Safety & Performance
## Synthetic Turf – Research Update

### Safety
- Injuries
- Skin infections
- Surface temperature
- Exposure to harmful chemicals
- Environmental risk

### Performance
- Traction
- Surface Testing Methods
  - American Society for Testing and Materials (ASTM)
  - FIFA Quality Concept
- What do the players think?
Injuries

• Research.....

  – Are injuries more common on synthetic turf?

  – Different types on injuries on synthetic turf?
Synthetic Turf - Injuries

Sports Illustrated, November 1, 1993

A Fight Over Turf

Three recent injuries on AstroTurf have underscored NFL players' calls for a return to grass. By Peter King

CHICAGO Bears receiver Wendell Davis feels his leg as he sits on the bench during a game against the Philadelphia Eagles. "The doctor says it's just a sprain," Davis says. "But I think it's more than that."

Davis injured his knee last season when he slipped on AstroTurf and fell on his knee. "The turf is not safe," Davis says. "I've had three surgeries on my knee, and I still have pain."

AstroTurf is a synthetic material made of polyethylene and polypropylene fibers. It is used in sports fields and is commonly used in soccer, football, and baseball fields.

The debate over AstroTurf has gained attention in light of recent injuries to NFL players. The NFL has been under pressure to make changes to the artificial turf used in its stadiums.

The NFL has been discussing the possibility of using natural grass in its stadiums, but the cost and maintenance of grass fields have been concerns.

The debate has also been fueled by concerns about the safety of AstroTurf. Some studies have suggested that AstroTurf leads to a higher risk of injury, including torn ligaments and concussions.

The NFL has been working with researchers to find ways to improve the safety of AstroTurf. The league has also been looking at the possibility of using a combination of grass and artificial turf in its stadiums.

Despite the debate, the NFL has not yet made a decision on the future of AstroTurf. The league has said that it will continue to evaluate the safety of the material and will make changes as needed.
Injury (Epidemiological) Studies

• Very few studies – WHY?
  – Separate contributors to injuries
    • Caused by field?
    • Contact vs. non-contact
    • Shoe type
    • Who records the data?
    • Statistics – need large sample size
Injury Studies

- 11 scientific injury studies published – infilled synthetic turf vs. natural grass
  - Soccer – 8 studies
    - Europe
    - Professional players, youth players
    - Boys and girls
    - Game vs. practice
  - Football – 2 studies
    - High school
    - College
  - Rugby – 1 study
- So, are injuries more common on synthetic turf?
Injury Studies - Findings

- **No** study found higher overall injury rate on synthetic turf
  - 1 football study – lower overall injury rate on synthetic turf

- **Statistical trends**
  - Ankle injuries – more and less common on synthetic turf
  - Soccer study – ACL injuries 4x more common on synthetic turf
<table>
<thead>
<tr>
<th>Synthetic turf – higher incidence of.........</th>
<th>Natural grass – higher incidence of.........</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Zero-day time loss injuries</td>
<td>• 1-2 day time loss injuries</td>
</tr>
<tr>
<td>• Non-contact injuries</td>
<td>• 22+ day injuries</td>
</tr>
<tr>
<td>• Surface/epidermal injuries</td>
<td>• Head and neural trauma</td>
</tr>
<tr>
<td>• Muscle-related trauma</td>
<td>• Ligament injuries</td>
</tr>
<tr>
<td>• Injuries during high temps.</td>
<td>• *most of injuries on dry fields</td>
</tr>
</tbody>
</table>
Concussions

- 10 – 20% of concussions from impact with the surface
- Meyers (2004) – higher concussion rate on natural grass
  - Dry field conditions
Injury Risk Conclusion

No difference in overall injury risk between infilled synthetic turf and natural grass.
Additional Injury Research

• ACL injury potential using cadavers (Drakos, et al., 2010)
  – Measured ACL strain on synthetic turf and natural grass with various shoes
    – Lowest strain: Screw-in cleats on natural grass
    – Highest strain: Molded studs on first generation synthetic turf
ACL – Cadaver Research

Realistic?

Muscular stabilization in live humans
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<tr>
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<td>– American Society for</td>
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<tr>
<td>• Exposure to harmful chemicals</td>
<td>Testing and Materials</td>
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<tr>
<td></td>
<td>(ASTM)</td>
</tr>
<tr>
<td>• Environmental risk</td>
<td>– FIFA Quality Concept</td>
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<td></td>
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</table>
A High-Morbidity Outbreak of Methicillin-Resistant Staphylococcus aureus among Players on a College Football Team, Facilitated by Cosmetic Body Shaving and Turf Burns

Background. Athletics-associated methicillin-resistant Staphylococcus aureus (MRSA) is a high-profile national problem with substantial morbidity.

