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Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology published online 13 June 2011
DOI: 10.1177/1754337111398407

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Human health issues on synthetic turf in the USA

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The manuscript was received on 30 August 2010 and was accepted after revision for publication on 6 January 2011.

DOI: 10.1177/1754337111398407

Abstract: As the popularity of infilled synthetic turf continues to increase, concerns over potentially negative impacts on the health of field users have arisen. One of the main health issues on synthetic turf fields is high surface temperature, which can contribute to physiological stress of athletes and can cause serious heat-related illnesses. At The Pennsylvania State University, various methods to reduce surface temperatures have been evaluated including irrigation, covering the surface with a tarpaulin, and amending infill with calcined clay. Many of the regimes tested were initially successful in lowering the surface temperature to that of natural turf grass; however, these low temperatures could not be maintained for periods of time equal to the length of standard sporting events. Another issue that has received attention is the possibility of athletes contracting bacterial skin infections, specifically those caused by *Staphylococcus aureus* bacteria. Infilled synthetic turf has been targeted as a potential source for harbouring *S. aureus* bacteria. A survey of 20 infilled synthetic turf fields was conducted to determine microbial population and presence of *S. aureus* bacteria. *S. aureus* colonies were not found to be present on any field; however, *S. aureus* colonies were found on other tested surfaces, including blocking pads, used towels, and weight equipment.

Keywords: synthetic turf, surface temperature, *Staphylococcus aureus*

1 INTRODUCTION

Originally developed as a playground surface for inner-city youth, synthetic turf can now be found on the playing field at some of today's most prestigious sporting venues. Following its initial installation for use as a sports surface at the Houston Astrodome in 1966, the popularity of Astroturf (non-infilled) grew and many fields at the collegiate and professional levels were converted from natural turf grass to synthetic turf in the following decades [**1**]. However, in the early 1990s, increased concerns over athlete safety and an emphasis on nostalgia, particularly in baseball [**2**], began to limit synthetic turf usage. By the end of the 1990s, synthetic turf systems were redesigned to include a higher pile height and granular infill material in an effort to create a more natural grass-like surface. These design improvements created a softer, less abrasive surface than traditional synthetic turf systems [**3**] and are major reasons for the recent resurgence in the use of synthetic turf [**4**]. Limited primarily to high-end facilities such as professional stadiums during its first wave of popularity, the new generation of synthetic turf, commonly referred to as infilled synthetic turf, is now found on a wide variety of fields, including municipal parks and school playgrounds.

A number of human health and safety concerns have arisen regarding infilled synthetic turf. For example, the incidence of injuries [**5–7**] and the potential exposure to volatile organic compounds [**8**, **9**] have been the subject of investigation. This paper focuses on two issues that are receiving attention in the USA: the surface temperature and the presence of *Staphylococcus aureus* bacteria. The

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New York City Department of Health and Mental Hygiene recognizes excessive surface temperatures as the most important health concern associated with infilled synthetic turf [**10**]. Surface temperatures as high as 93 °C have been recorded on infilled synthetic turf in a study conducted in Provo, Utah, USA [**11**]. A high surface temperature is not limited to infilled synthetic turf, as the temperatures on traditional Astroturf (non-infilled) have been reported to be 35–60 °C higher than those on natural turf grass [**12**] and slightly higher than those on infilled synthetic turf systems [**3**] in studies conducted in University Park, Pennsylvania, USA. Buskirk *et al.* [**12**] placed thermocouples on the inner soles of cleated shoes and concluded that the heat transfer from the surface to the sole of the individual's foot was sufficiently significant to contribute to greater physiological stress.

Researchers have studied techniques to mitigate high surface temperatures on synthetic turf. The application of irrigation water can significantly lower surface temperature; however, the effects are short lived. Williams and Pulley [**11**] reported that irrigation water immediately reduced the temperature of an infilled synthetic turf surface from 79 °C to 29 °C, but the temperature rebounded to 49 °C after 5 min and to 73 °C after 20 min. Devitt *et al.* [**13**] investigated the effects of black crumb rubber painted white on the surface temperature. Although a loose pile of white crumb rubber was 9.1 °C cooler than a pile of black crumb rubber, when installed in synthetic turf, the difference was only 5.3 °C, indicating that the synthetic turf fibres also contribute to elevated surface temperatures. The notion that the fibres themselves, independent of infill colour, significantly contribute to high surface temperatures is supported by the fact that the surface temperatures of traditional non-infilled Astroturf are similar to those of infilled synthetic turf [**3**].

