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EFFECTS OF VARYING SURFACE CHARACTERISTICS ON THE HARDNESS AND TRACTION OF BASEBALL FIELD PLAYING SURFACES

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ABSTRACT

Within most baseball fields there is a non-turfed basepath surface in addition to a turfed playing surface that can be either natural or synthetic. Two important properties of any playing surface are its ability to absorb the energy generated upon impact (surface hardness) and the level of traction it provides to the athlete during play. Studies were conducted to determine the effects of varying surface characteristics on the hardness and traction of non-turfed basepath, natural turfgrass (*Poa pratensis* L.) and synthetic turf surfaces used for baseball. On non-turfed basepath surfaces, increases in soil compaction resulted in increases in surface hardness and both linear and rotational traction. Increasing scarification depth on plots receiving the highest level of compaction reduced both hardness and linear traction. Topdressing with a porous ceramic amendment, calcined clay, had no effect on surface hardness or linear traction, but reduced rotational traction values. Footwear worn by baseball players on non-turfed basepaths may be providing excessive traction on turfed areas of the field, both natural and synthetic, due to the configuration and shape of the studs on the sole of the shoe.

Keywords: non-turfed basepath, infill, synthetic turf, calcined clay, PENNFOOT

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INTRODUCTION

Baseball is a sport typically played on varying surfaces. Within most fields there is a turf area and a non-turfed basepath soil. Field managers spend much of their time grooming this non-turfed area. Maintenance practices include surface scarification, soil moisture management through irrigation and tarping, as well as the addition of soil conditioners like calcined clay. Calcined clay is a porous ceramic amendment often applied to non-turfed basepath surfaces as a topdressing to create a uniform color, keep the surface loose when players slide, and to manage soil moisture content (Puhalla et al., 2003).

An athlete interacts with a surface in two ways: by falling on it, and through foot-to-shoe-to-surface interactions (Baker and Canaway, 1993). Two important properties of a playing surface are its ability to absorb the energy generated when an athlete impacts that surface and the level of traction it provides to the athlete during play.

Surface hardness has been defined as the ability of a surface to absorb the impact energy created by any object striking that surface (Rogers III, 1988). Softer surfaces will absorb a larger percentage of the energy generated upon impact than harder surfaces (Bell and Holmes, 1988). When this impact energy is generated by an athlete's foot striking the playing surface, it is referred to as ground reaction force (Nigg et al., 1984). Ground reaction forces, which are commonly 2.5 to 3.0 times greater than one's body weight during an athletic maneuver, have been cited as risk factors in the incidence of both chronic and acute athletic injuries (Boden et al., 2000; Chappell et al., 2007; LaStayo et al., 2003).

During athletic competitions players often wear studded footwear to improve their ability to perform athletic maneuvers without slipping or falling. Forces that resist this motion have been termed traction forces, as they do not always obey the classical laws of friction (Shorten et al., 2003). If traction forces are too high, foot fixation may occur, placing a great deal of stress on lower extremity ligaments during movement (Shorten et al., 2003).

During a survey of baseball field surface conditions, Brosnan and McNitt (2008a, 2008b) reported similar surface hardness values for synthetic and natural turf, but found that non-turfed basepath surfaces measured significantly higher than either the synthetic or natural turf sections of fields. On natural turfgrass surfaces, Brosnan and McNitt (2008a, 2008b) reported that surface hardness was negatively correlated with soil moisture content ($r = -0.423$, $p \leq 0.001$). On infilled synthetic turf surfaces, they reported that increases in infill depth were associated with reductions in surface hardness ($r = -0.517$, $p \leq 0.001$). On non-turfed basepath surfaces, the researchers reported that reductions in surface hardness were associated with increases in the depth of loose soil on the surface following maintenance scarification ($r = -0.681$, $p \leq 0.001$), increased application rates of the soil conditioner, calcined clay, ($r = -0.522$, $p \leq 0.001$), and soil moisture content ($r = -0.684$, $p \leq 0.001$). Although not measured, Brosnan and McNitt (2008a) suggested that the amount of non-turfed basepath soil compaction that occurred during construction may be a significant factor in the high surface hardness of these areas.

