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Surface Conditions of Highly Maintained Baseball Fields in the Northeastern United States: Part 2, Synthetic versus Natural Turfgrass

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Abstract

Pace is a measure of the relative velocity at which a ball travels after impacting a playing surface. Information about the pace of balls impacting highly maintained natural and synthetic turf baseball field surfaces is minimal. A survey was conducted in 2005 to document the pace and surface hardness of baseball field playing surfaces in the northeastern United States. Nine natural turfgrass baseball fields and five synthetic turf fields were evaluated. Surface pace and surface hardness values of these highly maintained fields differed little between synthetic and natural turfgrass. Surface pace measurements on synthetic turf surfaces were slightly less variable from field to field than those measured on natural turfgrass surfaces. Much greater differences in surface pace and hardness were detected between the non-turfed basepaths, reported in Part 1 of the project, compared to either natural or synthetic turf. Within the parameters of this study, the natural turfgrass surfaces and the infilled synthetic turf surfaces evaluated differed little in surface pace or surface hardness.

Variability Affects Playing Quality

Baseball field playing surfaces can be extremely variable. Within most fields there are two distinct types of playing surfaces: non-turfed basepath soil and turfed areas including the infield and outfield surfaces. Natural turfgrass surfaces can differ in species, cultivar, density, cutting height, and rootzone soil (10), while synthetic surfaces can differ in infill depth, infill compaction, matting of upright fibers, and the presence or absence of an underlying pad (5,12).

This variability may affect the quality of the playing surface. Playing surface quality is defined as the suitability of a surface for a particular sport (4), encompassing interactions between both the player and the ball with the surface. Competing on poor quality playing surfaces cannot only compromise the integrity of the game, but jeopardize player safety as well (13).

Interactions between the athlete and the playing surface and between the ball and the playing surface have been evaluated for the sports of soccer and cricket (1,6,7). Pace is a measure of the relative velocity at which a ball travels after impacting a surface. Researchers have attempted to characterize how varying surface conditions affect the hardness and pace of these surfaces (1,6,7). However, little information on the playing quality of surfaces used for the sport of baseball has been reported.

The objective of this study was to compare the surface hardness and pace of highly maintained natural and synthetic turf baseball field playing surfaces, as well as to document some surface characteristics that may affect surface hardness and pace on these fields.

Field Sampling Scheme

In the summer of 2005 a survey of baseball fields was conducted across the northeastern United States (8). Both natural and synthetic turf fields were included in the survey. The survey included three Major League Baseball fields (MLB), five minor league baseball fields (Professional), six National Collegiate Athletic Association fields (NCAA), and one municipal field (Other). Nine of the fields were a natural turfgrass playing surface and six of the fields were infilled synthetic turf playing surfaces.

Playing surface hardness and pace measurements were made on each type of playing surface on every field in the survey. Within the infield and outfield, measurements were made in three 6.1 by 6.1-m sampling zones. Infield sampling zones included an area centered six meters in front of homeplate and two areas centered six meters inside of the 13.7-m mark of the second and third baselines, as measured from home plate (Fig. 1). Outfield sampling zones were located 83.8 m from first and third base as measured by intersecting second base. Thus, the area in right field was 83.8 m from third base and the area in left field was 83.8 m from first base. A third, center field zone, was centered between the other two (Fig. 1).