Skin infections associated with contact with synthetic turf have received national media attention in the USA. *S. aureus* is a common bacterium found on human skin and in the nasal cavity that can cause various types of skin and soft tissue infections [**14**]. In most cases, the presence of this bacterium causes few serious problems and often goes unnoticed; however, antibiotic-resistant strains can cause serious, and sometimes fatal, health complications. Outbreaks of methicillin-resistant *S. aureus* (MRSA) have resulted in the temporary closing of school buildings and athletic facilities while the facilities are cleaned [**15**]. Infilled synthetic turf surfaces have been implicated as potentially harbouring *S. aureus* bacterium although no scientific evidence has been published to support such a claim [**16**]. However, the concern may be warranted as *S. aureus* has been shown to survive on various synthetic materials for up to 40 days [**17**]. Although no scientific evidence shows high levels of *S. aureus* on synthetic turf [**18**], an increasing number of fields are being treated, often at a great expense, with antimicrobial agents.

A pair of studies focusing on two separate outbreaks of MRSA each examined the causes and the role of infilled synthetic turf in infection. Kazakova *et al.* [**19**] examined an MRSA outbreak among five members of the St Louis Rams, a professional football team in the USA that plays on infilled synthetic turf, and Begier *et al.* [**20**] studied an MRSA outbreak that occurred on a collegiate football team, also playing on synthetic turf. Both studies concluded that turf burns caused by synthetic turf could facilitate skin infection through person-to-person contact; however, neither study suggested that the players contracted the infection directly from the synthetic turf. Kazakova *et al.* [**19**] and Begier *et al.* [**20**] each implicated poor sanitary conditions in locker rooms and training facilities together with physical contact between players as the most likely causes for the outbreaks. Begier *et al.* [**20**] also suggested that small cuts from body shaving provide an avenue for infection.

The objectives of this research were to address several human health concerns associated with the use of synthetic turf but, more specifically, first, to investigate techniques to reduce the surface temperature of infilled synthetic turf and, second, to determine whether the *S. aureus* bacterium is present on infilled synthetic turf.

2 METHODS

2.1 Surface temperature amelioration experiments

This study was initiated to determine the effects of various irrigation regimes, covering the surface with a tarpaulin, and the addition of calcined clay to infill material on the surface temperature of synthetic turf systems. Synthetic turf test plots were established over a gravel drainage layer consisting of 10.2 cm of coarse gravel covered with 1.9 cm combination of fine gravel and coarse sand at the Joseph Valentine Turfgrass Research Facility (University Park, Pennsylvania, USA) in the autumn of 2002. The plots consisted of infilled synthetic turf from various manufacturers (Table 1). Treatment plots were 4.5 m square. There were three replications arranged in

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Table 1 Characterization of synthetic turf systems

Product	Fibre material	Fibre type	Fibre length (mm)	Infill material	Infill depth (mm)	Pad
Astroplay	Polyethylene	Slit film	55	SBR*	42	Yes
Astroturf (non-infilled)	Nylon	Monofilament	13	—	—	Yes
FieldTurf	Polyethylene	Slit film	64	SBR* + sand	43	No
Geoturf	Unknown	Monofilament	64	Experimental	28	No
Nexturf	Polyethylene	Monofilament	30	SBR*	23	Yes
Omnigrass 41	Polyethylene	Slit film	50	SBR*	40	No
Omnigrass 51	Polyethylene	Slit film	64	SBR*	49	No
Sofsport	Polyethylene	Slit film	50	SBR* + sand	32	Yes
Sprinturf	Polyethylene	Slit film	50	SBR*	26	No

*Styrene–butadiene rubber (crumb rubber).

a completely random design for each test except for the calcined clay, which had no replications.