Studies have investigated traction on natural turfgrass playing surfaces used for American football and soccer (Baker and Canaway, 1993; McNitt et al., 2004). Goodall et al. (2005) evaluated the rotational traction of five soil mixes used for non-turfed basepaths with a studded disc apparatus developed by Canaway and Bell (1986). However, in a review of the validity of methods used to evaluate the traction characteristics of playing surfaces, Nigg (1990) suggested that tests provide relevant information only when appropriate shoe soles are used and when the actual vertical force (loading weight) applied is similar to that applied by athletes. Little data are published on the traction of standard baseball footwear with steel studs (also termed “cleats”). Unlike the athletic footwear worn by American football or soccer players, baseball footwear contains flat metal studs as opposed to rounded studs. Kirk et al. (2006a) reported that cuboid shaped studs yield traction values 20% higher than cylindrical shaped studs (Kirk et al., 2006b).

The objective of this research was to determine the effects of varying surface characteristics on the surface hardness and traction of playing surfaces used for baseball.

MATERIALS AND METHODS

Three experiments were conducted to determine the effects of varying surface conditions on the three types of playing surfaces used for baseball. These include: non-turfed basepath soil, natural turfgrass and infilled synthetic turf. All three experiments were conducted at the Joseph Valentine Turfgrass Research Center, University Park, PA. Plots were constructed in an attempt to represent the range of conditions reported in a baseball field survey conducted by Brosnan and McNitt (2008a, 2008b).

Plot construction

Non-turfed basepath experiment

Nine 37.2- by 37.2-m plots were constructed to a depth of 10 cm using Diamond-Tex Premium infield mix (Diamond-Tex, Inc., Honeybrook, PA). Particle size analysis indicated that basepath soil measured 10% gravel, 56% sand (16% of particles 2.0-1.0 mm; 9% of particles 1.0-0.5 mm; 8% of particles 0.5-0.25 mm; 6% of particles 0.25-0.15 mm; 17% of particles 0.15-0.05 mm), 27% silt, and 7% clay.

Treatments included compaction of the sub-base soil layer, scarification depth, and the amount of soil conditioner (calcined clay) present. Treatments were oriented in a strip-split plot design. Soil compaction served as the whole plot treatment. Compaction treatments were applied with a 907-kg roller pulled by a Ventrac tractor (Model 4200 VXD, Ventrac Inc., Orrville, OH) with a dual turf tire package. Plots were rolled in order to achieve soil bulk densities of approximately 1.8, 1.5, and 1.2 Mg m^{-3} on high, medium, and low compaction plots, respectively. Soil bulk density measurements were made using a Troxler 3400-B surface moisture density gauge (Troxler Electronic Laboratories, Research Triangle Park, NC) according to the methods of Gardner (1986).

Whole plots were divided into four 1.5- by 1.5-m subplots that received applications of a calcined clay soil conditioner (heat treated, 649˚C, 74% SiO_2, average diameter 1.2 mm; Turface MVP, Profile Products, Buffalo Grove, IL) at four rates: 0, 4883, 9767, 14650 kg ha^{-1}.

Each block was divided into 1.5 by 6.1-m strips that ran across all whole plots. Each strip was scarified to a different depth (0, 6.5, 12.7, and 19.0-mm). Scarification depth treatments were applied with a nail drag apparatus constructed according to the procedures outlined in ASTM specification F-2107 (American Society for Testing Materials, 2005a).

Natural turfgrass experiment

Natural turfgrass plots, 18.6- by 18.6-m in size, were constructed using thick cut (44 mm) Kentucky bluegrass (*Poa pratensis*, L.) big roll sod (40% 'P-105', 30% 'Midnight Star', 30% 'Brilliant') harvested from a sandy soil (92.4% sand, 4.5% silt, 2.8% clay). Sod was installed in October of 2005 over a tilled and leveled Hagerstown silt loam soil (fine, mixed Mesic Typic Hapludalf). Soil testing prior to installation revealed no nutrient deficiencies. Seams were filled with sand and the sod was rolled after installation with a 907-kg roller pulled by the previously described Ventrac tractor.

