random areas within each plot and gravities (“G-max”) measurements were recorded. Visual wear ratings were based on scale of 1 to 9 where 1=no living turfgrass remaining, 6=acceptable amount of remaining healthy turf, and 9=full, healthy turfgrass cover.

Volumetric moisture content of the soil was recorded at three random locations using time domain reflectometry (TDR) technology, recorded with a FieldScout TDR 300 Soil Moisture Meter (Spectrum Technologies, Inc). Surface stability was evaluated with a Shear Strength Tester (Turf-Tech International) to measure shear vane strength. The device was

inserted into the surface at three random locations within each plot and turned until the turf began to tear and give way. The maximum amount of torque applied by the device was recorded for each location.

Before treatments began, white clover patches were established by removing a soil core to a depth of 12.7 cm from each subplot with a 10.8 cm diameter cup cutter. The void in each subplot was replaced with an identically sized soil core taken from an off-site white clover weed plot at the HTRC. Upon conclusion of the study, the smallest and largest diameter of each white clover patch was measured with a ruler and the average of the two measurements was recorded.

All data were tested using analysis of variance (ANOVA) to determine significant effects ($p \leq 0.05$). When treatment differences were significant analyzed using the proc MIXED procedure of SAS 9.2 (SAS Institute Inc., Cary, NC) and means were separated using Fisher's protected least significant difference (LSD) procedure at $\alpha = 0.05$.

RESULTS AND DISCUSSION

NDVI

NDVI measurements, as an indicator of turfgrass performance, were taken on scale of 0-1 and ranged between 0.680 and 0.764. The mean turfgrass quality rating across all treatments was 0.737 in 2013 and 0.722 in 2014. For the main effect of rolling frequency, in both 2013 and 2014, there was only one rating date in each year with statistical differences among rolling treatments. On 27 September 2013, plots rolled 16 times wk^{-1} had the lower turfgrass quality and were statistically lower than all treatments other than not rolled. On 11 July 2013, plots rolled 16 times wk^{-1} again had the lowest turfgrass quality; this time statistically lower than 4 and 8 times wk^{-1} . Also, on that date, rolling 8 times wk^{-1} improved turfgrass quality versus not rolling (Table 15). These differences did not occur often enough to indicate that any frequency of use with this roller influences NDVI, or turf performance.

NDVI differences among traffic treatments were consistently significant. Plots that received practice-like simulated (high) traffic had statistically lower turfgrass quality ratings than the other two treatments on eight out of the 10 dates across both years. For the first rating of 2014 (5 May), high traffic had better quality than the other traffic treatments and on the second rating of 2014 (30 May), there were no differences among traffic treatments. Plots that received low traffic resulted in lower turfgrass quality ratings than the no traffic plots on only one date, 25 October 2013 (Table 16). These results show that traffic clearly has a more significant impact on NDVI than rolling. It also shows that increasing the amount of traffic creates a more significant detrimental effect on turf performance.

Table 15. NDVI as affected by rolling treatment.

Rolling Treatment	2013			2014						
	27-Sep	11-Oct	25-Oct	5-May	30-May	12-Jun	11-Jul	31-Jul	15-Aug	5-Sep
	-----NDVI [†] -----									
Not Rolled	0.725ab	0.762	0.714	0.706	0.720	0.680	0.717bc	0.706	0.760	0.760
Rolled 2x wk ⁻¹	0.732a	0.769	0.719	0.693	0.721	0.693	0.722abc	0.707	0.758	0.763
Rolled 4x wk ⁻¹	0.734a	0.766	0.721	0.697	0.727	0.687	0.725ab	0.707	0.754	0.769
Rolled 8x wk ⁻¹	0.734a	0.765	0.718	0.696	0.722	0.702	0.734a	0.707	0.757	0.769
Rolled 16x wk ⁻¹	0.717b	0.765	0.709	0.697	0.707	0.683	0.708.44c	0.695	0.759	0.759
P Value	0.0054 [‡]	0.911	0.3541	0.3954	0.2187	0.4538	0.0459 [‡]	0.3311	0.9202	0.7002

[†] NDVI (0-1) measured using normalized vegetative difference index.

[‡] Means in a column followed by the same letter are not significantly different according to Fisher's protected LSD (p=0.05).

Table 16. NDVI as affected by rolling treatment.

Rolling Treatment	2013			2014						
	27-Sep	11-Oct	25-Oct	5-May	30-May	12-Jun	11-Jul	31-Jul	15-Aug	5-Sep
	-----NDVI [†] -----									
No Traffic	0.742a	0.779a	0.726a	0.691b	0.724	0.711a	0.739a	0.717a	0.775a	0.775a
Low Traffic	0.735a	0.769a	0.717b	0.689b	0.716	0.704a	0.729a	0.708a	0.768a	0.771a
High Traffic	0.707b	0.748b	0.706c	0.713a	0.718	0.651b	0.696b	0.689b	0.730b	0.746b
P Value	0.0001 [‡]	0.0002 [‡]	0.0001 [‡]	0.0226 [‡]	0.5921	0.0001 [‡]	0.0001 [‡]	0.0002 [‡]	0.0001 [‡]	0.0001 [‡]

[†] NDVI (0-1) measured using normalized vegetative difference index.