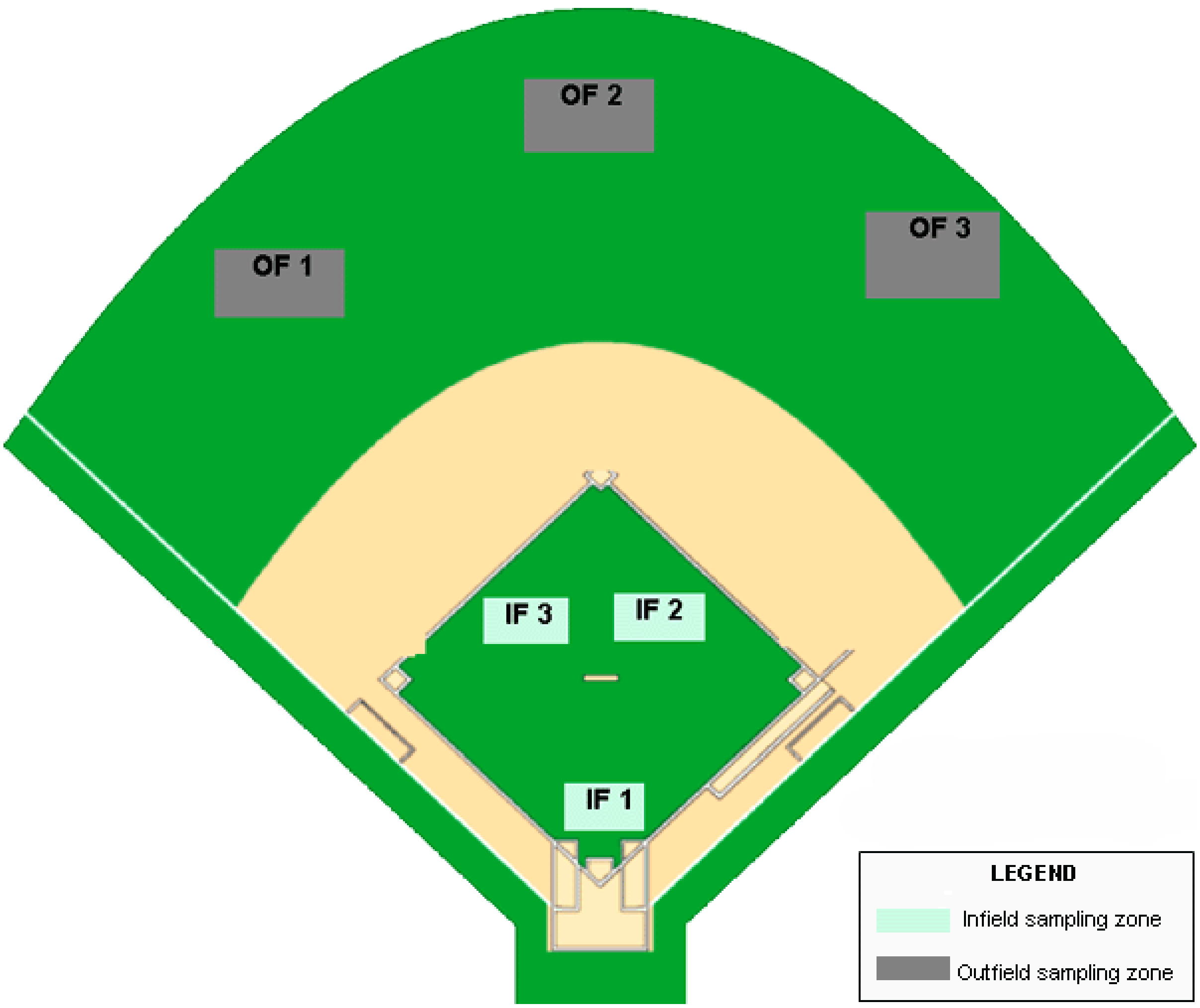

Fig. 1. Layout of 6.1 by 6.1-m sampling zones used in the data collection process.

All fields were "in use" during the testing period. Measurements were made on days when the fields did not have a scheduled game. Field managers were not asked to do anything to prepare the playing surface for testing outside of their normal maintenance routine.

Surface hardness was measured using two devices: a Clegg Impact Soil Tester (CIST) (2,11) and the F-355 apparatus A (3). Both the F-355 apparatus A and the CIST were used on synthetic surfaces. On natural turfgrass surfaces, measurements were only made with the CIST (electronic equipment on the F-355 can be damaged on certain natural turfgrass surfaces). 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. A single F-355 measurement consisted of dropping the missile three times in the same location, with a 3-min interval between each drop. The value reported as Gmax was the average of the second and third drop in the same location. Two Gmax measurements were made in each zone and the average of those measurements was used to represent the surface hardness of that zone as measured by using the F355 device. Similarly, the average of six single drop measurements taken in six different locations within each sampling zone was used to represent the surface hardness of that zone as measured using the CIST.

Playing surface pace was quantified in each sampling zone by measuring the coefficient of restitution (COR) of a baseball impacting the surface. As in Part 1 of this project (8), all measurements were made using Pennbounce configured at a 0.44-radian impact angle (25°) and a testing velocity of 40.2 m/sec (90 mph), as previous research found this configuration to best represent ball-to-surface interactions on baseball field playing surfaces (9). For a more complete description of this device see Brosnan et al. (9). The average of six COR measurements was used to represent the surface pace of each sampling zone.