Thatch layer thickness and cutting height served as treatments in this study. Treatments were arranged in a strip-plot design, with thatch thickness serving as the whole plot treatment and cutting height serving as the strip plot treatment. Thatch treatments were applied by subjecting plots to various numbers of passes with a vertical mower (Sensation, Model # 18720, Plymouth, WI) set to different depths. Ten plugs were removed from each whole plot on 22 June 2006 and thatch thickness was measured under a 479 gram weight (Skogley and Sawyer, 1992). High thatch plots averaged 18.9 mm, medium plots averaged 12.8 mm, and low thatch plots averaged 4.0 mm.

Whole plots were split into strips of three cutting heights; 3.8 cm, 5.1 cm and 6.4 cm, respectively. Strips were 1.00- by 6.09-m in size, and mowed two times per week with a Craftsman rotary mower (Model # 917387500, Chicago, IL). Clippings were returned to the surface during mowing

Synthetic turf experiment

Synthetic turf plots had previously been installed at the Joseph Valentine Turfgrass Research Center, University Park, PA. These plots were constructed in the fall of 2002. For a more detailed description of plot construction see McNitt (2005).

Six synthetic turf systems were evaluated in this study; Fieldturf (FTOS1-F, Dalton, GA), Sportexe ('Omnigrass-41,' and 'Omnigrass-51,' Round Rock, TX), Sprinturf (Wayne, PA), Sofsport (Lancaster, PA), and Astroturf (SRI Sports, Dalton, GA). Three replications of each synthetic turf system were arranged in a completely randomized design.

Plots were split with varying levels of simulated traffic. Traffic was applied with the Brinkman Traffic Simulator (Cockerham and Brinkman, 1989) pulled by the previously described Ventrac tractor.

Two levels of traffic were evaluated on synthetic turf plots; no traffic and high traffic (eight passes, three times per week, totaling 24 passes for an entire week). High wear plots received 24 passes per week (12 games) until a total of 96 simulated games had been applied each year from 2003 through 2006. Traffic applications ceased each year after 96 games had been applied in order to collect data.

Data Collection

Surface hardness

Two devices were used to measure surface hardness in these experiments: a Clegg Impact Soil Tester (CIST) (Lafayette Instrument Company, Lafayette, IN) and the F-355 Apparatus A (F-355) (American Society for Testing Materials, 2000a). Impact attenuation, as measured by an accelerometer mounted on the missiles of each instrument, was used to indicate surface hardness and was reported as Gmax.

The CIST was equipped with a 2.25-kg missile that was dropped from a height of 440 mm (American Society for Testing Materials, 2000b). A single CIST measurement represented the average of three drops on each subplot. CIST data were collected as part of the non-turfed basepath, natural turfgrass, and synthetic turf experiments.

The F-355 was equipped with a 9.1-kg missile that was dropped from a height of 610 mm (American Society for Testing Materials, 2000a). A single F-355 measurement consisted of dropping the missile three times in the same location, with a three minute interval between each drop. A single F-355 measurement represented the average of the second and third drop in the same location on each subplot. F-355 data were only collected as part of the synthetic turf experiment.

Traction

PENNFOOT, an apparatus developed by McNitt et al. (1997), was used to measure both linear and rotational traction in each experiment. This apparatus conforms to the standard for measuring the traction of the athletic shoe-sports surface interface, F-2333 (American Society for Testing Materials, 2005b), except that the foot moves at 0.5 m s^{-1} instead of the 1.0 m s^{-1} allowed by the specification with notation.

Two components of linear traction were measured in this study: static and dynamic. Static-linear traction measures the peak amount of horizontal force (N) required to initiate motion, while dynamic-linear traction measures the amount of force to maintain translational movement at a rate of travel of approximately 0.5 m s^{-1} (McNitt, 2005). Rotational traction measurements quantified the peak moment of horizontal force (Nm) required to initiate and maintain rotational movement through 0.70 radians (40 degrees) of rotation.