Approximately 2 cm of water was applied to all plots using hand-held irrigation. Surface temperatures were recorded immediately after irrigation and at regular time intervals thereafter. Both the temperature of the playing surface and the temperature of the air approximately 1 m above the surface were measured using an infrared thermometer (Scheduler Model 2 LiCor Corporation) in order to evaluate the differences in the temperature. Three temperature measurements were made on each treatment plot and the average was used to represent the temperature reading at a specific time. On 3 August 2004, irrigation began at 12.40 pm. The air temperature during the test period averaged 30 °C with 33 per cent relative humidity and a wind speed of 1–3 km/h. On 2 June 2005, irrigation began at 11.15 am. The air temperature averaged 25 °C during this period with 39 per cent relative humidity and the wind speed was 6 km/h. Replicate treatment data were analysed using analysis of variance, and Dunnett's test was used compare the temperatures of the surfaces at each time interval with the temperature of the treatment plots prior to irrigation.

In 2004, the effects of predawn irrigation and covering the surface with a tarpaulin on the temperature of test plots were evaluated. On 24 August 2004, two of the FieldTurf plots were irrigated with approximately 2 cm of water before dawn (6.10 am). One of these plots was covered with a CoverMaster white vinyl field cover used on American football fields prior to events to prevent natural precipitation from falling on the turf grass (CoverMaster Inc., Rexdale, Ontario, Canada). The cover was placed directly on the synthetic turf surface. The other plot was left uncovered. A third plot was irrigated with the same amount of water 7 h after the first two plots were irrigated. The tarpaulin on the first plot was removed at this time. A fourth plot was not covered with a tarpaulin and had no irrigation applied; therefore it served as a control. The study included three replications arranged in a completely randomized design. Means were analysed using analysis of variance and Fisher's least significant difference (LSD) test at the 0.05 level. An LSD was not calculated when the *F* ratio was not significant at the 0.05 level. The surface temperatures were recorded at regular time intervals after the tarpaulin had been removed using the previously described procedure.

On 7 July 2006, four surfaces were evaluated for changes in the surface temperature after irrigation. These were Astroturf (non-infilled), Fieldturf, Sprinturf, and Sprinturf with infill material amended with calcined clay (Profile Products, Buffalo Grove, Illinois, USA). The Sprinturf was amended with calcined clay (80:20 m^3/m^3) in an attempt to prolong the cooling effect of the irrigation. The surface temperatures were recorded at regular time intervals after irrigation using the procedure described in experiment 1. Irrigation began at 1.00 pm. This was a preliminary unreplicated screening to determine whether the addition of calcined clay warranted further investigation.

2.2 Survey for the presence of *S. aureus* study

All samples in this study were collected between 15 June 2006 and 30 June 2006. Infilled synthetic turf systems were located at facilities in Pennsylvania and were in use by all levels of play ranging from elementary to professional athletes. No surfaces had been previously treated with anti-microbial products. Two samples of crumb rubber were collected from both a 'high-use' and a 'low-use' area of each field. A high-use area typically was a goalmouth or, for a football-only field, an area between the 30 yd and 40 yd lines between the hash marks. A low-use area was typically an area towards the edge of the field (but within the field of play) or an end zone. Approximately 2–3 ml of crumb rubber were removed from each area of the field using sterile test tubes inserted directly into the infill. Pile fibre

