4.0 POTENTIAL HEALTH EFFECTS RELATED TO PHYSICAL PROPERTIES OF SYNTHETIC TURF FIELDS

The potential physical health effects associated with synthetic turf systems include heat-related illnesses, burns, injuries, abrasions, and infections. The concern for these adverse health effects is based on the distinct physical characteristics of synthetic turf systems which differentiate them from grass, dirt and asphalt fields. Consideration is also given to the variety of synthetic turf configurations and technologies which have evolved since the first fields were developed in the 1950's.

The older generation of synthetic turf systems were comprised of a carpet-like, short pile synthetic turf installed over a foam pad on an asphalt or concrete surface. Subsequent generations of synthetic turf systems have been developed. Longer and softer "grass fibers" have decreased the abrasiveness and the underlayment materials include rubber and foam pads reducing risk of impact injuries. Many of the synthetic turf systems in use in New York City consist of a recycled SBR rubber pad or a foam pad underlayment topped with the synthetic fiber system. This fiber system is infilled with a cushioning infill material of crumb rubber that is produced from recycled tires that have been processed to the size of coarse sand. The crumb rubber material is spread two to three inches thick over the turf material and raked down in between the plastic fibers which simulate grass. The crumb rubber helps support the blades of fiber, and also provides a surface with some give, that feels more like the soil under a natural grass surface. Research in this area includes studies conducted by universities, the National Collegiate Athletic Association (NCAA), sports medicine associations, and public health departments.

Heat-Related Illness. Research focused on heat-related health and environmental effects is grounded in the observation that synthetic turf systems absorb radiant heat much more efficiently than grass and asphalt playing surfaces. This increase in temperature of the turf system may contribute to a local "heat island" effect, a phenomenon in which the absorption of heat by impervious surfaces increases surrounding ambient air temperature, and by doing so, may adversely affect players' health by increasing risk of heat-related illness. Research has documented that children who are not well hydrated are more prone to heat-related illness, therefore, increased water intake is recommended on hot days. In addition, the American Academy of Pediatrics, Committee on Sports Medicine and Fitness provides recommendations to address the prevention of heat-related health effects during exercise for children and adolescents. The increased surface temperature of the synthetic turf systems may also cause burns and blisters. Two documented cases of foot burns have been found in the literature, the first case was of a football coach at Brigham Young University (Williams and Pulley 2002) and the second was of six Peruvian soccer players having burns and blisters on their feet as a result of playing on synthetic "pitch" (SI.com 2007).

Physical Injuries. In addition to potential heat-related effects, another concern raised about the use of synthetic turf materials is the potential for increased injury to players as compared to natural turf materials. Characteristics such as surface hardness, abrasive index and traction of the turf systems may have an effect on the injury rates seen as a result of playing on the synthetic turf surfaces.

Surface hardness is important due to the risk of concussion upon impact with the ground surface. Surface hardness has been shown to affect both player performance and player safety. Surface hardness is measured in Gmax: the higher the Gmax value, the harder the surface. The American Society for Testing and Materials (ASTM) has established an upper limit for surface hardness of 200 Gmax above which head trauma is more likely to occur and at which point the ASTM suggests repairing or replacing the surface. McNitt and Petrunak (2007) of the University of Pennsylvania are in the process of evaluating 10 different brands of synthetic turf in-filled surfaces in a long-term study. One of the parameters that they are evaluating is surface hardness or impact attenuation on "no wear" turf and "wear" turf which simulated turf after having up to 96 games played on it. Using two different ASTM Methods the hardness index remained well below the maximum Gmax rating of 200 for all scenarios tested (McNitt and Petrunak 2007). A study conducted by Naunheim et al. (2002, 2004) evaluated the impact attenuation of three indoor fields: the first field was an indoor domed stadium with AstroTurf with a 5/8 inch foam underlayment, the second field was an indoor practice field with AstroTurf with a 1 inch foam underlayment, the third field was an infilled FieldTurf system which replaced the indoor practice AstroTurf field. These fields were compared to the impact attenuation of a natural outdoor field measured at 72 degrees and 32 degrees. The change from a foam-based Astroturf system to a shredded rubber-based system (FieldTurf) had no effect on impact attenuation overall. However, areas in the shredded rubber-based field were significantly compacted; causing some sites to be much harder than the foam-based surface it replaced (Naunheim et al. 2004).

The Naunheim studies showed that the shredded-tire based system showed significant compaction in high-use areas of the field. However, these studies were conducted on indoor fields and the FieldTurf system used was installed over a graded surface of shredded tire and silica sand. The McNitt and Petrunak study did not show an increase in compaction of the fields with simulated wear. The fields evaluated in the McNitt and Petrunak studies were in-filled systems with either foam or rubber pads, similar to what has been installed in the New York City parks. The synthetic turf fields in New York City are in-filled systems with a shock pad made of either rubber or a foam pad. Furthermore, per the City's specifications for installation:

> "The warranty shall also guarantee a G-Max rating below 130 at the time of installation and below 180 for the remaining term of the warranty. Warranty shall clearly state that if test results show that G-Max rating has not been met, the manufacturer will repair or replace product within the warranty period as necessary to meet those requirements at no cost to the City."

Concerns over the potential for increased injuries associated with the use of synthetic turf systems have led to a number of studies to evaluate the potential for increased injuries. These studies, for the most part, do not differentiate between types of synthetic turf fields. Studies by Fuller et al. (2007a, b) and Steffen et al. (2007) evaluated the incidence of injuries of both female and male soccer players playing on synthetic turf systems compared to natural grass turf systems, while Meyers and Barnhill (2004) evaluated the incidence of injury among high school football players. Fuller et al. (2007a,b) concluded that there were no major differences between synthetic turf and natural grass in the incidence rate, severity, nature or cause of injuries sustained during training or match play of male and female collegiate soccer players. Meyers and Barnhill (2004) did find significant playing surface effects by injury time loss, injury mechanism, anatomical location of injury, and type of tissue injured. Natural grass fields actually had the higher incidences of injury time loss and more severe injuries such as head and neural trauma and ligament injuries. The synthetic turf fields had higher incidences of minor injuries such as surface/epidermal (skin) injuries, muscle related trauma and a higher incidence of injury occurrence during higher temperatures. Steffen et al. (2007) found that the incidence of acute injuries did not differ between synthetic turf and natural turf. However there was an increasing trend towards more ankle sprains on synthetic turf than natural grass and there was a higher incidence of severe injuries (more than 21 days lost playing time) with synthetic turf fields. The rate of minor injuries also tended to be lower on synthetic turf fields in the Steffen study.

Differences in these results and conclusions may be a result of differences in sport (soccer versus football) and age of the athletes (college versus high school).