[‡] Means in a column followed by the same letter are not significantly different according to Fisher's protected LSD (p=0.05).

Surface Hardness

Surface hardness measurements were taken and gmax ratings ranged between 48.1 and 76.9. The mean gmax rating across all treatments was 56.5 in 2013 and 56.6 in 2014. The only rating date with statistical surface hardness differences among rolling treatments was 11 July 2014, in which plots rolled 2 times wk^{-1} had a significantly lower gmax rating than any other rolling treatment (Table 17). Significant differences resulted from surface hardness measurements among traffic treatments on numerous occasions. In 2013, on the final rating date (25 October), the high simulated traffic treatment resulted in a harder surface than low traffic plots, which in-turn were significantly harder than the no traffic treatment. These same differences occurred on 15 August 2014. Overall in 2014, the high simulated traffic treatment was significantly harder than both the low simulated traffic and no traffic plots on six of the eight rating dates, including the last five (Table 18). Just as with other sports field performance measures, surface hardness was more affected by traffic than rolling. The results also consistently showed that increasing the amount of traffic led to even more surface hardness.

Table 17. Surface Hardness as affected by rolling treatment.

Rolling Treatment	2013				2014							
	13-Sep	27-Sep	11-Oct	25-Oct	5-May	30-May	12-Jun	27-Jun	11-Jul	31-Jul	15-Aug	5-Sep
	-----Surface Hardness [†] -----											
Not Rolled	58.4	57.2	52.8	56.5	52.5	63.3	49.8	55.4	55.7a	67.7	55.7	51.9
Rolled 2x wk ⁻¹	56.2	56.3	52.6	56.3	51.4	60.1	46.2	53.6	50.4b	68.9	54.7	51.2
Rolled 4x wk ⁻¹	57.9	59.3	53.3	57.8	52.1	63.3	48.2	51.8	54.7a	68.7	53.7	50
Rolled 8x wk ⁻¹	58.3	59	52.4	56.7	53.8	66.7	49.8	53.9	57.2a	69.8	53.3	50.7
Rolled 16x wk ⁻¹	58	58.6	54.6	59.1	55.6	67.2	50.6	56.6	56.6a	73.7	58.6	55.5
P Value	0.7838	0.2458	0.7373	0.7536	0.2529	0.2988	0.3934	0.298	0.0388 [‡]	0.7144	0.2273	0.194

[†] Surface Hardness (gmax) measured using Clegg Impact Soil Tester.

[‡] Means in a column followed by the same letter are not significantly different according to Fisher's protected LSD (p=0.05).

Table 18. Surface Hardness as affected by traffic treatment.

Traffic Treatment	2013				2014							
	13-Sep	27-Sep	11-Oct	25-Oct	5-May	30-May	12-Jun	27-Jun	11-Jul	31-Jul	15-Aug	5-Sep
	-----Surface Hardness [†] -----											
No Traffic	58.2	57.5	52.4	54.9c	52.1b	65.1	50.3	51.9b	50.7b	64.3b	51.5c	48.2b
Low Traffic	56.2	57.7	53.3	57.1b	51.7b	62.0	48.3	53.1b	52.6b	68.0b	54.6b	50.0b
High Traffic	58.9	59.1	53.8	59.9a	55.4a	65.2	48.1	57.7a	61.4a	76.9a	59.5a	57.3a
P Value	0.0634	0.2653	0.299	0.0004 [‡]	0.0374 [‡]	0.2442	0.2404	0.0036 [‡]	0.0001 [‡]	0.0001 [‡]	0.0001 [‡]	0.0001 [‡]

[†] Surface Hardness (gmax) measured using Clegg Impact Soil Tester.

[‡] Means in a column followed by the same letter are not significantly different according to Fisher's protected LSD (p=0.05).

Surface Stability

Shear strength measurements were obtained to evaluate surface stability and ratings ranged between 15.2 and 25.8 Newton meters (Nm). The mean shear vane rating across all treatments was 20.0 Nm in 2013 and 24.5 Nm in 2014. There were no rating dates with statistical shear strength differences among rolling treatments in 2013 and one date in 2014. On 11 July 2104, plots rolled 16 times wk^{-1} had significantly less shear vane strength than plots rolled 4 and 8 times wk^{-1} (Table 19). While there were no treatments resulting in statistical shear strength differences in 2013, in 2014 statistical differences resulted among traffic treatments on all but one reading date. Plots receiving high traffic treatments consistently had lower shear vane strength than plots receiving no traffic throughout 2014. On each of the last five rating dates, high traffic plot also had lower shear vane strength than the low traffic plots. On three instances in the last half of 2014, the low traffic plots had lower shear vane strength than the no traffic plots (Table 20). Traffic again had a more significant effect on shear strength than rolling, and high traffic had a greater effect than low traffic. Since shear strength is essentially a measurement of the strength of the turfgrass plant in the upper rootzone, the results are likely due to the to the turfgrass plants inability to withstand the heavy stress incurred by the simulated traffic.