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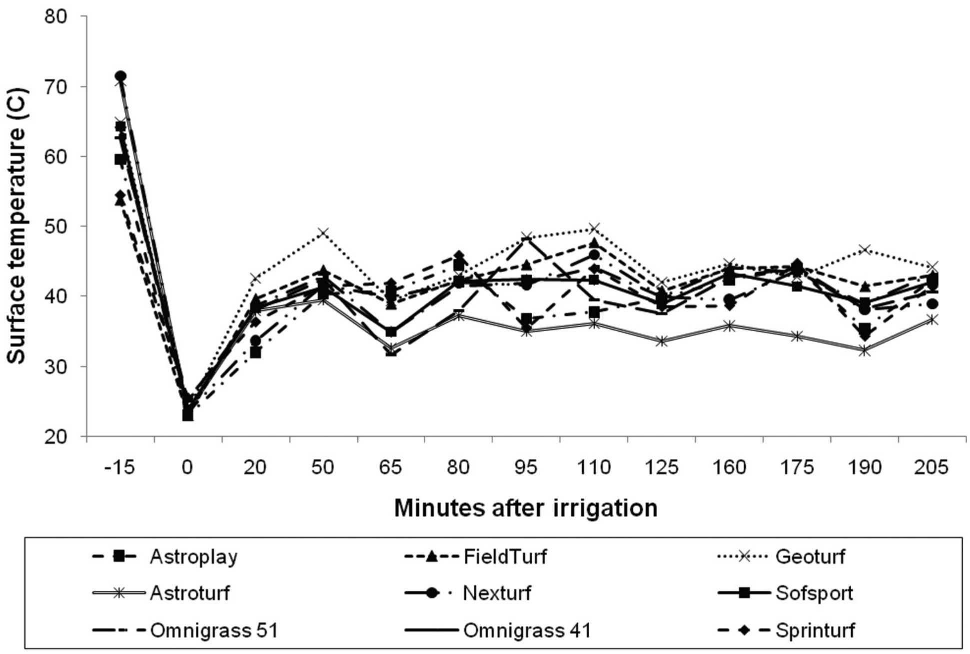

Fig. 1 Surface temperatures of synthetic turf surfaces on 3 August 2004

samples were also collected from fields by clipping several fibres from the backing and transferring the fibres to a sterile test tube. Samples of crumb rubber and pile fibres were taken from 20 fields. Samples were stored in a cooler and processed as soon after collection as possible.

Approximately 0.075 g of crumb rubber was transferred to a test tube containing 10 ml of sterile 0.1 per cent peptone broth. The sample was agitated for 30 s. Serial dilutions of each sample were plated up to 10^{-3} on both R2A agar for total organism populations and Baird-Parker agar, a selective media for *Staphylococcus* [**21**]. Duplicate platings were made for each media and each dilution. Petri plates were parafilmed and incubated at room temperature; colony counts were made 72 h after processing. Samples on Baird-Parker agar were also observed again after 5 days. Calculations were made to determine the number of colony-forming units (CFUs) per gram of crumb rubber. For comparison purposes, soil samples were also collected from a native soil and a sand-based natural turf-grass athletic field. Samples were processed in the same manner as the crumb rubber samples with the use of 0.2 g of soil for processing.

Samples were collected from common surfaces in public areas as well as from surfaces in an athletic training area by swabbing surfaces with sterile cotton swabs. Random individuals were also tested by swabbing their hands and/or their faces. Both R2A and Baird-Parker agar plates were wiped with the sterile swabs. Plates were incubated at room temperature and colony counts were conducted after 72 h for R2A agar and again at 5 days for Baird-Parker media.

Gram stains and latex agglutination tests [**22**] were performed on colonies suspected of being *S. aureus*. Several potential *S. aureus* colonies isolated from hand and facial swabs were also included in the testing.

3 RESULTS AND DISCUSSION

3.1 Surface temperature

The application of water initially lowered the surface temperature of all synthetic turf surfaces (Fig. 1). 20 min after irrigation ceased, temperatures were typically 10–15 °C higher than they were immediately following irrigation. Temperatures then remained relatively stable for 210 min. On the day that the test was conducted, there were intermittent cumulus clouds. The effect of the passing clouds can be seen in the erratic nature of the data. For this reason, an additional set of data was obtained on a clear sunny day (Fig. 2); however, air temperatures were not as high as on the previous rating date. According to Dunnett's mean separation procedure, the temperature of the surfaces after irrigation was statistically lower than the pre-irrigation surface temperature for each rating time and for all surfaces on both rating dates ($p < 0.05$).