Abrasiveness. Abrasiveness has also been raised as an issue, especially with older synthetic turf materials. New generation synthetic turf systems have been manufactured to be soft and more resilient, unlike older versions which were hard and abrasive. A study conducted by the University of Pennsylvania on 10 synthetic in-filled turf systems showed that all fields with infill material systems were less abrasive than the traditional, carpet-like Astroturf, and on-going maintenance tended to lessen the abrasiveness (McNitt and Petrunak, 2007).

MRSA. In addition to physical injuries, there are some concerns that have been raised over the increased potential for bacterial infections, such as methicillin-resistant S. aureus (MRSA) infections, to occur in athletes playing on synthetic turf. However, studies have shown that although synthetic turf burns provide a means of access for MRSA infections, increased physical contact and poor sanitary practices in the locker rooms and training facilities account for the transmission of the disease (Beiger et al 2004, Kazakova et al 2005). Another study found that synthetic turf systems are not a hospitable environment for microbial activity, further indicating a lack of correlation between bacterial infections in athletes and bacterial skin infections (McNitt and Petrunak 2007).

4.1 Temperature of Synthetic Fields

Synthetic turf materials have shown significant temperature increases at the surface of the field and in ambient air above the playing field as compared to other turf surfaces such as grass and asphalt. Heat islands, a phenomenon where impervious surfaces absorb heat, and when this heat dissipates, causes elevated ambient air temperatures, are created when grass and trees are replaced by surfaces such as rooftops and asphalt, which absorb heat. Synthetic turf fields absorb rather than reflect sunlight, causing the fields to emit heat, thus the elevated temperatures associated with synthetic turf materials may also contribute locally to an urban heat island effect. Heat islands in large cities have regional-scale impacts on energy demand, air quality, and public health. Synthetic turf fields may be one contributor to this effect, albeit a very small one, since building roof tops and roadways make up the majority of heat absorbent surfaces in cities.

Elevated surface temperatures of synthetic turf may result in heat-related injuries associated with direct contact such as burns or blisters. Elevated ambient air temperatures associated with synthetic turf fields may contribute to heat stress, although there are no specific published reports documenting such effects. However, since synthetic turf materials have been shown to elevate ambient temperatures above the field to temperatures in excess of 95° F, there is the potential for heat stress to occur in children. Studies have shown that children are less able to adapt to changes in temperatures, especially when humidity is high.

In order to address the elevated temperatures and potential heat stress associated with the use of synthetic turf materials, increased water intake and the installation of devices designed to reduce body temperature have been employed. Dehydration has been shown to be a significant contributor to elevated core temperatures in children. Therefore, increased water intake is recommended. In addition, the American Academy of Pediatrics has published recommendations for children and adolescent athletes to address heat stress and dehydration.

It is recommended that the DPR staff, field users, coaches, athletic staff and parents be made aware of the potential for heat-related illness and how to prevent it. Shaded areas should also be provided for athletes to rest and cool down and drinking water fountains should be easily accessible.

4.1.1 Impact of Synthetic Turf Fields on Ambient and Surface Level Temperatures

Synthetic turf fields tend to significantly increase surface level temperatures and ambient air temperatures above the surface of the playing field in comparison to natural turf fields. Synthetic turf fields do tend to have higher temperatures than grass and asphalt playing surfaces (Adamson 2007; McNitt and Petrunak 2007; Williams and Pulley 2002). However, this is not limited to SBR synthetic turf fields, research as far back as the early 1970s found that surface temperatures of synthetic turf were as much as 35-60° C (95° to 140° F) higher than natural turf grass surface temperatures (Buskirk, et al. 1971 (as cited by McNitt and Petrunak 2007)). This not only may adversely affect players' health, but also may contribute to a local "heat island" effect, which is defined as an increase in urban temperature as compared to surrounding suburban and rural temperature (Rosenzweig, et al. 2006).

The contribution of synthetic turf to urban heat islands is presently unknown. However, due to the increased temperatures measured on these synthetic turf systems, they may contribute local increased ambient temperatures, but their contribution to the overall urban heat island effect is likely to be small. Urban heat islands are created when grass and trees are replaced by impervious surfaces like rooftops and asphalt, which absorb heat. Summer temperatures in New York City are approximately seven degrees higher than surrounding suburban and rural areas due to this effect. Urban heat islands increase demand for energy (particularly air conditioning), intensify air pollution, and can lead to heat-related morbidity/mortality and excess mortality due to other causes such as heart disease. A study of heat island effect mitigation strategies conducted in New York City in the summer of 2002 found that increasing vegetation has a great effect on reducing temperatures and recommends planting street trees in open spaces as well as building living roofs to provide the greatest cooling potential by area (Rosenzweig et al 2006).

According to the NYC DPR, efforts are already underway to address this issue. Over the last ten years fewer than 300 acres of parkland (that's about 1 percent of the total acreage of parkland and less than 10 percent of the grass ballfields) have been converted to synthetic surfaces, including all of the asphalt yard renovations. Over that same period, Parks has acquired over 1,900 acres of mostly undeveloped natural areas, restored or improved hundreds of those acres, launched the Greenstreets program (which has converted approximately165 acres of asphalt on 2,114 sites into plants and tree beds), preserved community gardens, and planted more than 100,000 trees (Benepe 2007).

Various studies conducted at Universities have shown significant increases in synthetic turf temperatures as compared to natural grass and other surfaces and the ambient air. Temperatures measured at the University of Missouri's Faurot Field, on a 98-degree day registered 173 ° F on the surface of the synthetic grass. Nearby natural grass showed a temperature of 105 ° F on the surface. Temperatures taken at head-level height over the synthetic turf registered 138 ° F (Adamson, 2007). At Brigham and Young University, after the complaint of a coach receiving burns on his feet from the new synthetic turf field, an investigation was launched to determine the range of temperatures, the effect of water on cooling the fields and how the temperatures compared to other surfaces (Williams and Pulley 2002). Preliminary temperature measurements showed that the surface temperature of the synthetic turf was 37 ° F higher than asphalt and 86.5 ° F hotter than natural turf. Irrigation of the turf with cooling water for 30 minutes had a significant effect on surface temperature, dropping the temperature on the surface from 174 ° F to 85 ° F, but there was a rapid rebound effect with the temperature rising to 120 ° F in 5 minutes and to 164 ° F at 20 minutes (Williams and Pulley 2002). These investigators also found that the temperature of the turf was more dependent on the amount of light, rather than the air temperature. White lines and shaded areas are less affected because of reflection and decreased intensity of light, respectively. Average surface temperature measurements of natural and synthetic turf taken in the shade show an approximate 9.5° difference (66.35° F versus 75.89° F) between the two, respectively. However, the synthetic turf field's maximum temperature rose to 99° F while that of the natural turf rose to 75° F (Williams and Pulley 2002). The large synthetic turf study conducted by Penn State's Department of Crop Management and Soil Science tested 10 synthetic turf systems for surface temperatures and ambient air temperatures 3 feet above the field surface. The investigators tried to limit temperature measurements to days that were bright and sunny, because cloudy days resulted in more erratic measurements. The surface temperatures of the fields ranged from 113.7 ° F to 125.4 ° F using a LiCor Scheduler infrared thermometer. The ambient air temperatures registered 3 feet above the turf surface ranged from 78.1 ° F to 80.6 ° F (McNitt and Petrunak 2007). The ambient air temperatures varied by a few degrees among the turfs, but did not appear to be correlated with the surface temperatures of the turf systems.