Table 19. Surface Stability as affected by rolling treatment.

Rolling Treatment	2013			2014							
	27-Sep	11-Oct	25-Oct	5-May	30-May	12-Jun	27-Jun	11-Jul	31-Jul	15-Aug	5-Sep
	----- Surface Stability [†] -----										
Not Rolled	20.7	19.7	19.8	23.06	22.61	19.89	21.33	22.17ab	22.17	20.72	20.67
Rolled 2x wk ⁻¹	19.7	19.3	19.8	23.22	22.44	20.61	21.28	22.61ab	22.89	21.50	19.83
Rolled 4x wk ⁻¹	20.4	19.8	20	23.11	23.67	20.56	21.50	23.28a	23.17	20.89	20.39
Rolled 8x wk ⁻¹	20.3	20.2	20.6	22.94	22.11	20.00	20.72	23.89a	22.50	20.50	21.00
Rolled 16x wk ⁻¹	21	19.3	20	21.89	22.17	20.11	20.28	21.00b	21.17	20.00	19.83
P Value	0.6672	0.7993	0.7606	0.5467	0.4784	0.949	0.3022	0.0386 [‡]	0.2061	0.5153	0.7464

[†] Root Stability (Nm) measured by testing shear vane strength.

[‡] Means in a column followed by the letter are not significantly different according to Fisher's protected LSD (p=0.05).

Table 20. Surface Stability as affected by rolling treatment.

Traffic Treatment	2013			2014							
	27-Sep	11-Oct	25-Oct	5-May	30-May	12-Jun	27-Jun	11-Jul	31-Jul	15-Aug	5-Sep
	----- Surface Stability [†] -----										
No Traffic	20.1	19.4	20.3	23.6a	23.0	21.4a	21.9a	23.4a	24.6a	22.9a	23.2a
Low Traffic	20.9	19.7	19.6	23.1a	22.5	21.0a	21.0b	22.9a	23.0b	22.4a	21.9b
High Traffic	20.3	19.9	20.1	21.9b	22.2	18.3b	20.1c	21.4b	19.5c	16.8b	15.9c
P Value	0.5366	0.9619	0.2874	0.0296 [‡]	0.3647	0.0001 [‡]	0.0014 [‡]	0.0033 [‡]	0.0001 [‡]	0.0001 [‡]	0.0001 [‡]

[†] Root Stability (Nm) measured by testing shear vane strength.

[‡] Means in a column followed by a different letter are significantly different according to Fisher's protected LSD (p=0.05).

Soil Moisture Content

Volumetric moisture content in the soil, or soil moisture content (SMC), ranged between 22.5 and 49.7%. The mean SMC measurements were 40.2% in 2013 and 38.2% in 2014. There were no ratings resulting in statistical SMC differences among rolling treatments (Table 21). On 11 and 25 October 2013, high traffic plots had a higher SMC than low and no traffic plots. On four of the final five rating dates of 2014, high traffic plots had a higher SMC than no traffic plots. For three of those dates, high traffic plots also had a higher SMC than low traffic plots (Table 22). The increase in soil moisture content for high traffic treatments was likely due to compacted soil and an increase in moisture held within micropores, which is not typically plant available water.

Turf Wear

Turfgrass wear was evaluated visually as a percentage of turf area that was depleted or thinned. In 2013, percentage of worn turf ranged from 5 to 21% and 3.7 to 35% in 2014. There were no statistical differences in wear by rolling treatment on any date in either year (Table 23). The high traffic treatment created more wear, statistically, than either of the other traffic treatments on every rating date in both years, except for 30 May 2014. Additionally, the low traffic treatment had significantly more wear than the no traffic treatment plots on the final two rate dates of the study (Table 24). Turf wear, like shear strength, was most affected by high traffic treatments due to repeating stress on the turfgrass plant. The plants inability to withstand, or recover from, that repeated stress caused there to be more areas of worn turf.

Table 21. Soil Moisture Content as affected by rolling treatment.

Rolling Treatment	2013			2014							
	27-Sep	11-Oct	25-Oct	5-May	30-May	12-Jun	27-Jun	11-Jul	31-Jul	15-Aug	5-Sep
	-----Soil Moisture Content [†] -----										
Not Rolled	41.2	42	36.9	30.36	23.09	47.08	46.51	38.98	33.6	43.64	40.1
Rolled 2x wk ⁻¹	43.3	42.4	36.4	31.36	24.8	49.14	46.98	42.13	33.07	43.43	39.67
Rolled 4x wk ⁻¹	41.5	40.6	36.4	32.09	23.43	49.73	47.54	40.51	33.49	43.44	40.51
Rolled 8x wk ⁻¹	38.7	42.2	37.6	31.2	22.53	47.33	47.26	40.87	32.6	43.48	39.52
Rolled 16x wk ⁻¹	44	44.1	36.6	30.14	23.01	46.8	46.12	40.39	29.08	43.14	40.6
P Value	0.315	0.1515	0.9284	0.6364	0.6176	0.447	0.804	0.516	0.646	0.9885	0.9195

[†] Soil Moisture Content (%) measured using time domain reflectometry (TDR).