Although not compared statistically, Astroturf (non-infilled) showed a tendency to have the lowest temperature after irrigation. This may be because

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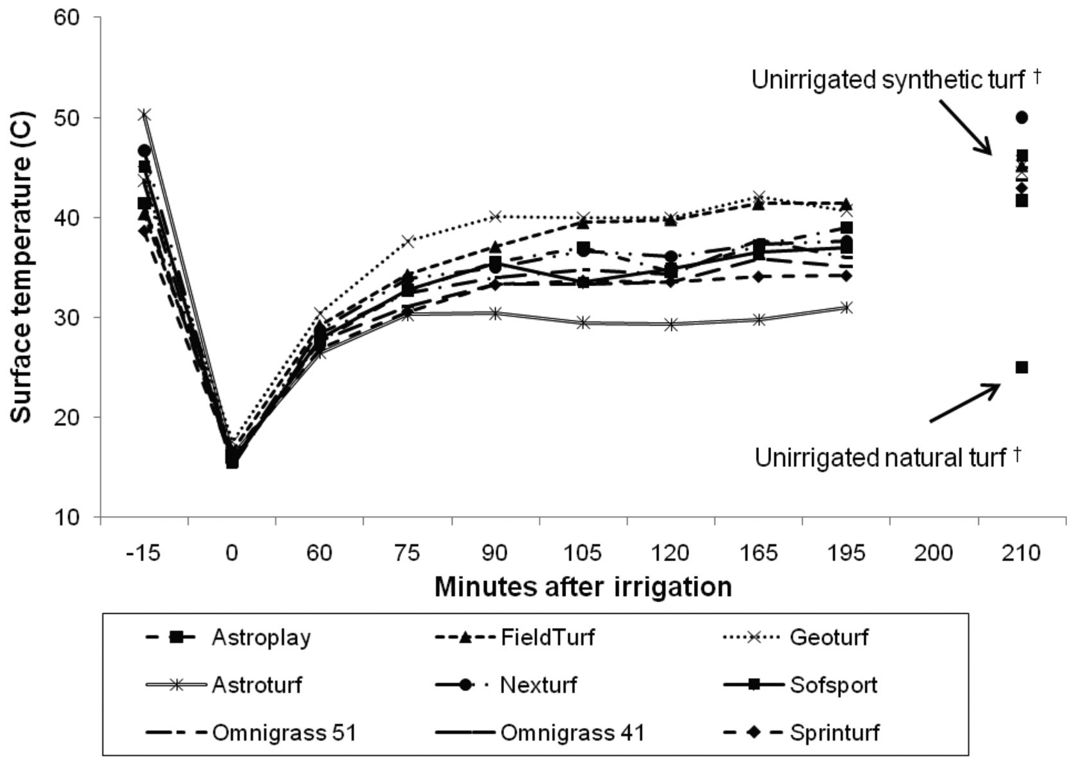

Fig. 2 Surface temperatures of synthetic turf surfaces on 2 June 2005. †Data taken from unirrigated plots (210 min) for reference purposes only

the underlying pad retains moisture, as the Astroturf (non-infilled) plots remained visually moist for a longer period of time than the other surfaces did. Some of the other surfaces included an underlying pad (Nexturf, Sofsport, and Astroplay), but these pads were further from the surface and were covered with infill material. The temperatures of unirrigated plots and a nearby Kentucky bluegrass (*Poa pratensis* L.) turf are shown for comparison purposes and were not part of the statistical analysis. Covering the surface with a tarpaulin had no effect on the surface temperature (data not shown). Additionally, preliminary (unreplicated) screening showed that adding calcined clay to crumb rubber infill had no effect on the surface temperature and therefore did not warrant further investigation (Fig. 3). Overall, the surface temperatures of non-irrigated synthetic turf surfaces were approximately 20 °C higher than those of the nearby Kentucky bluegrass that had not received precipitation for at least 5 days.

3.2 Survey of the presence of *S. aureus* bacteria

Indoor fields tended to have lower overall microbial populations (0–7267 CFU/g of infill) than outdoor fields (0–80 000 CFU/g) (Table 2). While it is clear that microbes exist on synthetic turf surfaces, the number was low compared with those on natural turf grass. The total microbial population on tested synthetic turf surfaces did not exceed 80 000 CFU/g, while the microbial populations were 259 000 CFU/g and 309 500 CFU/g on turf grown on native soil and sand-based soil respectively. It should be remembered that microbes tend to be present on most surfaces that humans come into contact with and the simple presence of microbes should not be cause for concern. In fact, many products on the market claim to boost the microbial populations of natural turf-grass soils with higher microbial populations considered to be beneficial and a functioning microbial system essential.