Table 4-1 summarizes the information reviewed for the assessment of the impact of synthetic turf on ambient and surface temperatures.

TABLE 4-1. INFORMATION REVIEWED ON THE IMPACT OF SYTHETIC TURF ON AMBIENT AND SURFACE TEMPERATURES			
Reference	**Evaluation**	**Major Conclusions**	**Major Limitations**
Benepe, A. 2007	Commissioner testimony focusing on the history of synthetic turf, synthetic turf today, the challenges of maintaining the parks and fields in light of the increased population of New York City and the increased use of the park facilities. Provides statistics on the increased use of the parks as evidenced by the increase in permit hours.		
Adamson 2007	This article presents a series of temperature measurements conducted by the University of Missouri.	Temperatures were measured at the University of Missouri's Faurot Field, on a 98-degree day and registered 173 °F on the surface of the synthetic grass. Nearby natural grass showed a temperature of 105° F on the surface. Temperatures taken at head-level height over the synthetic turf registered 138° F.	Methodology and equipment used in the temperature studies not discussed.
Williams and Pulley 2002	This article presents a report by the authors on a series of heat studies conducted on synthetic surfaces at Brigham Young University.	The results of the preliminary experiments showed that the surface temperature of the synthetic turf was 37° F hotter than asphalt and 86.5 °F hotter than natural turf. Irrigation of the synthetic turf with cooling water had a significant effect on surface temperature, dropping the temperature on the surface from 174 °F to 85 °F, but there was a rapid rebound effect with the temperature rising to 120 °F in 5 minutes and to 164 °F at 20 minutes. Shading decreases the amount of heating of synthetic turf. Average surface temperature measurements of natural and synthetic turf taken in the shade show an approximate 9.5 ° difference (66.35° F versus 75.89° F) between the two, respectively. However, the synthetic turf field's maximum temperature rose to 99° F while that of the natural turf rose to 75° F.	Actual methods are not provided. Average temperatures between a 12-hour span are provided, but no back-up data for individual readings is provided. No corresponding air temperatures provided for measurement time period. Maximum temperatures were only provided for turf (synthetic and natural), not for asphalt. Regarding the use of water as a coolant, water quickly cooled the surface temperature, but temperatures quickly rose. The material is hydroscopic and is not meant to retain water at the surface.

TABLE 4-1. INFORMATION REVIEWED ON THE IMPACT OF SYTHETIC TURF ON AMBIENT AND SURFACE TEMPERATURES

Reference	Evaluation	Major Conclusions	Major Limitations
McNitt, A.S. and Petrunak, D. 2007	This study tested 10 synthetic turf systems for surface temperatures and ambient air temperatures 3 feet above the field surface. The investigators also looked at the effect of irrigation on the temperature of the synthetic turf fields.	The surface temperatures of the fields ranged from 113.7 to 125.4 degrees. The ambient air temperatures 3 feet above the turf surface ranged from 78.1 to 80.6 degrees. However, the ambient temperature did not appear to be correlated with the surface temperatures of the turf systems. The application of water cooled down all synthetic surfaces, but they rebounded quickly. At the end of the experiment the irrigated fields averaged about 14 degrees cooler than the non-irrigated fields.	Actual methods are not provided. The study did not provide any discussion on discrepancy between this study and others concerning ambient air temperatures, where other studies found temperature differences and this one did not.
Rosenzweig, Solecki and Slosberg 2006	This study evaluated heat island effect mitigation strategies for New York City in the summer of 2002. These strategies include urban forestry, living/green roofs and light surfaces.	The results of the study indicated that increasing vegetation has a great effect on reducing temperatures and recommends planting street trees in open spaces as well as building living roofs to provide the greatest cooling potential by area.	No discussion of potential for synthetic turf fields to contribute to heat island effect.

4.1.2 *Potential Heat-related Illnesses and Dermal Injuries*

There are no specific published reports pertaining to heat stress from the use of synthetic turf fields, although heat stress and dehydration are potential risks for children playing in a high heat environment. Exercising children are able to dissipate heat effectively in a neutral or mildly warm climate. However, when air temperature exceeds 35°C (95°F), they have a lower exercise tolerance than do adults. It is important to emphasize that humidity is a major component of heat stress, sometimes even more important than temperature. Therefore, in general, exercising children do not adapt to extremes of temperature as effectively as adults when exposed to a high climatic heat stress (Anderson et al. 2000). These differences are due to:

1. Children have a greater surface area-to-body mass ratio than adults, which causes a greater heat gain from the environment on a hot day and a greater heat loss to the environment on a cold day.

2. Children produce more metabolic heat per mass unit than adults during physical activities that include walking or running.

3. Sweating capacity is considerably lower in children than in adults, which reduces the ability of children to dissipate body heat by evaporation.

At temperatures exceeding 115° F (46°C) the potential for dermal injuries due to burns increases. The extent of damage depends on surface temperature and contact duration (Naradzay and Alson 2006). Two reports have been identified documenting thermal burns (blisters) from contact with synthetic turf. The first is a report of a Bringham Young University coach getting "a blister on his feet through his tennis shoes" (Williams and Pulley 2002), and the second, a recent news report of six Peruvian soccer players having burns and blisters on their feet (SI.com 2007). The actual incidence of thermal burns as a result of contact with synthetic turf is unknown, however, children ages 4 and under are at greater risk from burn-related injury. Young children have a less developed keratinized layer in their epidermis than that of older children and adults, their skin burns at lower temperatures and more deeply (CT Safe Kids 2008).

4.1.3 *Prevention of Heat-related Illness and Dermal Injury*

Overheating and dehydration are an issue for athletes of all ages during the height of the summer, whether on a grass field, an asphalt yard, or a synthetic field. Dehydration can lead to mild to severe heat-related illnesses, such as heat cramps, heat exhaustion and heatstroke. By coaches and players remaining conscious of their water intake and taking frequent breaks, the danger of heat exhaustion can be greatly minimized. The NYC DPR has taken the step of starting to install water "misters" near the benches of fields that might get particularly hot in an effort to allow players to cool down more easily (Benepe 2007). It is also recommended that shaded areas be provided for the players to rest.