Table 22. Soil Moisture Content as affected by traffic treatment.

Traffic Treatment	2013			2014							
	27-Sep	11-Oct	25-Oct	5-May	30-May	12-Jun	27-Jun	11-Jul	31-Jul	15-Aug	5-Sep
	-----Soil Moisture Content [†] -----										
No Traffic	41.0	41.4b	35.9b	31.3	23.0	47.0	45.4c	39.3b	29.7b	42.5b	39.3
Low Traffic	41.4	41.4b	35.5b	30.3	23.3	47.7	46.7b	40.2ab	31.1b	42.8b	40.0
High Traffic	42.9	44.0a	39.0a	31.5	23.8	49.4	48.6a	42.2a	36.4a	44.9a	40.9
P Value	0.256	0.0035 [‡]	0.0008 [‡]	0.1793	0.8255	0.1166	0.0001 [‡]	0.0349 [‡]	0.0011 [‡]	0.0464 [‡]	0.1926

[†] Soil Moisture Content (%) measured using time domain reflectometry (TDR).

[‡] Means in a column followed by the same letter are not significantly different according to Fisher's protected LSD (p=0.05).

Table 23. Turfgrass wear as affected by rolling treatment.

Rolling Treatment	2013		2014							
	11-Oct	25-Oct	5-May	30-May	12-Jun	27-Jun	11-Jul	31-Jul	15-Aug	5-Sep
	-----Percent wear [†] -----									
Not Rolled	13.4	14.0	16.4	11.6	15.2	12.8	14.6	15.8	17.7	14.0
Rolled 2x wk ⁻¹	10.1	8.5	14.6	10.9	14.0	12.2	12.2	15.2	14.6	15.2
Rolled 4x wk ⁻¹	10.7	10.7	15.2	10.3	15.8	10.9	12.8	14.0	14.6	14.0
Rolled 8x wk ⁻¹	12.3	13.4	17.1	9.7	15.8	13.4	15.8	17.1	18.3	13.4
Rolled 16x wk ⁻¹	12.9	17.3	16.4	15.2	18.3	17.1	17.1	18.9	17.1	13.4
P Value	0.2165	0.1719	0.1191	0.2878	0.5960	0.0707	0.0854	0.3143	0.6579	0.7530

[†] Percent wear (0-100) based on visual assessment of worn turf.

Table 24. Turfgrass wear as affected by traffic treatment.

Traffic Treatment	2013		2014							
	11-Oct	25-Oct	5-May	30-May	12-Jun	27-Jun	11-Jul	31-Jul	15-Aug	5-Sep
	-----Percent wear [†] -----									
No Traffic	9.0b	9.6b	12.9b	9.2	12.2b	11.1b	9.6b	11.4b	10.0c	7.8c
Low Traffic	10.1b	11.2b	14.7b	12.2	13.6b	11.8b	12.9b	13.3b	14.4b	11.1b
High Traffic	16.7a	17.3a	20.2a	13.3	21.7a	16.9a	21.0a	23.9a	25.0a	23.2a
P Value	0.0001 [‡]	0.0001 [‡]	0.0001 [‡]	0.0511	0.0001 [‡]	0.0001 [‡]	0.0001 [‡]	0.0001 [‡]	0.0001 [‡]	0.0001 [‡]

[†] Percent wear (0-100) based on visual assessment of worn turf.

[‡] Means in a column followed by the same letter are not significantly different according to Fisher's protected LSD (p=0.05).

Clover Patch Size

Upon completion of the study (October 2014), smallest and largest diameter of each pre-placed clover patch were measured and the average of the two was recorded. Smallest diameters ranged between 3 and 33 cm, while largest diameters ranged between 8 and 52 cm. Average diameter of each clover patch ranged between 5.5 cm and 42.5 cm. There were no statistical differences in average clover patch size among rolling treatments (Table 25). The high traffic treatments had a statistically smaller average diameter of patch clover (17.5 cm) than the low traffic treatments (24.7 cm) and the no traffic treatments (24.1 cm) (Table 26). The decrease in amount of clover when subjected to high traffic is likely due, in part, to the nature of the clover plant and the inability of its shallow root system to withstand frequent, heavy foot traffic compared to that of Kentucky bluegrass. The fact that traffic decreased clover size, but not rolling, could also indicate that a heavier, more aggressive roller for sports fields might result in a decrease in broadleaf weeds, as was reported by Nikolai on research putting greens.

Table 25. Clover diameter as affected by rolling treatment.

Rolling Treatment	2014
	5-Sep
	Clover Diameter [†]
Not Rolled	25.7
Rolled 2x wk ⁻¹	26.1
Rolled 4x wk ⁻²	24.8
Rolled 8x wk ⁻¹	19.8
Rolled 16x wk ⁻¹	19.0
P Value	0.1605

[†] Clover diameter (cm) averaged from shortest and longest diameters

Table 26. Clover diameter as affected by traffic treatment.