Pile fibre samples were also collected from fields (data not shown). The number of CFUs for fibre samples ranged from 200 to 2933 per fibre sample (two fibres approximately 1 cm long), indicating that the fibres in this study generally exhibited lower microbial populations than the infill. Microbial colonies isolated from field samples generally included both fungi and bacteria. Some fields had predominantly one organism type while other fields contained a variety of organisms. No colonies isolated from any crumb rubber or fibre samples tested positive for *S. aureus* via selective media, Gram stain, or latex agglutination tests.

The fact that *S. aureus* colonies were not found on any playing surface is not surprising. The temperature range for *S. aureus* is 7–48 °C, with the optimal

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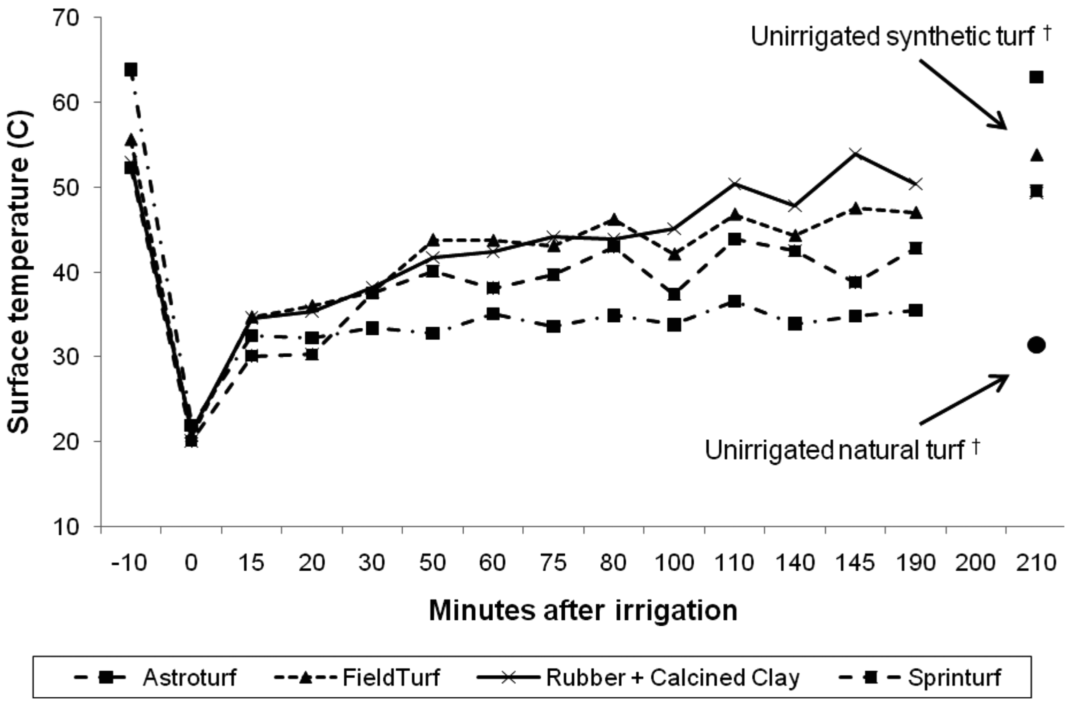

Fig. 3 Surface temperatures of synthetic turf surfaces including infill amended with calcined clay on 2 June 2005. †Data taken from unirrigated plots (210 min) for reference purposes only