It has been found that children frequently do not feel the need to drink enough to replenish fluid loss during prolonged exercise. This may lead to severe dehydration. A major consequence of dehydration is an excessive increase in core body temperature. Thus, the dehydrated child is more prone to heat-related illness than the fully hydrated child. For a given level of hypohydration, children are subject to a greater increase in core body temperature than are adults. Water will help replace the fluids lost during exercise and is essential to proper cardiovascular function. Drinks with too much sugar (juices) or sugars such as fructose (soda pop) are not well absorbed and cause nausea. Fluids that contain caffeine are not recommended as caffeine acts as a diuretic, increasing urination and fluid loss. Caffeine can also cause agitation, stomachache, diarrhea, nausea, and an increased heart rate, all of which can lower performance. Salt tablets are also not recommended as they also cause nausea (AAP 2000, Goodale 2008, U.VA. 2004).

In general, exercising children do not adapt to extremes of temperature as effectively as adults when exposed to a high climatic heat stress. These differences are due to:

1. Children have a greater surface area-to-body mass ratio than adults, which causes a greater heat gain from the environment on a hot day and a greater heat loss to the environment on a cold day.

2. Children produce more metabolic heat per mass unit than adults during physical activities that include walking or running.

3. Sweating capacity is considerably lower in children than in adults, which reduces the ability of children to dissipate body heat by evaporation.

Exercising children are able to dissipate heat effectively in a neutral or mildly warm climate. However, when air temperature exceeds 35°C (95°F), they have a lower exercise tolerance than do adults. The higher the air temperature, the greater the effect on the child. It is important to emphasize that humidity is a major component of heat stress, sometimes even more important than temperature.

Proper health habits can be learned by children and adolescents. Athletes who may be exposed to hot climates should follow proper guidelines for heat acclimatization, water intake, appropriate clothing, and adjustment of activity according to ambient temperature and humidity. High humidity levels, even when air temperature is not excessive, result in high heat stress.

In addition, the American Academy of Pediatrics (Anderson, et al., 2000) recommends the following for children and adolescents engaged in activities on hot days regardless of the playing surface or location:

1. The intensity of activities that last 15 minutes or more should be reduced whenever relative humidity, solar radiation, and air temperature are above critical levels. One way of increasing rest periods on a hot day is to substitute players frequently.

2. At the beginning of a strenuous exercise program or after traveling to a warmer climate, the intensity and duration of exercise should be limited initially and then gradually increased during a period of 10 to 14 days to accomplish acclimatization to the heat. When such a period is not available, the length of time for participants during practice and competition should be curtailed.

3. Before prolonged physical activity, the child should be well-hydrated. During the activity, periodic drinking should be enforced (e.g., each 20 minutes 150 mL [5 oz] of cold tap water for a child weighing 40 kg (88 lbs) and 250 mL [9 oz] for an adolescent weighing 60 kg (132 lbs)), even if the child does not feel thirsty. Weighing before and after a training session can verify hydration status if the child is weighed wearing little or no clothing.

4. Clothing should be light-colored and lightweight and limited to one layer of absorbent material to facilitate evaporation of sweat. Sweat-saturated garments should be replaced by dry garments. Rubberized sweat suits should never be used to produce loss of weight.

4.1.4 Techniques for Measuring Heat Effects from Synthetic Turf Fields

Air and surface temperatures can be measured a number of ways, including via an infrared thermometer (McNitt and Petrunak 2007, Williams and Pulley 2002) or a traditional thermometer. Noncontact infrared (IR) thermometers use infrared technology to quickly and conveniently measure the surface temperature of objects. They provide fast temperature readings without physically touching the object. The user aims, pulls the trigger and reads the temperature on the LCD display. Lightweight, compact, and easy-to-use, IR thermometers can safely measure hot, hazardous, or hard-to-reach surfaces without contaminating or damaging the object. Also, infrared thermometers can provide several readings per second, as compared to contact methods where each measurement can take several minutes.

Temperatures of the subsurface can be taken with a soil thermometer (Williams and Pulley 2002). A soil thermometer is designed to measure the ground temperature. The thermometer, after being inserted into the ground, measures the temperature at the end of the probe.

Finally, the wet bulb globe temperature (WBGT), an index of climatic heat stress, which is influenced by air temperature, radiant heat, air movement, and humidity can be measured. A special apparatus for measuring WBGT can be used to assess heat stress conditions. It is noteworthy that 70% of climatic heat stress is due to humidity, 20% to radiation, and only 10% to air temperature (Anderson et al. 2000).

4.2 Hardness, Abrasiveness, Injury Types and Infection Risk of Synthetic Fields

In addition to potential heat-related effects, one of the concerns raised about the use of synthetic turf materials is the potential for increased injury to players as compared to natural turf materials. The different measurable factors that influence injury by type, frequency and severity are hardness, abrasiveness and traction. The standard method for measuring the surface hardness of synthetic turf is the American Standard Testing Method (ASTM) F355 Method A. Surface hardness has been shown to affect both player performance and player safety. Surface hardness is measured in Gmax: the higher the Gmax value, the harder the surface. The ASTM has established an upper limit for surface hardness of 200 Gmax above which head trauma is more likely to occur and above which ASTM suggests repairing or replacing the surface. ASTM (2000c) states:

> "The aim of this specification is to provide a uniform means and relatively transportable method of establishing this characteristic in the field based on historical data. According to historical data, the value of 200 G is considered to be a maximum threshold to provide an acceptable level of protection to users.
>
> The test method used in this specification (Procedure A of Test Method F 355), has been documented, through "unofficial" use for testing impact in fields for over 20 years. The development of this 2 ft fall height method can be traced back to the Ford and General

> Motors crash dummy tests of the 1960's, medical research papers from the 1960's and 1970's, and a Northwestern University study in which an accelerometer was fixed to the helmet of a middle linebacker to measure the impact received during actual play. This study found the impact to be 40 ft/lb that translates to the 20 lb at a height of 2 ft used in Procedure A of Test Method F 355. The maximum impact level of 200 average Gmax, as accepted by the U.S. Consumer Product Safety Commission, was adopted for use here."

The device to measure hardness is simply a hollow tube through which a 20 pound weight is dropped onto the surface from a height of two feet (ASTM 2000a). A device inside the weight measures how quickly the weight stops upon impact. The faster the weight comes to a stop, harder the surface.