Traffic Treatment	2014
	5-Sep
	Clover Diameter [†]
No Traffic	27.1a
Low Traffic	24.7a
High Traffic	17.5b
P Value	0.0056 [‡]

[†] Clover diameter (cm) averaged from shortest and longest diameters

[‡] Means in a column followed by the same letter are not significantly different according to Fisher's protected LSD (p=0.05).

CONCLUSIONS

Simulated traffic is a critical component to sports field research, particularly when evaluating a possibly detrimental practice like rolling. Both rolling and athlete foot traffic, on their own, have the potential to cause compaction, harder surfaces, deplete turf cover, and cause an overall reduction in turf quality. When a playing surface is exposed to both frequent traffic and rolling, it is imperative to understand the effects of the combination to truly evaluate the merits of frequent rolling.

This research did not necessarily result in any beneficial reasons to warrant advocating frequent rolling on native soil sports fields. There were simply not enough instances of improved conditions created by rolling versus not rolling and no indication from this research that frequent rolling has the potential to improve the conditions of a native soil sports field. However, it is worth considering that the roller used in this study potentially did not generate enough psi on a higher cut turf to result in many of the benefits gained from rolling golf course putting greens. However, the lack of any significant detrimental effect of rolling 8 times wk^{-1} or less, should alleviate hesitation to frequently roll sports fields, particularly those constructed with a high sand rootzone.

It is clear from this research that the impact athletes can have on the surface of a sports field can be far more detrimental than that of a roller. High traffic treatments simulating five events wk^{-1} consistently resulted in significant increases in surface hardness and wear, which led to decreases in surface stability/strength and overall turf quality. Similar results were seen with traffic treatments simulating one event wk^{-1} , just not as often, or severe, as the high traffic treatments.

Also, of note, very rarely were any interactions observed among rolling frequency and traffic level with respect to parameters measured. With a good amount of confidence, it can be concluded that no additional benefit of rolling is created by changing the amount of traffic that a sports field receives. Similarly, the detriments caused in this research by traffic on a field were not dependent upon the frequency of rolling that took place.

While it is important to include amount of traffic as a consideration when performing mechanical practices, the data gathered did not show rolling had much of an effect on anything measured in this research. And while traffic, and particularly repeated traffic, has a significant effect on many parameters, combining traffic with rolling did not seem to intensify, nor negate, those effects.

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Chapter 3:

Effect of Rolling on Athlete Performance and Perception of Playing Conditions

INTRODUCTION

Countless hours and dollars go into maintaining high-level professional and amateur sports fields all over the world. These fields are maintained to meet expectations of advertisers, field managers, coaches, fans, parents, and most importantly: the athletes who perform on them. Athletes are highly critical of the physical properties of their playing surface (Baker and Canaway, 1993). For the sport of association football, they are particularly critical of two things: the grip of their foot on the surface, or traction, and the interaction of the ball with the surface, which can be described as surface smoothness.

Traction gained, or lost, during the athlete's interaction with the playing surface can have immense impact upon the athlete and their performance (McNitt, 1994). Beyond the vastly studied impact of traction on the potential for debilitating injuries to athletes, the amount and consistency of foot traction provided by the playing surface can be an important factor in the results of games.

In the highest-level sports, the smallest of errors on the field can have enormous and widespread economic impact. For example, at the end of every season in the English League Championship (or second division) of association football, there is a playoff game between two clubs to determine which will be promoted to the top division, called the English Premier League (EPL). With the EPL being widely considered the most popular league in the world's most popular sport, the winner of that game was estimated to earn at least 40 million British Pounds (GBP) of overseas broadcast income in 2012, compared to just 3 million GBP for the loser. That is a difference of roughly 46 million US Dollars in just TV revenue (Ma, 2012). Since the start of

the 21st century, this playoff game has been decided by only one goal 12 of the 17 times it has been played. Simply put, in a game of that magnitude, one small error created by a poor playing surface could end up costing a club, at the very least, tens of millions of dollars.

Just as important as the lack of actual slips, tears, and divots caused by a poor surface can be the perception an athlete has in the surface and their confidence in it. While a weakness in the turf causing an athlete to misstep, slow down, or fall can cause an immediate impact on a play in the short term, the lasting effect of that one moment can be the athlete's waning confidence in what he or she can accomplish on the playing surface for the remainder of that game.

Another important factor, particularly in association football, to an athlete's overall impression of a playing surface is the smoothness of the surface as it interacts with the ball (Bell, et al., 1985). While it is important to conduct rolling research that evaluates surface smoothness, another piece of the puzzle to determining the merit of rolling sports fields is: how do athletes perceive a smoother surface? Karcher, et al. (2001) performed research that tested golfer's abilities to gauge differences in green speeds on putting greens. They concluded golfers could not detect differences in green speed (BRD) of 15cm or less.

In golf, a putt is executed while standing still and isolated in complete silence, while the movements in association football and other contact sports are typically done under the pressure of movement, as well as various audible and visual distractions. A Fieldgauge, or other testing device, may tell us a surface is smoother, but can the athlete pick up on that difference while performing upon it?