Surface Characterization

On natural turfgrass surfaces, each sampling zone was characterized by measuring soil moisture content (m^3/m^3), cutting height, and thatch thickness. Soil moisture content measurements were made using a capacitance probe inserted to a depth of 60 mm (Theta Probe, Model # ML2X, Dynamax Inc., Houston, TX). Rectangular plugs (14.0 cm x 3.2 cm x 7.6 cm in depth) were removed from each sampling zone and uncompressed thatch thickness and cutting height were measured using a ruler. For each characteristic, six sub-samples were averaged to represent the sampling zone.

On synthetic surfaces, infill depth was measured using a point gauge. The gauge consisted of a pointed metallic rod attached to a ruler. The rod was inserted into the pile until contacting the backing of the carpet. The depth of penetration was recorded. The average of six measurements was used to represent the infill depth of a sampling zone.

Statistical Analysis

The experimental design was completely randomized. Means were calculated for each surface type, each sampling zone within each field, and each sampling zone across all fields. Means were analyzed using the GLM procedure in SAS STAT software (version 9.1, SAS Institute Inc., Cary, NC). Means separation was performed when the F-ratio was significant at the 0.05 level. Tukey's studentized range test was used to compare overall surface means, as sample sizes were unequal. Within each surface type, means were compared using a Duncan's new multiple range test ($\alpha = 0.05$). Pearson's correlation coefficients were calculated to determine relationships between measured variables.

Surface Hardness Measurements

When compared across all sampling zones and all fields tested, the surface hardness of synthetic turf fields did not differ from natural turfgrass fields (Table 1). Measurements of surface hardness on synthetic turf averaged 66.3 Gmax with the CIST and 136.8 Gmax with the F-355 apparatus. All synthetic surfaces measured below the United States Consumer Product Safety Commission surface hardness limit of 200 Gmax. On natural turfgrass fields surface hardness averaged 64.6 Gmax with the CIST (Table 1). To determine if natural turfgrass surfaces exceeded the United States Consumer Product Safety Commission threshold of 200 Gmax, as measured using the device described in ASTM F355 (3), CIST measurements were converted into F355 equivalents using the equation, $F355 = CIST \times 1.52 + 9.3$, reported by McNitt (12). All natural turfgrass surfaces evaluated in this study were below the 200 Gmax threshold.

Table 1. Surface pace and hardness means for natural turfgrass, and synthetic turf surfaces characterized in a 2005 survey of baseball fields.

Surface	**N**	**Surface pace**[x] (COR)	**Surface hardness**[y] (Gmax)
Natural turfgrass	324	0.479 b[z]	64.6 b
Synthetic turfgrass	180	0.520 a	66.3 b

[x] Surface Pace (COR) = the ratio of the velocity of a ball after impact with a surface divided by the velocity of a ball prior to impact.

[y] Surface hardness (Gmax) measured with the Clegg Impact Soil Tester using a 2.25-kg missile.

[z] Means with different letters are significantly different from one another (Tukey's HSD, α = 0.05).

Statistically significant differences were observed in the surface hardness of synthetic turf sampling zones using both the CIST and the F-355 apparatus (Table 2). Infield sampling zones measured slightly lower in surface hardness than outfield sampling zones according to CIST (Table 2). Overall, these differences were small and of little practical significance.

Table 2. Mean surface pace, CIST, F-355, and infill depth values for each synthetic turf sampling zone evaluated during a survey of baseball fields in 2005.

Area	**Surface pace**[w] (COR)	**Surface hardness (CIST)**[x] (Gmax)	**Surface hardness (F-355)**[y] (Gmax)	**Infill depth** (mm)
Infield	0.520 a[z]	63.1 b	135.0 a	35.4 a
IF 1	0.506 b	61.8 c	137.9 ab	34.6 b
IF 2	0.528 a	65.1 bc	135.3 ab	36.8 a
IF 3	0.525 ab	62.4 bc	131.9 b	34.9 b
Outfield	0.520 a	69.6 a	138.5 a	35.1 a
OF 1	0.519 ab	68.4 ab	143.0 a	35.6 ab
OF 2	0.517 ab	67.6 abc	139.3 ab	35.0 b
OF 3	0.523 ab	72.7 a	133.1 b	34.9 b

[w] Surface Pace (COR) = the ratio of the velocity of a ball after impact with a surface divided by the velocity of a ball prior to impact.