Surface hardness is important due to the risk of head injuries upon impact with the ground surface. Surface hardness has been shown to affect both player performance and player safety. McNitt and Petrunak (2007) evaluated surface hardness or impact attenuation on "no wear" turf and "wear" turf which simulated turf after having up to 96 games played on it. Using two different ASTM methods (Methods F355 and the Clegg Impact Soil Tester (CIST)), the hardness index remained well below the maximum Gmax rating of 200 for all scenarios tested (McNitt and Petrunak 2007). A study conducted by Naunheim et al. (2002, 2004) evaluated the impact attenuation of three indoor fields: the first field was an indoor domed stadium with AstroTurf with a 5/8 inch foam underlayment, the second field was an indoor practice field with AstroTurf with a 1 inch foam underlayment, the third field was an infilled FieldTurf system which replaced the indoor practice AstroTurf field. These fields were compared to the impact attenuation of a natural outdoor field measured at 72 degrees and 32 degrees. The change from a foam-based Astroturf system to a shredded rubber-based system (FieldTurf) had no effect on impact attenuation overall. However, areas in the shredded rubber-based field were significantly compacted; causing some sites to be much harder than the foam-based surface it replaced (Naunheim et al. 2004).

In addition to concerns raised about the hardness of synthetic turf systems, abrasiveness has been raised as an issue, especially with older synthetic turf materials. New generation synthetic turf systems have been manufactured to be soft and more resilient, unlike older versions which were hard and abrasive. Abrasiveness is measured by ASTM Method F1015. Friable foam blocks, made of rigid closed-cell isocyanurate, were attached to a weighted platform that is pulled over the turf surface in four directions. The weight of the foam that is abraded away determines the abrasiveness of the surface. An Abrasiveness Index is calculated by taking the weight loss of all four blocks in grams and dividing by 0.0606 per ASTM F1015. A study conducted on 10 synthetic turf systems showed that all fields with infill material systems were less abrasive than the older generation, carpet-like synthetic turf system, and on-going maintenance tended to lessen the abrasiveness (McNitt and Petrunak 2007).

A number of studies have been conducted evaluating the potential for injuries occurring on synthetic turf versus natural grass. The studies have shown either no major differences in the incidence, severity, nature or cause of injuries sustained on natural grass or synthetic turf by men or women (Fuller, et al 2007a, 2007b) or that injury rates are similar but that the type of injury varies between the two surfaces (Meyers and Barnhill 2004, Steffen et al. 2007). A study conducted by Meyers and Barnhill (2004) found that surface to skin injuries and muscle strains were more common on synthetic turf, while on the natural grass fields they documented a greater incidence of head concussions and ligament tears. A study conducted on young female football players (soccer players) conducted by Steffen et al (2007) showed that injury rates (i.e., the number of injuries per 1000 hours of exposure) were similar between synthetic turf and grass. However, there were differences in types of injuries between synthetic turf and grass. In matches, twice as many severe injuries occurred on synthetic turf as on grass; however, the rate for minor injuries was significantly lower when playing on synthetic turf than on grass. More ligament and knee injuries occurred on synthetic turf than on grass (Steffen et al 2007). None of the above studies documented the type of synthetic turf surfaces that were played on. In addition, differences between the studies may be due to the sport (soccer versus football) or the age of the athletes (collegiate versus high school).

In addition to physical injuries, there are concerns over the increased potential for severe bacterial infections, such as methicillin-resistant S. aureus (MRSA) infections, to occur in athletes playing on synthetic turf. Studies have shown that although synthetic turf burns provide a means of access for MRSA infections, increased physical contact and poor sanitary practices in the locker rooms and training facilities facilitate the transmission of the disease (Beiger et al 2004, Kazakova et al 2005). Another study found that synthetic turf systems are not a hospitable environment for microbial activity, further indicating a lack of correlation between bacterial infections in athletes and bacterial skin infections (McNitt and Petrunak 2007). Based on the above information, it does not appear that synthetic turf is a source of MRSA infection; however, turf burns may act as a means of entry for the MRSA infection. It is recommended that coaching staff be aware of the potential for MRSA transmission and infection among athletes. Should abrasions occur, they should be washed with soap and water and covered immediately. Athletic departments of schools utilizing these fields should engage in good hygienic practices in their locker rooms and treatment facilities. Uniforms should be washed and equipment (shoulder, hip and elbow pads, etc) should be periodically sanitized as they can be a reservoir for MRSA infection.

4.2.1 Assess Impact Attenuation of Different Field Surfaces

The NYC DPR's Capital Projects Team assesses the danger of head trauma from impact with the ground using a G-rating system which measures surface hardness (Benepe 2007). The surface hardness refers to the ability of a surface to absorb impact energy. Playing surface hardness affects both player performance and player safety. A soft field may create early fatigue in leg muscles, while fields that are hard may be dangerous when players fall. Therefore, a balance is sought between the two which maximizes playability while still protecting players. The standard method for measuring the surface hardness of synthetic turf is standard ASTM F355 Method A. The device is simply a hollow tube through which a 20 pound weight is dropped onto the surface from a height of two feet (ASTM 2000). A device inside the weight measures how quickly the weight stops upon impact. The faster the weight comes to a stop, the harder the surface. Surface hardness is measured in Gmax: the higher the Gmax value, the harder the surface. The ASTM upper limit is 200 Gmax; above that, they suggest repairing or replacing the surface. This number was originally generated from the auto industry and data regarding the force of a human head impacting a dashboard (McNitt 2007).

DPR has every synthetic field tested by an independent third-party to ensure compliance with Consumer Product Safety Commission standards, which state that a Gmax rating of 200 or above represents an increased risk of head trauma from a fall. When the DPR installs a field it has to have a rating of 130 at installation and can never be above 180 for the life of the 8 year warranty. When the NYC DPR installs these synthetic turf fields they generally have a rating of about 120, which is considered very safe. After six months, when the field settles and has received some use, that rating typically goes up to about 140 in the most heavily used parts of the field, but then, in general, that number will plateau over the next few years so it stays well below

200 (Benepe 2007). Natural grass fields have an average G-Max rating of approximately 80-140, depending on the moisture in the soil. For comparison, a muddy grass field will have a G-Max value of approximately 65, a frozen grass field will have a G-Max value of approximately 225 (Academy Sports Turf 2007), and an asphalt field will have a G-Max value of approximately 1440 (Hoerner 1997).