MATERIALS AND METHODS

Research was conducted on 10 October 2014 at the Hancock Turfgrass Research Center (HTRC) and 30 September 2014 at the Old College Field (OCF) soccer practice field, both located on the campus of Michigan State University in East Lansing, Michigan. The HTRC site was a Kentucky bluegrass sports turf research plot established in 2005. The soil type was a native soil base, which consisted of approximately two-thirds Colwood-Brookston loam (a poorly drained loam soil) and one-third Aubbeenaubbee-Capac sandy loam (a somewhat poorly drained sandy loam soil). The OCF site was a Kentucky bluegrass soccer field used by the Michigan State University Men's and Women's Varsity Soccer Teams. The soil type was a native soil base, Cohoctah silt loam (a poorly drained silt loam soil).

Each site was mowed at a 2.54 cm cutting height 3 times wk⁻¹ using a John Deere 2653B Precision Cut Trim and Surrounds Mower (Deere & Company, Moline, IL) at the HTRC and a Toro 3500D Groundsmaster Sidewinder (The Toro Company, Bloomington, MN).

Two hours before athlete evaluations were taken, half of each field was rolled 5 times to ensure differences in surface smoothness and the other half of each field was rolled only once to give the entire surface a similar appearance. Ball roll distance (BRD) measurements were taken using a Soccer Fieldgauge (Cockerham, et al. 1995) and a FIFA-approved Nike Incyte Premium Match Ball (Nike, Inc., Beaverton, OR). BRD was measured three times in one direction and three times in the opposite direction along same path at two different locations for both the rolled and untreated halves of each site (Table 27).

Research plots were rated at OCF by 12 members of the Michigan State University Women's Varsity Soccer Team and at HTRC by 20 members of the Mason High School Boys' Varsity Soccer Team.

Table 27. Ball roll distance measurements (meters) taken two hours prior to athlete ratings.

	Old College Field		Hancock Turfgrass Research Center	
	1x Rolled	5x Rolled	1x Rolled	5x Rolled
Mean	8.59	9.79	9.00	10.93
Median	8.54	9.91	9.00	10.98
Range	2.75	1.83	0.92	5.19

Surface smoothness was evaluated by the athletes performing a soccer passing drill in four directions for a total of 90 seconds. Plots were then rated for smoothness on a scale of 1 to 5 based to the movement of the ball across the surface throughout the 90 seconds. The rating scale was as follows:

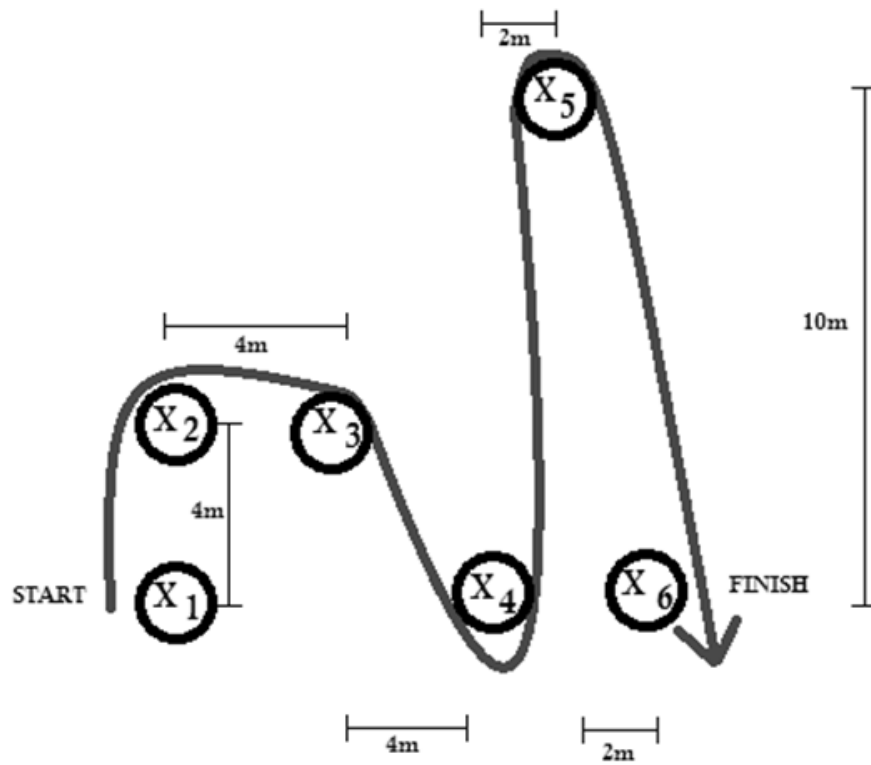
- 1 = Excellent; no surface imperfections
- 2 = Very Good
- 3 = Good; some effect on ball roll but still a quality surface
- 4 = Fair
- 5 = Poor; surface conditions are virtually unplayable

Traction was evaluated by the athletes running through a course designated by cone markers (Figure 1). Plots were rated by the athletes for traction on a scale of 1 to 5 based to the traction, or lack thereof, while the athlete ran the course. The rating scale was as follows:

- 1 = Excellent; no lack of traction throughout
- 2 = Very Good
- 3 = Good; some loose footing but still a dependable surface
- 4 = Fair
- 5 = Poor; traction was minimal and unsafe

Estimated probabilities of surface smoothness and traction being rated as “Excellent”, “Very Good”, “Good”, “Fair”, and “Poor” were determined using logistic regression analysis of data collected from the HTRC and OCF plots.