All traction measurements were made using a baseball shoe (Air Zoom Clipper, Nike USA Inc., Beaverton, OR). This shoe contained 8 square metal studs (12.7 x 12.7 mm, 1.5 mm thick) around the perimeter of the foot, and ten smaller studs (6.35 x 6.35 mm, 3.175 mm thick). Eight of these smaller studs were located on the fore-foot region of the shoe and two were located on the rear-foot portion (Figure 1). This is the same shoe worn by the Penn State men's baseball team in 2006. Two sub-samples were averaged to represent the linear and rotational traction of each subplot.

Volumetric soil moisture content and soil bulk density

Volumetric soil moisture content and soil bulk density were measured as part of the non-turfed basepath and natural turfgrass experiments using a Troxler 3400-B soil moisture-density gauge according to the methods of Gardner (1986). On natural turfgrass plots, measurements of volumetric soil moisture content and soil bulk density were taken at a depth of 5.1 cm below the surface. A 5.1-cm guide hole was created in the soil using a template and guide rod. The ^{137}Cs source was inserted into this guide hole during measurement. On non-turfed basepath plots, this rod could not penetrate deep enough into the soil to collect data at a 5.1-cm depth.

<u>Statistical Analyses</u>

Non-turfed basepath experiment

Data were collected on non-turfed basepath plots twice in 2006 (27 April to 2

May and 16 July to 21 July) and analyzed using a repeated measures analysis of variance. No interactions between sampling period (time) and treatments were detected (except where noted) in surface hardness data, so pooled means are reported here. Significant interactions between treatment effects and time were detected in traction data; therefore, results will be presented for the first and second sampling periods individually. A trend analysis was conducted to model treatment effects on surface hardness and traction when the F-ratio was significant at the 0.05 level.

Natural turfgrass and synthetic turf experiments

Data were collected on natural turfgrass plots from 28 June through 6 July 2006. Measurements were made on synthetic turf plots from 6 July to 9 September 2006. All data were analyzed using analysis of variance. In the natural turfgrass experiment a trend analysis was conducted to model treatment effects when the F-ratio was significant at the 0.05 level. For the synthetic turf experiment a Fisher's least significant difference test was conducted when the F-ratio was significant at the 0.05 level.

RESULTS AND DISCUSSION

Surface Hardness

Non-turfed basepath experiment

Surface hardness measurements varied due to soil compaction level on non-turfed basepath plots. A quadratic relationship between soil compaction levels was reported (Table 1), with increasing levels of soil compaction yielding increases in surface hardness (Gmax). Surface hardness values were similar to those observed in other studies. Goodall et al. (2005) reported a compacted non-turfed basepath of a similar soil texture to average 109 Gmax at a soil moisture content of 0.10 m^3m^{-3} and 101 Gmax at a soil moisture content of 0.14 m^3m^{-3} using the CIST. Plots receiving the high soil compaction treatment in this study averaged 122.8 Gmax at a soil moisture content of 0.12 m^3m^{-3} (Table 1).

Changes in soil bulk density may explain the increased surface hardness reported with increasing levels of soil compaction. Plots receiving low, medium, and high levels of soil compaction yielded bulk density values of 1.46, 1.54, and 1.63 Mg m^{-3}, respectively (Table 1). Baker et al. (1998) found increases in surface hardness on cricket pitches to be a function of increased soil bulk density.

Increases in surface hardness could also be related to reductions in soil moisture content on plots receiving increased levels of soil compaction (Table 1). A quadratic relationship was detected, with plots receiving the high and medium compaction treatments measuring lower in soil moisture content than plots receiving the low soil compaction treatment (Table 1).

Scarification depth treatments significantly affected surface hardness (Gmax) on plots receiving medium and high levels of soil compaction (data not shown). Pratt (1968) reported a similar effect when scarifying the surface of a thoroughbred horseracing track; the effects of scarification on surface hardness were greatly reduced on surfaces that were less compact.