Table 2 CFUs detected on R2A media per gram of crumb rubber infill or root zone

Surface identification	Infill type	Microbial population (CFU g^{-1} crumb rubber)	
		High-use area	Low-use area
1	100% crumb rubber	20 200	32 667
2	Crumb rubber–sand mix	3533	133
3	Crumb rubber–sand mix	3467	13 133
4	100% crumb rubber	9467	30 267
5	Crumb rubber–sand mix	18 867	8333
6	Crumb rubber–sand mix	267	28 333
7	Crumb rubber–sand mix	4800	55 333
8	Crumb rubber–sand mix	4867	24 133
9	100% crumb rubber	9800	17 867
10*	Crumb rubber–sand mix	0	67
11	Crumb rubber–sand mix	33 200	28 000
12	100% crumb rubber	333	800
13*	100% crumb rubber	267	67
14	100% crumb rubber	8267	—
15	Crumb rubber–sand mix	8600	3867
16*	100% crumb rubber	200	0
17*	Crumb rubber–sand mix	0	7267
18	100% crumb rubber	5000	5533
19	Crumb rubber–sand mix	53 067	80 000
20	Crumb rubber–sand mix	54 333	8867
Silt loam soil (mesic Typic Hapludalfs)		259 500	—
Sand-based soil		309 500	—

*Sample collected from an indoor field.

temperature for growth being 37 °C [**23**]. As outlined in the previous section describing the surface temperatures and also as reported by other researchers [**11**, **13**], the surface temperatures often exceed the temperature range for growth of *S. aureus* bacteria. However, high surface temperatures do not explain the reason for indoor surfaces containing a relatively low number of total microbes since the temperature of an indoor surface is similar to the ambient air temperature. These low numbers may, in part, be explained by the low moisture content on indoor synthetic surfaces although this was not measured.

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Table 3 Number of colonies per swab detected on R2A media of various surfaces and those that tested positive (+) or negative (−) for the presence of *S. aureus* colonies

Source	Number of colonies	Presence of *S. aureus*
Common surfaces		
Computer mouse	>600	−
Elevator button	155	−
Outside door handle	80	−
Computer keyboard	33	−
Human hand	N/A*	+
Human face	N/A*	+
Athletic training facility		
Cold pool	24	−
Blocking pads†	130	+
Sauna	536	−
Football†	142	−
Weight equipment†	414	+
Towel hamper	103	−
Stretching table	14	+
Used towels†	29	+
Trash can for drink cups	205	−

*N/A, not available.
†Sampled immediately after use.

Surfaces other than athletic playing surfaces were tested for the presence of microbes and *S. aureus*. These surfaces are not granulated and thus the results are listed in Table 3 as the total number of colonies per swab as opposed to the number of CFUs per gram of granulated material. Microbial colonies isolated from surfaces included a mixture of fungi and bacteria. Colonies from the trash can were predominantly fungi. While not specifically identified, all colonies from the sauna swab appeared to be the same. *S. aureus* was positively identified from several samples including towels, blocking pads, weight equipment, and the stretching table (Table 4). In addition, *S. aureus* was positively identified from every facial and hand swab tested.

4 CONCLUSIONS

With the increased adoption of infilled synthetic turf, questions related to health impacts have been raised. This paper addresses two of those concerns: the surface temperature and the presence of *S. aureus*. Irrigation was successful in significantly lowering the surface temperature for only about 20 min after irrigation. The temperature then rebounded to within approximately 10 °C of the pre-irrigation temperature after 3 h. Observations indicate that the amounts of cloud cover and haze, which each reduce direct sunlight, play a much larger role in lowering the surface temperature than applying irrigation water. The prudence of using an irrigation system compared with the short-term reduction in the surface temperature must be considered by athletic associations prior to installation.

Data from this study indicate that the irrigation regimes evaluated, including covering the surface with a tarpaulin and the preliminary screening of calcined clay use, were not effective methods to reduce the surface temperature substantially over the length of a standard sporting event (3 h). Although irrigation reduced the surface temperature initially, it is not feasible to irrigate a playing field multiple times during an event, as would be necessary to maintain cool surface conditions. Administrators and athletic trainers should be aware of potentially high surface temperatures and be prepared to adjust practice schedules and to take other precautions to limit the exposure of field users to high temperatures.

Based on the findings of the *S. aureus* survey, concern that infilled synthetic turf harbours and provides a breeding ground for *S. aureus* bacteria is unwarranted within the context of this study. *S. aureus* bacteria were found on a number of surfaces that athletes commonly come into contact with, such as towels and blocking pads; however, the tested synthetic turf did not contain any *S. aureus*. It is important to note that synthetic turf is more abrasive than natural turf grass and, as a result, breaks in the skin are more common, creating a pathway for infection when in contact with an infected surface.

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