A number of studies have been conducted to measure surface hardness or impact attenuation of synthetic turf fields. The ability a surface has to absorb energy created by a player upon impact is referred to as surface hardness, or impact attenuation (McNitt 2000). In a study conducted by Penn State's Department of Crop and Soil Sciences, surface hardness measurements were conducted in accordance with two ASTM methods (F355 and the Clegg Impact Soil Tester (CIST)) on 10 different synthetic turf systems that represented a "no wear" and a "wear" scenario. Simulated foot traffic was first applied to the turf fields using a "Brinkman Traffic Simulator". The traffic simulator weighs 410 kg and consists of a frame with two 1.2m rollers, with steel "cleats" welded to them was pulled with a tractor. Two passes of the traffic simulator produces the equivalent number of cleat dents created between the hash marks at the 40-yard line during one National Football Game (Cockerham and Brinkman, 1989). Thus, 24 passes per week are equivalent to the cleat dents sustained from 12 games per week. Surface hardness and impact attenuation were then conducted in accordance with ASTM methods on "no wear" turf and "wear" turf which simulated turf after having up to 96 games played on it. The CIST and the F355 methods were used to measure surface hardness. The CIST method is similar to the F355 method, except it uses a 5 pound weight which has a smaller impact surface area. The Gmax generated by the CIST method is smaller than the F355 method. The CIST method is the ASTM standard for measuring the surface hardness of natural turf (ASTM 2000b). Under all scenarios tested, the hardness index remained well below the maximum Gmax rating of 200 or the comparable 135 rating of the CIST method (McNitt and Petrunak 2007).

Naunheim et al. (2002, 2004) conducted studies evaluating the hardness of various fields in order to test the surfaces of football fields used by a professional team to determine their impact attenuation properties. Four playing surfaces used by a professional football team were tested. The first field was an AstroTurf (5/8-inch foam padding over concrete) field at a domed stadium, the second field was an indoor practice field with AstroTurf (1-inch padding over concrete), the third was an outdoor grass practice field, measured at 72° F and 32° F and the fourth field was the infill FieldTurf surface that replaced the AstroTurf (1-inch padding) in the indoor practice field. A computerized impact recording device (IRD) was used to determine whether a new shredded rubber-based turf improves impact attenuation. The device was dropped 20 times from a height of 48 inches onto each of the surfaces. Five different areas of each field were tested; the center of the field at the 30-yard line, the center of the field at the 50-yard line, the hash marks on either side of the 50-yard line, and the mid 30-yard line at the opposite end of the field. These areas were chosen because they would see the most use during game play. Of the five measurements, there was no difference in the measured surface hardness between the infill FieldTurf field and the AstroTurf field with one inch padding. Both of these fields had significantly less surface hardness than the AstroTurf with 5/8-inch padding and the measurements taken on the grass fields at both temperatures (Naunheim et al., 2002, 2004). The authors also note that the FieldTurf field evidenced surface compaction in high traffic areas resulting in areas that were harder than the foam-based AstroTurf field it replaced (Naunheim et al. 2004)

Table 4-2 summarizes the information reviewed for assessing surface hardness of synthetic turf fields.

TABLE 4-2. INFORMATION FOR ASSESSING SURFACE HARDNESS OF SYNTHTIC TURF FIELDS			
Reference	**Evaluation**	**Major Conclusions**	**Major Limitations**
McNitt and Petrunak 2007	This study evaluated surface hardness and impact attenuation as part of a large project undertaken by Penn State to evaluate the playing surface quality of various infill systems over time under no wear and wear scenarios. Wear was simulated on the turf fields using the "Brinkman Traffic Simulator"	The results show that after wear simulating up to 96 games, the hardness index remained well below the maximum Gmax rating of 200, indicating that the turf materials maintained their engineered hardness level after wear.	Measurements only taken on two days during the summer, no readings during colder weather. For comparison, it would be informative to have data from actual playing fields instead of just from the experimental turf fields used in this study.
Naunheim et al 2002, 2004	These studies compare the impact attenuation for a newer generation of synthetic turf as compared to older versions of synthetic turf used in indoor playing surfaces.	Both the shredded rubber-based system (FieldTurf) and the foam-based AstroTurf field it replaced demonstrated g values of ~184. The g values of the other three fields included 261.6 (indoor domed stadium with AstroTurf and 5/8 foam padding), 264.4 (outdoor warm grass) and 398.2 (frozen outdoor grass field). The change from a foam-based Astroturf system to a shredded rubber-based system (FieldTurf) had no effect on impact attenuation overall. However, areas in the shredded rubber-based field (FieldTurf) were significantly compacted, resulting in some sites to be much harder than the foam-based surface (AstroTurf) it replaced.	Did not use ASTM Method F355 for measurement of Gmax, which is the standard method for testing hardness of synthetic turf. By using an alternate method, unable to compare with other studies, since this study's g-values are substantially higher than recordings noted elsewhere. Warm outdoor grass was noted as having a g-value of 264.4, however, it's Gmax value is typically cited as 140 or less. The FieldTurf field underlayment consists of shredded tire and sand, not crumb rubber, with a infill material.

4.2.2 *Assess Abrasiveness of Different Field Surfaces*

The older generation of synthetic turf was carpet-like, harder and more abrasive than the "newer generation" of synthetic turf. The shorter fibers are stiffer and more abrasive. The more abrasive a surface, the more apt the surface is to cause friction burns when an athlete's bare skin comes into contact with the surface. Friction burns (turf burns) were a common complaint from athletes using the older generation of synthetic turf (Academy Sports Turf 2007). The "new generation" synthetic turf has been manufactured to be soft and spongy and more "grass-like". The newest generation of synthetic turf places a fine-textured canopy of polyethylene fibers (the synthetic blades of grass) over a base of well-drained aggregate consisting of crumb rubber and in some cases sand. The fibers are then top-dressed with a layer of crumb rubber or a combination of crushed rubber and sand to provide extra padding and keep the grass upright. The infill also serves as a ballast to hold the carpet down and acts as a shock absorber to help prevent serious injuries and create a safer, more resilient surface (Academy Sports Turf 2007, Morrison 2005, Benepe 2007).

In Penn State's Department of Crop and Soil Sciences long-term study on 10 synthetic turf systems, abrasiveness of the synthetic turf systems were measured using ASTM Method F1015. Friable foam blocks, made of rigid closed-cell isocyanurate, were attached to a weighted platform that was pulled over the turf surface in four directions. The weight of the foam that is abraded away determines the abrasiveness of the surface. An Abrasiveness Index is calculated by taking the weight loss of all four blocks in grams and dividing by 0.0606 per ASTM F1015. All infill systems were less abrasive than the traditional, carpet-like, Astroturf. Grooming of the surfaces tended to lessen the abrasiveness. The test is being modified for use on natural turf.

Table 4-3 summarizes the information reviewed for the abrasiveness of synthetic turf fields.