Surface hardness was not affected by the addition of calcined clay in this experiment (data not shown). These results differ from those reported by Goodall et al. (2005), who reported that applications of calcined clay increased the surface hardness (Gmax) of non-turfed basepaths. Goodall et al. (2005) blended calcined clay throughout various non-turfed basepath profiles, at rates (0, 4.9, 9.8, 19.6 kg m^{-2}) twenty times greater than those used herein. Applications of calcined clay in this manner are commonly made during non-turfed basepath construction (Puhalla et al., 2003).

Table 1. Mean soil bulk density, soil moisture content, and surface hardness values for each level of soil compaction on non-turfed basepath plots in 2006.

Soil Compaction Level	**Soil Bulk Density**†	**Soil Moisture Content**‡	**Surface Hardness**§
	---Mg m^{-3}---	**----$m^3 m^{-3}$---**	**----Gmax---**
High	1.63	0.122	122.8
Medium	1.54	0.131	90.7
Low	1.46	0.143	59.9
Linear	*	**NS**	***
Quadratic	**	*	***

† Soil bulk density measured with a Troxler 3400-B Series Moisture Density Gauge.
‡ Volumetric soil moisture content measured with a Troxler 3400-B Series Moisture Density Gauge.
§ Surface hardness (Gmax) = the ratio of maximum negative acceleration on impact, in units of gravities, relative to the acceleration due to gravity, measured with the Clegg Impact Soil Tester equipped with a 2.25-kg missile
*,**,*** Significant at $p \leq 0.05, 0.01, 0.001$ levels, respectively

In this experiment, calcined clay treatments were applied as topdressing, and scarified into the uppermost (< 6.5 mm) portion of the soil surface to investigate the effects of calcined clay as part of a non-turfed basepath maintenance program.

Natural turfgrass experiment

Surface hardness averaged 57 Gmax and was not affected by cutting height or thatch thickness treatments in this experiment. Rogers III (1988) reported similar results on Kentucky bluegrass and tall fescue (*Festuca arundinacea* Schreb.) cultivars mowed at 7.6, 5.1, and 2.5 cm, and fine fescues (*Festuca rubra* L.), zoysiagrasses (*Zoysia japonica* Steud.) and Kentucky bluegrasses having various thatch thicknesses. Zebarth and Sheard (1985) found no differences in the surface hardness of Kentucky bluegrass mowed at 3, 9, and 15 cm, with uncompressed thatch layers of 1.6 cm and 2.3 cm.

The lack of turfgrass-related effects in this experiment is evidence that playing surface hardness on natural turfgrass is likely a function of soil type, soil compaction, and their effect on soil moisture. These findings support the hypothesis of Rogers III (1988) that soil physical properties affect surface hardness more than plant related factors.

Synthetic turf experiment

Due to space limitations, only data from subplots receiving simulated traffic will be presented. Surface hardness (Gmax) values were affected by synthetic surface type. Variation in infill depth may have been the reason that surfaces varied in surface hardness (Gmax). Infill depth was significantly correlated to Gmax measured with the CIST ($r = -0.72$, $p \leq 0.001$) and the F-355 ($r = -0.73$, $p \leq 0.001$). Astroturf, a surface constructed without infill, yielded the highest Gmax values, while the surface with the most infill, Omnigrass-41, yielded the lowest Gmax values using both devices (Table 2)

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Table 2. Mean infill depth and surface hardness (CIST and F-355) and rotational traction values for synthetic turf plots receiving simulated traffic in 2006.

Surface	**Infill Depth**	**Surface Hardness (CIST)†**	**Surface Hardness (F-355)**	**Rotational Traction‡**
	--mm--	**--Gmax---**	**---Gmax--**	**-----Nm----**
Astroturf	---------	84.4	128.5	120.1
Fieldturf	37.9	66.2	112.0	92.3
Sofsport	31.4	66.5	98.9	99.3
Sprinturf	28.4	70.9	130.7	98.4
Omnigrass-41	45.8	49.1	92.4	80.5
Omnigrass-51	36.1	60.7	105.9	92.8
LSD ($p \leq 0.05$)	**1.6**	**6.1**	**4.7**	**10.3**

† Surface hardness (Gmax) = the ratio of maximum negative acceleration on impact, in units of gravities, relative to the acceleration due to gravity, measured with the Clegg Impact Soil Tester (2.25-kg missile) or the F-355 apparatus

‡ Rotational Traction = peak amount of force (Nm) to initiate rotational motion of footwear using a 121-kg loading weight measured with PENNFOOT

McNitt (2005) reported that infill depth had a significant effect on surface hardness (Gmax) measurements made with the CIST and F-355 on synthetic turf.