Methods. To investigate an MRSA outbreak involving 21 players, a cohort study of all 100 players was performed. A case was defined as MRSA acquisition, diagnosis, or treatment from 6 August (the start of football camp) through 1 October.
Staph Infections

- *Staphylococcus aureus* bacteria
- Methicillin-resistant *S. aureus* (MRSA)
- Synthetic turf – harboring *S. aureus*?
  - Antimicrobial Treatments
Staph Survey

- 20 fields (summer)
- Indoor and outdoor
- High and low use areas
- All bacteria and \textit{S. aureus}
Colony forming units (CFU) detected on R2A media per gram of crumb rubber infill or rootzone

CFUs g⁻¹: Indoor (0-7267) vs. Outdoor (0-80,000)
Colony forming units (CFU) detected on R2A media per gram of crumb rubber infill or rootzone

No S. aureus found via selective media, gram stain, or latex agglutination tests at any test location

* = Indoor Field
Surfaces that test positive (+) or negative (-) for the presence of S. aureus colonies

<table>
<thead>
<tr>
<th>Source</th>
<th>Result</th>
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</thead>
<tbody>
<tr>
<td>Public areas</td>
<td></td>
</tr>
<tr>
<td>Human hands</td>
<td>+</td>
</tr>
<tr>
<td>Human faces</td>
<td>+</td>
</tr>
<tr>
<td>Computer mouse</td>
<td>-</td>
</tr>
<tr>
<td>Elevator button</td>
<td>-</td>
</tr>
<tr>
<td>Outside door handle</td>
<td>-</td>
</tr>
<tr>
<td>Computer keyboard</td>
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<thead>
<tr>
<th>Source</th>
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<tbody>
<tr>
<td>Athletic training facility</td>
<td></td>
</tr>
<tr>
<td>Natural turfgrass playing field</td>
<td></td>
</tr>
<tr>
<td>Synthetic turf playing field</td>
<td>-</td>
</tr>
<tr>
<td>Cold pool</td>
<td>-</td>
</tr>
<tr>
<td>Blocking pads*</td>
<td>+</td>
</tr>
<tr>
<td>Sauna</td>
<td>-</td>
</tr>
<tr>
<td>Football*</td>
<td>-</td>
</tr>
<tr>
<td>Weight equipment*</td>
<td>+</td>
</tr>
<tr>
<td>Towel hamper</td>
<td>-</td>
</tr>
<tr>
<td>Stretching table</td>
<td>+</td>
</tr>
<tr>
<td>Used towels*</td>
<td>+</td>
</tr>
<tr>
<td>Trash can for drink cups</td>
<td>-</td>
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*Sampled immediately after use
Staph Bacteria Survivability

- Live bacteria placed on synthetic turf (indoor and outdoor)

- Tested bacteria survivability
  - Commercially available antimicrobial sprays
  - Laundry detergent

- Results
  - Outdoors – nearly all bacteria dead within 3 hours (heat, UV light)
  - Indoors – some bacteria survived for several days
  - Both treatments equally effective (indoors)
Staph Bacteria

- Synthetic turf - more abrasive than natural grass
- Skin Break = Entry Point
- Synthetic turf – not a “breeding ground”
Prevention of Staph Infections

[Images of people spraying down equipment and hands with soap and water.]
# Synthetic Turf – Research Update

## Safety
- Injuries
- Skin infections
- **Surface temperature**
- Exposure to harmful chemicals
- Environmental risk

## Performance
- Traction
- **Surface Testing Methods**
  - American Society for Testing and Materials (ASTM)
  - FIFA Quality Concept
- What do the players think?
Surface Temperature
Not a New Problem.....

- 1970’s research – 1st generation Astroturf (no infill)
  - Up to 50° F hotter than grass

- Black crumb rubber?
Children less able to adapt to changes in temperature
Surface Temperature

• When do these surfaces get hot?
  – Sunny
  – Low humidity
  – No clouds
  – Noon – 3:00 PM
Cloud Cover

High Humidity/Haze
Reasons for High Temperatures

- Black crumb rubber?
  - Research: very small differences for different colors (< 10° F)
    **painted black rubber
  - 1st generation – hot without any infill

- Fibers?
  - Major contributor to high surface temperatures
  - Natural turf plants transpire
Temperature Testing

- Outdoors
  - Infrared thermometer

- Laboratory
  - Heat lamp
  - Data logger
  - Controlled conditions
Surface Temperatures with and without infill

Surface Temperature (F)

Time

1 hr  2 hr  3 hr  4 hr

No Infill  Infill Installed (Black Crumb Rubber)
Lowering Surface Temperature

- **Irrigation**
  - **Short-term** cooling
  - Temperatures rebound quickly (20 minutes)
  - *Can we keep the turf wetter for a longer period of time?*
Temperature Research

Super-Absorbent Polymer (SAP) Layer
Calcined Clay?