TABLE 4-3. SUMMARY OF ABRASIVENESS STUDIES				
Reference	**Evaluation**	**Major Conclusions**	**Major Limitations**	**Study Relevance**
McNitt and Petrunak 2007	This study evaluated the abrasiveness of various synthetic turf systems, including infilled systems and the traditional, carpet-like AstroTurf as part of a large project undertaken by Penn State to evaluate the playing surface quality of various infill systems over time. Surface quality was evaluated periodically as the systems were exposed to weather and simulated foot traffic, using the Brinkman Traffic Simulator. The effects of various maintenance activities on the playing surface quality of these systems were also evaluated.	All infill systems were less abrasive than traditional Astroturf. Grooming of the surfaces tended to lessen the abrasiveness. The test is being modified for use on natural turf.	No context provided for the Abrasiveness Index, other than comparison to AstroTurf which was used as the standard for abrasiveness.	Relevant

4.2.3 *Frequency of Injury in Different Playing Fields*

Four types of traction have been defined by Shorten and Himmelsbach (2002) and they include translational, rotational, static, and dynamic traction (summaries from McNitt and Petrunak 2007):

- Translational traction refers to the traction that resists the shoe's sliding across the surface. For the athlete, high translational traction equates to the shoe gripping the surface and low translational traction means the shoe tends to slip.

- Rotational traction refers to the traction that resists rotation of the shoe during pivoting movements. For the athlete, high rotational traction equates to a greater tendency for foot fixation during changes of direction and low rotational traction means the shoe tends to release from the surface more easily.

- Static traction is the resistance to sliding or pivoting when there is no movement between the shoe and the surface. Static traction forces tend to resist the initiation of sliding or pivoting.

- Dynamic traction is the resistance that occurs during a sliding or pivoting motion. Dynamic traction forces tend to resist or decelerate pivoting motions.

Because of the link between foot fixation and knee injuries, resistance to rotation (rotational traction) between the shoe and the ground should be as low as possible providing adequate translational traction is maintained (Shorten and Himmelsbach 2002). McNitt and Petrunak's on-going study of synthetic turf systems at the University of Pennsylvania compared the rotational and translational traction of 10 synthetic turf systems under "no-wear" and "wear" conditions, with and without grooming. In addition, they tested two different types of turf shoes, a post-type cleat and a molded shoe. The study was conducted in accordance with the proposed traction standard ASTM WK486 (ASTM 2000c). The preliminary results of the study show there were few meaningful traction differences between synthetic turf systems in the no-wear scenario, although the traditional, carpet-like Astroturf measured consistently higher in linear traction compared to the infill systems. This trend was not evident in the rotational traction results. Measurements taken shortly after field grooming showed that translational traction tended to increase after grooming whereas rotational traction tended to have no change or trend slightly lower. During 2004, grooming resulted in a greater reduction in rotational traction compared to 2003. In addition, there continued to be a trend of increased translational traction after grooming for the no wear treatments but the trend was less evident in the treatments receiving wear. This was true regardless of shoe type. It may be that as these systems age, grooming will have a diminished affect on translational traction. When traction was measured on the various synthetic turf surfaces during wet conditions, traction was generally reduced. The overall significance of this data, as it relates to injury, is that, immediately after grooming, an athlete will experience increased translational (linear) traction and either no change or a slight decrease in rotational traction, thus allowing, for example, a football lineman more traction when pushing but affecting no change or a slight reduction in the rotational foot fixation that Shorten and Himmelsbach (2002) state has a direct affect on lower extremity injuries (McNitt and Petrunak 2007).

The concerns over the potential for increased injuries associated with the use of synthetic turf systems have led to a number of studies comparing risk for increased injuries on synthetic turf versus natural turf. These studies have shown either no major differences in the incidence, severity, nature or cause of injuries sustained on natural grass or synthetic turf by men or women (Fuller, et al 2007a, 2007b) or that injury rates are similar but that the type of injury varies between the two surfaces (Meyers and Barnhill 2004, Steffen et al. 2007). Studies by Fuller et al. (2007a, b), Meyers and Barnhill (2004) and Steffen et al. (2007) evaluated the incidence of injuries of both female and male soccer players playing on synthetic turf systems compared to natural grass turf systems. Fuller et al. evaluated the incidence of injuries occurring during matches (2007a) and during training (2007b) of a total of 106 male teams and 136 female teams over two competitive seasons and concluded that there were no major differences between synthetic turf and natural grass in the incidence rate, severity, nature or cause of injuries sustained during training or match play. Meyers and Barnhill (2004) compared the incidence of injuries of eight high school football teams over five competitive seasons playing on synthetic turf or natural grass fields. Statistical analyses indicated significant playing surface effects by injury time loss, injury mechanism, anatomical location of injury, and type of tissue injured. Natural grass fields had the higher incidences of injury time loss and more severe injuries such as head and neural trauma and ligament injuries. The synthetic turf fields had higher incidences of minor injuries such as surface/epidermal (skin) injuries, muscle related trauma and a higher incidence of injury occurrence during higher temperatures. Steffen et al. (2007) evaluated the risk of injury on synthetic turf compared to natural turf systems. Two thousand and twenty (2020) female soccer players from 109 teams participated in the study. The incidence of acute injuries did not differ between synthetic turf and natural turf. During matches, there was a higher incidence of severe injuries (more than 21 days lost playing time) found with synthetic turf fields. Also, the rate for minor injuries tended to be lower on synthetic turf fields than on grass fields.

None of the above studies documented the type of synthetic turf surfaces that were played on. In addition, differences between the studies may be due to the sport (soccer versus football) or the age of the athletes (collegiate versus high school).

Table 4-4 summarizes the information reviewed for the assessment of the incidence of injuries sustained on synthetic turf fields.

TABLE 4-4. SUMMARY OF INJURY STUDIES

Reference	Evaluation	Major Conclusions	Major Limitations	Study Relevance
McNitt and Petrunak 2007	Evaluated rotational and translational traction of 10 synthetic turf fields as a measure of the potential for lower limb injuries.	Measurements taken shortly after field grooming showed that translational traction tended to increase after grooming whereas rotational traction tended to have no change or trend slightly lower. As the fields aged, grooming resulted in a greater reduction in rotational traction compared to earlier measurements. There continued to be a trend of increased linear traction after grooming for the no wear treatments but the trend was less evident in the treatments receiving wear. This was true regardless of shoe type.	No standard value for comparison. Traction compared against traditional AstroTurf surface.	Relevant
Fuller et al 2007a,b	This study evaluated the incidence of injuries sustained by men and women football players (i.e. soccer), playing on either natural grass or "new generation" synthetic turf (i.e. synthetic turf with rubber crumb infill material).	The studies concluded that there were no major differences in the incidence, severity, nature or cause of injuries sustained on natural grass or synthetic turf by either men or women.	Subjects were college athletes, with higher degrees of physical capabilities and conditioning.	Relevant
Meyers and Barnhill 2004	A five year study was conducted to compare game-related, high school football injuries between natural grass and FieldTurf from 1998 to 2002.	The results of the study indicate no significant differences between playing surfaces across injury categories and time of injury. However, there were observable differences between the two playing surfaces. Natural grass fields actually had the higher incidences of injury time loss and more severe injuries such as head and neural trauma and ligament injuries. The synthetic turf fields had higher incidences of minor injuries such as surface/epidermal (skin) injuries, muscle related trauma and a higher incidence of injury occurrence during higher temperatures.	The weather was characterized as dry and low humidity, resulting in hard, natural grass playing surfaces.	Relevant