Traction

Non-turfed basepath experiment

Linear traction values were affected by soil compaction treatments in the first sampling period (Table 3). A quadratic effect was detected between compaction levels, as plots receiving medium and high levels of soil compaction yielded greater linear traction values than those receiving the lowest compaction level. Although not statistically significant at the $\alpha = 0.05$ level ($p < 0.10$), this quadratic trend was apparent in data collected in the second sampling period (Table 3). Rotational traction was significantly affected by soil compaction treatments in both sampling periods (Table 3), with a quadratic relationship reported between treatment levels.

Differences in static-linear, dynamic-linear, and rotational traction among soil compaction levels may be due to soil bulk density. The high and medium soil compaction treatments measured greater in soil bulk density than the low level soil compaction treatment (Table 1). Increases in soil bulk density typically result in an increase in soil strength (Budhu, 2007). Increasing soil strength likely resulted in greater resistance to the movement of studs through the profile, thus increasing traction values. Other researchers have reported that higher soil bulk density levels significantly increased linear and rotational traction (Zebarth and Sheard, 1985; McNitt et al., 2004).

Table 3. Mean static-linear, dynamic-linear, and rotational traction values for soil compaction and calcined clay treatments during the first and second sampling periods on non-turfed basepath plots in 2006.

	First Sampling Period			Second Sampling Period		
Level	Static-Linear Traction†	Dynamic-Linear Traction‡	Rotational Traction§	Static-Linear Traction	Dynamic-Linear Traction	Rotational Traction
Soil Compaction	----µ----	----µ----	----Nm----	----µ----	----µ----	----Nm----
High	1.25	1.19	73.6	1.27	1.20	100.1
Medium	1.16	1.11	71.2	1.18	1.12	97.0
Low	1.04	1.02	68.5	1.09	1.07	88.8
Linear	**	**	NS	NS	NS	NS
Quadratic	***	***	*	NS	NS	*
Calcined Clay (kg ha^{-1})						
0	1.16	1.11	73.0	1.19	1.15	95.8
4883	1.14	1.10	70.9	1.19	1.13	98.4
9767	1.16	1.11	73.0	1.18	1.13	95.7
14650	1.14	1.09	67.6	1.16	1.12	91.5
Linear	NS	NS	*	NS	NS	*
Quadratic	NS	NS	NS	NS	NS	*

† Static Linear Traction = peak amount of force (N) to initiate linear motion of footwear/amount of force (N) that is normal to the playing surface measured with PENNFOOT

‡ Dynamic Linear Traction= amount of force (N) to maintain linear motion of footwear/amount of force (N) that is normal to the playing surface measured with PENNFOOT

§ Rotational Traction = peak amount of force (Nm) to initiate rotational motion of footwear using a 121-kg loading weight measured with PENNFOOT

* Significant at $p \leq 0.05$

NS = not significant

Both static- and dynamic-linear traction were affected by scarification depth treatments in the first sampling period (data not shown). The effects of scarification depth treatments on static-linear and dynamic-linear traction were more pronounced on plots receiving high levels of soil compaction, compared to plots receiving low levels of soil compaction (data not shown). Scarification treatments reduced traction presumably by lowering soil bulk density at the point of stud-to-surface contact.

No calcined clay treatment effects on static-linear or dynamic-linear traction were detected in this study (Table 3); however, increasing calcined clay application rates yielded lower rotational traction values in both sampling periods (Table 3). These results differ from those reported by Goodall et al. (2005) who found applications of calcined clay to have no effect on rotational traction; however, traction measurements were made with a different apparatus than the one used herein, and calcined clay treatments were applied differently.