[x] Surface Hardness (Gmax) measured with the Clegg Impact Soil Tester using a 2.25 kg missile.

[y] Surface Hardness (Gmax) measured with F-355 apparatus A.

[z] Means with different letters are significantly different from one another (Duncan's nMRT, α = 0.05).

Natural turfgrass sampling zones yielded greater differences in surface hardness (Gmax) measured with the CIST. Natural turfgrass infield sampling zones, measured across all natural turfgrass fields tested, were found to be significantly harder than outfield zones, with Gmax values measuring 69.3 and 59.9, respectively (Table 3). This difference in surface hardness is likely related to maintenance procedures. Infields are often topdressed with sand and rolled in an effort to smooth the surface and achieve a consistent ball response.

Table 3. Mean surface pace, surface hardness, soil moisture content, cutting height, and thatch thickness values for each natural turfgrass sampling zone evaluated during a survey of baseball fields in 2005.

Area	**Surface pace**[x] (COR)	**Surface hardness**[y] (Gmax)	**Soil moisture content** (m^3/m^3)	**Cutting height** (mm)	**Thatch thickness** (mm)
Infield	0.484 a[z]	69.3 a	0.251 a	36.3 a	9.8 a
IF 1	0.510 a	73.2 a	0.260 a	35.3 bc	9.7 ab
IF 2	0.481 b	68.6 b	0.240 c	34.8 c	9.7 ab
IF 3	0.471 b	65.9 b	0.232 c	35.5 bc	10.2 a
Outfield	0.474 a	59.9 b	0.242 b	35.0 b	8.0 b
OF 1	0.481 b	59.9 cd	0.245 bc	36.3 ab	8.3 abc
OF 2	0.465 b	57.9 d	0.251 ab	36.6 a	8.1 bc
OF 3	0.475 b	62.0 c	0.258 ab	36.8 a	7.7 c

[x] Surface Pace (COR) = the ratio of the velocity of a ball after impact with a surface divided by the velocity of a ball prior to impact.

[y] Surface hardness (Gmax) measured with the Clegg Impact Soil Tester using a 2.25-kg missile.

[z] Means with different letters are significantly different from one another (Duncan's nMRT, $\alpha = 0.05$).

Surface Pace Measurements

Differences in surface pace were observed between synthetic turf surfaces (Table 4). The synthetic surface with the fastest pace yielded a COR of 0.549, while the slowest surface yielded a COR of 0.494 (Table 4). For natural turfgrass fields, COR values ranged from 0.533 to 0.428 (Table 5). There were no differences observed in surface pace between the infield and outfield sampling zones for synthetic turf surfaces (Table 2). For natural turfgrass surfaces, the home plate sampling zone (IF1) yielded a higher COR than the other sampling zones (Table 3). The variation among the six sampling zones within individual fields is shown in Table 6. While natural turfgrass fields yielded an average zone-to-zone variation slightly higher than synthetic turf, a two-sample t-test indicated that these differences were not significant ($\alpha = 0.05$). A larger sample size may yield a different result.

Table 4. Mean surface pace, surface hardness (CIST and F-355), and infill depth values for synthetic turf surfaces evaluated in a survey of baseball fields in 2005.

Field	**Surface pace**[w] (COR)	**Surface hardness** (CIST)[x] (Gmax)	**Surface hardness** (F-355)[y] (Gmax)	**Infill depth** (mm)
Professional #5	0.518 bc[z]	60.4 b	143.4 a	39.1 b
NCAA #3	0.549 a	77.9 a	143.9 a	26.6 d
NCAA #4	0.494 d	52.0 c	106.9 b	42.5 a
NCAA #5	0.535 e	77.2 a	140.8 a	33.5 c
NCAA #6	0.502 cd	64.1 b	149.8 a	34.8 c
Overall Mean	0.520	66.3	136.8	35.3

[w] Surface Pace (COR) = the ratio of the velocity of a ball after impact with a surface divided by the velocity of a ball prior to impact.

[x] Surface hardness (Gmax) measured with the Clegg Impact Soil Tester using a 2.25-kg missile.