TABLE 4-4. SUMMARY OF INJURY STUDIES

Reference	Evaluation	Major Conclusions	Major Limitations	Study Relevance
Steffen et al 2007	A retrospective cohort study to investigate the risk of injury on synthetic turf compared with natural grass among young female football players was conducted with 2020 players on 109 teams in 2005.	Acute injury rates (i.e., the number of injuries per 1000 hours of exposure) were similar between synthetic turf and grass. However, there were differences in types of injuries between synthetic turf and grass. Sprained ankles were the highest recorded injury, with an increasing trend towards more ankle sprains on synthetic turf. There was a higher incidence of severe injuries (more than 21 days lost playing time) with synthetic turf fields. Also, the rate for minor injuries tended to be lower on synthetic turf fields than on grass fields.	Differences in synthetic turf types were not accounted for in the study Players played on synthetic turf, grass, gravel and indoor floors, and the potential for injury due to varying play surfaces is unknown due to poor statistical power of the gravel and indoor floor cohorts. Maintenance status of the synthetic turf and grass fields was not accounted for in the study. Weather conditions were not noted in this study.	Relevant

4.2.4 *Assessment of Potential of Staphylococcus Aureus Infection Associated with Synthetic Turf*

Methicillin-resistant S. aureus (MRSA) is a drug resistant bacteria implicated in severe, sometimes life-threatening or fatal infection in health care settings. Cases of community acquired severe infection with MRSA are becoming more common. Investigations of outbreaks of MRSA in athletes have been published (Kazakova et al. 2005, Begier et al. 2004). Turf playing fields were evaluated as a potential risk factor for MRSA infection. Two possible risk factors for contracting a MRSA infection from synthetic turf fields are a) an increased risk for skin abrasions and other injuries leading to open wounds and b) whether the fields themselves harbor the bacteria. Two studies (Kazakova et al 2005) and Begier et al. 2004) were conducted with professional (Kazakova et al. 2005) and college (Beiger et al. 2004) football teams to determine the relationship between synthetic turf and MRSA infections. Kazakova et al. (2005) and Beiger et al. (2004) both concluded that skin abrasions and turf burns caused by synthetic turf provide a means of access for the MRSA infection. However, in both cases it was found that increased physical contact (due to position played) and poor sanitary practices in the locker rooms and training facilities facilitate the transmission of the disease (Beiger et al 2004, Kazakova et al 2005).

McNitt and Petrunak (2007) evaluated environmental bulk samples taken from a number of synthetic turf fields throughout Pennsylvania, ranging from elementary school to professional athletic fields and assayed them for total microbial growth as well as MRSA. In addition, they collected swab samples from common public areas, an athletic training facility as well as from the hands and face of random individuals. The investigators found no MRSA on any of the synthetic turf samples. Staphylococcus aureus was found, however, on blocking pads, weight equipment, stretching tables, and used towels, in addition to the hands of five randomly tested individuals. The McNitt study concluded that "These infilled systems are not a hospitable environment for microbial activity. They tend to be dry and exposed to outdoor temperatures, which fluctuate rapidly. Plus, the infill media itself (ground-up tires) contains zinc and sulfur, both of which are known to inhibit microbial growth. Considering the temperature range for growth of *S. aureus* is 7-48°C (44.6-118.4°F), we didn't expect to find this bacterium in fields exposed to sunlight, since the temperatures on these fields far exceed 48°C frequently."

Based on the above information, it does not appear that synthetic turf is a source of MRSA infection; however, abrasions may act as a means of entry for the MRSA infection. It is recommended that coaching staff be aware of the potential for MRSA transmission and infection among athletes playing on any playing surface. Should abrasions occur, they should be washed with soap and water and covered immediately. Athletic departments of schools utilizing these fields should engage in good hygienic practices in their locker rooms and treatment facilities. Uniforms should be washed and equipment (shoulder, hip and elbow pads, etc) should be periodically sanitized as they can be a reservoir for MRSA infection.

Table 4-5 presents a summary of the studies that assessed the association of S. aureus infections with synthetic turf.

4-5. Assessment of Association of S. Aureus Infections with Synthetic Turf			
Reference	**Evaluation**	**Major Conclusions**	**Major Limitations**
Kazakova et al 2005	A retrospective cohort study was conducted on members of the professional football team, the St. Louis Rams to evaluate potential causes or sources for the MRSA outbreak.	The results of the statistical analysis of the data showed that all MRSA skin abscesses developed at turf burn sites. These sites were usually not covered, and the authors concluded that these abrasions were likely the source and the vehicle for transmission of MRSA.	This study did establish a link between the occurrence of turf burns and MRSA infections; however, other factors, such as poor hygienic practices, may have contributed or caused the outbreak. Further study is needed to establish a causal link between synthetic turf burns and MRSA infections. The study evaluated activities conducted by professional football players, thus it more likely presents a more intensive use of the synthetic turf fields than would occur during recreational use of the fields.
Begier et al 2004	A retrospective cohort study was conducted to investigate a MRSA outbreak in 10 members of a college football team.	Turf burns were thought to facilitate infection and the authors suggest that eliminating turf burns would be the best way to prevent infection. The authors also note that study on the risk of abrasion from synthetic turf warrants further study. Authors note that players with high physical contact rates during games or practices, equipment such as elbow pads, shaving of body hair and the whirlpool in physical therapy all had high associations with an increased risk of contracting MRSA.	The study was a reflective cohort study; therefore, it did not include sampling of surfaces routinely contacted by the athletes and did not sample the whirlpool water to identify sources for the MRSA infections. The study evaluated activities conducted by college football players and thus likely presents more intensive use of the synthetic turf fields than would occur during recreational use of the fields.
McNitt and Petrunak 2007	The objective of this study was to determine the microbial population of several infilled synthetic turf systems as well as compare them to natural turf grass fields. In addition, other surfaces from public areas and from an athletic training facility were also sampled.	The study concluded that infill systems are not a hospitable environment for microbial activity.	The study did not indicate temperature of field at the time of sampling