Rotational traction values on non-turfed basepath plots were greater than those observed by other researchers. On a non-turfed basepath (of similar texture and bulk density), Goodall et al. (2005) found rotational traction to average 24 Nm using the studded disc apparatus developed by Canaway and Bell (1986). In this experiment, plots receiving high levels of soil compaction averaged 73.3 and 100.1 Nm during the first and second sampling periods, respectively (Table 2). Differences in rotational traction values are likely related to variation among testing devices, as the instruments used by Goodall et al. (2005) measured traction at a much lower loading weight (45 kg) than PENNFOOT (121 kg).

Natural turfgrass experiment

None of the traction parameters measured on natural turfgrass plots were affected by treatments in this study. Other researchers have reported similar results. McNitt et al. (2004) and Middour (1992) found cutting height to have no effect on rotational traction measured with PENNFOOT.

PENNFOOT was not able to measure static-linear or dynamic-linear traction on natural turfgrass plots. When configured with a 121-kg loading weight, PENNFOOT could not generate enough pulling force to linearly move a Nike Air Zoom Clipper men's baseball shoe through the turfgrass canopy. McNitt et al. (2004) did not experience this problem when measuring linear traction with studded football shoes at much higher loading weights.

The inability of PENNFOOT to measure linear traction in this study may have been related not only to the shape of the studs on the sole of the shoe, but their configuration as well. The bottom of the Nike Air Zoom Clipper shoe contained 8 flat, 12 x 12-mm rectangular shaped studs, which have a higher cross-sectional area than cylindrical or triangular shaped studs common to American football shoes (Figure 1). Kirk et al. (2006a) reported a linear relationship (R^2 = 0.995) between dynamic traction forces and stud cross sectional area, with a doubling of stud cross sectional area yielding a 60% increase in dynamic-linear traction. Studies comparing cuboid and cylindrical shaped studs on soccer footwear have shown that stud shape can affect the amount of force required to move footwear through the turfgrass canopy by as much as 20% (Kirk et al., 2006b). In this study, one of the rectangular studs on the Nike Air Zoom Clipper was positioned near the toe of the shoe, nearly perpendicular to the line of linear motion during testing (Figure 1).

Figure 1. Nike Air Zoom Clipper studded baseball shoe used in data collection

Considering stud geometry, this configuration likely yielded forces resisting the initiation of movement that were too large for PENNFOOT to overcome in order to make measurements. Future research needs to further investigate linear traction on natural turfgrass using various types of footwear worn by baseball players.

Synthetic turf experiment

Due to space limitations, only data from subplots receiving simulated traffic will be presented. PENNFOOT was not able to measure linear traction on synthetic turf plots in this study. This failure was likely a function of the shape of the studs on the footwear used during testing, and their placement on the sole of the shoe.

Rotational traction was affected by surface type on synthetic turf plots. Astroturf, a non-filled synthetic surface, yielded higher rotational traction values compared to infilled synthetic turf surfaces (Table 2). Shorten et al. (2003) and McNitt (2005) also found rotational traction measurements made on Astroturf to be greater than those made on infilled synthetic surfaces like Fieldturf.

Rotational traction values in this study were greater than those observed by other researchers. A studded baseball shoe used on synthetic turf plots yielded rotational traction values averaging 101.8 Nm. Using an array of testing equipment, rotational traction measurements for football and soccer footwear have been reported to range from 80.3 Nm to 30 Nm on synthetic turf surfaces. (McNitt, 2005; Livesay et al., 2006; Shorten et al., 2003)

CONCLUSION

Increases in soil compaction resulted in increases in the hardness of non-turfed basepath surfaces. The degree of soil compaction during construction should be managed to prevent unsafe increases in hardness. Field managers can increase scarification depth in order to soften excessively hard playing surfaces. The addition of calcined clay topdressing did not affect surface hardness.

The results of this study indicate that footwear worn by baseball players may be providing excessive traction on turfed areas of the field, both natural and synthetic. Studs with a large cross sectional area, such as those used on baseball footwear, can yield extremely high traction forces that may increase an athlete's likelihood of suffering an injury. Future research is needed to explore this issue in detail.

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