Figure 1. Running course design used to measure athlete traction.



RESULTS AND DISCUSSION

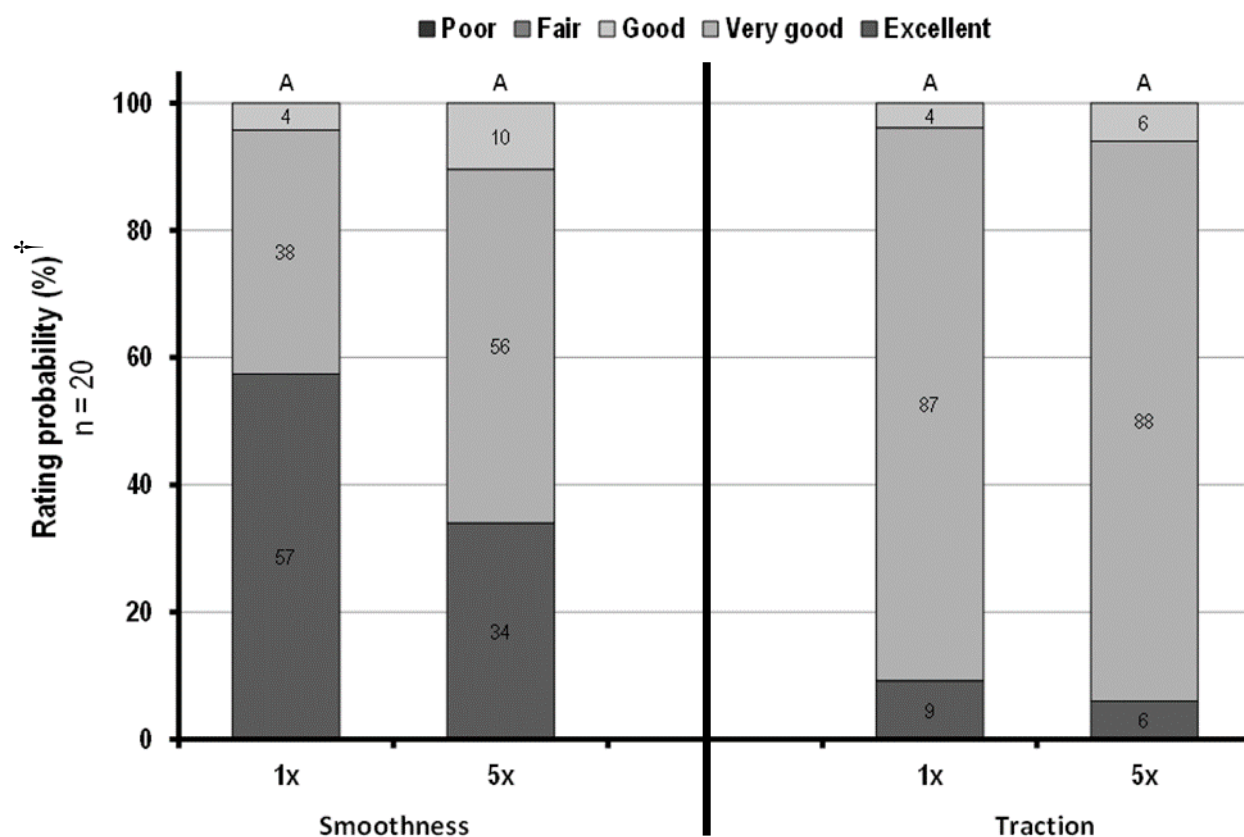
Surface Smoothness

All surface smoothness ratings were “Excellent”, “Very Good”, or “Good” at HTRC and OCF. In other words, no plots were rated as “Fair” or “Poor” at either location by any athlete. The HTRC 5 times rolled area had no statistically different probability of getting any certain smoothness rating than that of the once rolled area (Figure 2). The 5 times rolled area at OCF had a significantly higher probability of the smoothness being rated as only “Good” and significantly lower probability of being rated “Excellent”, as compared to the area rolled only once (Figure 3). This finding appears to be counterintuitive, but it could potentially explain that, at these ball roll distances, the ball was traveling too fast for the athletes to successfully receive the ball on their foot on a consistent basis. The lack of success in receiving the ball could have been attributed to a perceived lack of surface smoothness by the athletes. In other words, there may be a disconnect in the way ball roll distance and an athlete’s perception quantify a smooth surface. With that said, there was no evidence found in this evaluation to suggest that increasing ball roll distance by rolling had any effect on the traction the athletes as they performed on the plots.