[y] Surface Hardness (Gmax) measured with F-355 apparatus A.

[z] Means with different letters are significantly different from one another (Duncan's nMRT, $\alpha = 0.05$).

Table 5. Mean surface pace, surface hardness, soil moisture content, cutting height, and thatch thickness values for natural turfgrass surfaces evaluated in a survey of baseball fields in 2005.

Field	**Surface pace**[x] (COR)	**Surface hardness**[y] (Gmax)	**Soil moisture content** (m^3/m^3)	**Cutting height** (mm)	**Thatch thickness** (mm)
MLB #2	0.432 d[z]	60.8 b	0.269 b	31.7 d	13.2 b
MLB #3	0.428 d	59.2 b	0.269 b	25.4 e	1.0 de
Prof. #1	0.490 c	72.1 a	0.179 d	38.1 b	7.1 c
Prof. #2	0.443 d	60.41b	0.257 b	47.5 a	12.7 b
Prof. #3	0.498 bc	71.1 a	0.229 c	31.7 d	19.8 a
Prof. #4	0.449 d	60.8 b	0.229 c	38.1 b	3.0 d
NCAA #1	0.510 abc	69.7 a	0.231 c	38.1 b	0.5 e
NCAA #2	0.525 ab	69.4 a	0.261 b	33.3 c	1.3 de
Other	0.533 a	57.9 b	0.294 a	38.9 b	21.6 a
Overall mean	0.479	64.6	0.246	35.8	8.9

[x] Surface Pace (COR) = the ratio of the velocity of a ball after impact with a surface divided by the velocity of a ball prior to impact.

[y] Surface hardness (Gmax) measured with the Clegg Impact Soil Tester using a 2.25-kg missile.

[z] Means with different letters are significantly different from one another (Duncan's nMRT, $\alpha = 0.05$).

Table 6. Variation (% range) among surface pace means for each natural and synthetic turf field evaluated in a 2005 survey of baseball fields.

Surface type	**Variation** (% range)*
Synthetic Turf	24.82
Professional #5	36.36
NCAA#3	25.77
NCAA#4	12.19
NCAA#6	24.96
Natural Turfgrass	30.00
NCAA#2	31.13
Other	24.63
MLB#2	61.45
Professional#2	23.51
NCAA#1	30.73
MLB#3	18.52
Professional#4	28.73
Professional#3	26.84
Professional#1	24.47

* Range = [(Maximum value - Minimum Value) / Maximum Value] * 100

Correlating Data

On synthetic turf surfaces, infill depth had a small but significant correlation to COR (r = -0.381, $P \leq 0.001$). Infill depth was also negatively correlated with surface hardness measured with the CIST (r = -0.517, $P \leq 0.001$) and the F-355 (r = -0.406, $P \leq 0.001$). On natural turfgrass surfaces, soil moisture content and thatch thickness both had low but statistically significant correlations to playing surface pace, r = -0.148 and r = 0.173, respectively. Obviously, other factors affect pace to a greater degree than soil moisture content and thatch thickness. Future research should measure the effects of additional characteristics on pace, such as soil bulk density, verdure, shoot density, and resistance to surface deformation.

Surface hardness was significantly correlated to COR on synthetic turf using both devices (CIST, r = 0.349, $P \leq 0.001$; F-355, r = 0.339, $P \leq 0.001$). On natural turfgrass surfaces, COR and surface hardness (measured with CIST) were significantly correlated, as well (r = 0.523, $P \leq 0.001$). Although an increase in surface hardness was associated with an increase in surface pace, it is clear that surface pace is influenced by more than just surface hardness. This is especially apparent when examining the synthetic turf results. Estimating surface pace from surface hardness measurements will not accurately assess the pace of a baseball surface.

Comparison of Surface Types

While small differences existed between the surface hardness and pace of baseballs striking synthetic versus natural turfgrass surfaces, these differences were small when compared to the differences between the turfed portion of these fields and the non-turfed basepaths reported in Part 1 of this study. While average values of surface pace differed little between natural and synthetic turf, the synthetic turf fields tested were slightly more consistent from location to location within fields and more consistent across fields than natural turfgrass. Future research projects need to explore these effects in greater detail in order to help field managers develop maintenance programs that maximize baseball field playing quality.

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