Traction

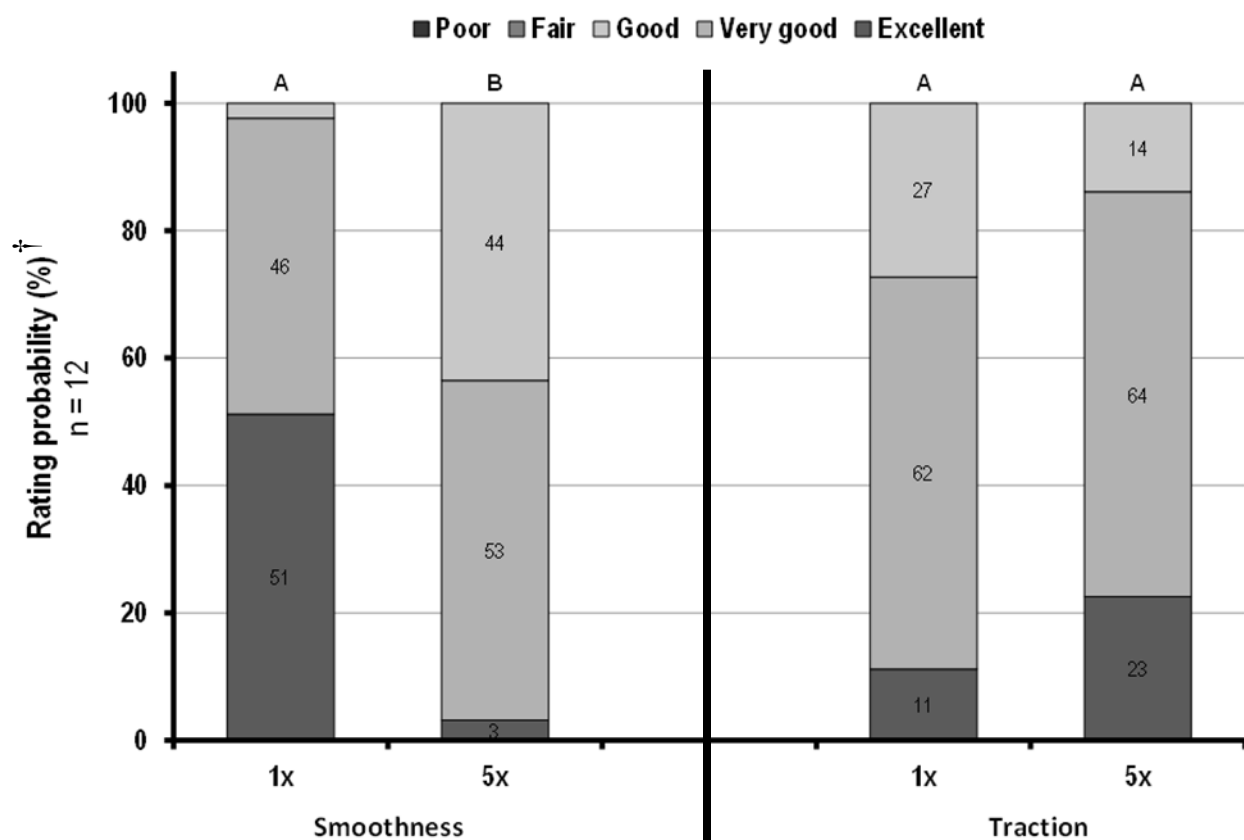
All traction ratings were “Excellent”, “Very Good”, or “Good” at HTRC and OCF. In other words, no plots were rated as “Fair” or “Poor” at either location by any athlete. The HTRC 5 times rolled area had no statistically different probability of getting any certain rating than that of the once rolled area (Figure 2). The 5 times rolled area at OCF had a significantly higher probability of being rated as only “Good” and significantly lower probability of being rated “Excellent” as compared to the area rolled only once (Figure 3).

Figure 2. Predicted probabilities of surface smoothness and traction ratings evaluated at the Hancock Turfgrass Research Center by the Mason High School Boys Varsity Soccer Team.



† Probabilities were estimated to be rated as either "Excellent", "Very Good", "Good", "Fair", or "Poor" using logistic regression analysis of data collected from plots Bars that do not share a letter are significantly different ($\alpha = 0.05$).

Figure 3. Predicted probabilities of surface smoothness and traction ratings evaluated at Old College Field by the Michigan State University Women's Varsity Soccer Team.



[†] Probabilities were estimated to be rated as either "Excellent", "Very Good", "Good", "Fair", or "Poor" using logistic regression analysis of data collected from plots. Bars that do not share a letter are significantly different ($\alpha = 0.05$).

CONCLUSIONS

The value of any maintenance input into a sports field certainly can, and should, be measured by how that field performs. While there are many great analytical devices to capture replicated data, it is important to place some value on the perception of the athletes who train and compete on those surfaces. While this study was limited in replications and parameters, the surface smoothness difference identified by the MSU Women may have teased out the idea that there is a disconnect in how research tools and athletes evaluate a playing surface. Or, more specific to surface smoothness discrepancy, there may be a threshold for ball roll speed in which athletes consider the surface “too fast for optimal performance.” Further research would be necessary to confirm, or discredit, either of those ideas.

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