- Previous testing – 20% calcined clay / 80% rubber
- New testing – 1 to 1 ratio
Surface Temperature - calcined clay vs 100% crumb rubber

Time after watering

Surface Temperature (F)

1 to 1 CC  100% rubber
Is Calcined Clay Stable?

Calcined clay broke down, lost cooling effect.
Surface Temperature

• No solution yet

• Fiber technology ?

• Schedule practices in morning and evening

• Monitor athletes
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Exposure to Harmful Chemicals
• Risk in everything

• Risk = Toxicity x Exposure

• Tylenol? Caffeine? Alcohol?

• If substance found – not necessarily a significant health risk
Potentially Harmful Contaminants

- **Polycyclic Aromatic Hydrocarbons (PAHs)**
  - From oils used in tire production
  - Some cancer-causing
  - Inhalation, skin absorption, ingestion
Potentially Harmful Contaminants

- **Volatile Organic Compounds (VOCs)**
  - From oil and tar used in tire production
  - Released from plastic bottles, gasoline, paint, etc.
  - Can cause eye, nose, throat, and skin irritation
Human Health - Exposure

- Inhalation
- Skin contact
- Ingestion
- Cancer risk
Studies of Risk
<table>
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<tr>
<td><strong>Polycyclic Aromatic Hydrocarbons (PAHs)</strong></td>
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<tr>
<td>• Indoor fields – no elevated health risks</td>
</tr>
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<td>• Outdoor fields – Not different from background levels</td>
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<tr>
<td><strong>Volatile Organic Compounds (VOCs)</strong></td>
</tr>
<tr>
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Inhalation

- PAHs and VOCs – similar to vehicular traffic
- Particulate matter
  - Same as background levels
- Weathering for 10 weeks
  - up to 80% decrease in emissions
Skin Contact

- PAHs
- Multiple Studies – no increased health risk
- Potential irritation - allergies
Skin Contact

• Human Testing for PAHs
  – Urine samples from players with repeated contact with rubber
  – No elevated levels of PAHs
Ingestion

• Based on 1 gram ingested per game/practice – no elevated health risk

• Heavy metal content – complies with European toy standards

• Ingestion – not considered relevant exposure scenario
Ingestion

- PAHs – exceed soil standards when new, not bioaccessible

- Lead – low concentrations – but higher bioaccessibility

- Playground rubber
  - Ingestion of small amounts of rubber by children – no increased risk of cancer
Cancer Risk

• Playground Rubber
  – Unlikely to produce adverse health effects
  – 1 time ingestion of 10 grams of rubber by 3 year old
    • Only zinc would exceed EPA health standards
    • No increased risk of cancer
  – Hand-to surface-to mouth test – slightly elevated cancer risk – but acceptable compared to overall cancer rate (CA Office of Environ. Health Hazard Assessment)
    • Regular playground use ages 1 - 12
Cancer Risk

- Nitrosamines (carcinogenic compound) – not present above turf
- Estimated risks are low compared to many common human activities
Fibers

- Lead – New Jersey
  - High lead levels – Traditional Astroturf

- 1 Study:
  - “slightly worrisome” chromium levels
  - Lead – low level, but high bioaccessibility
Fibers

  - Infilled synthetic turf – little to no lead, not harmful to children

NEWS from CPSC

U.S. Consumer Product Safety Commission

FOR IMMEDIATE RELEASE
July 30, 2008
Release #08-348

CPSC Staff Finds Synthetic Turf Fields OK to Install, OK to Play On
Human Health - Exposure

• Presence of chemicals alone not necessarily cause for concern
  – Many comparable to background levels
  – Enough to warrant a risk?

• All routes of entry – no elevated health risk

• No evidence of elevated cancer risk
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Environmental Risk
V. SUMMARY AND CONCLUSIONS

The Connecticut Agricultural Experiment Station study conclusively demonstrates that the tire crumbs and tire mulch release chemical compounds into the air and ground water. Thus, tire crumbs constitute a chemical exposure for humans and the environment.

- There is enough information now concerning the potential health effects from chemicals emanating from rubber tire crumbs to place a moratorium on installing any new fields or playgrounds that use ground-up rubber tires until additional research is undertaken.
Researching Environmental Impacts

• Laboratory
  – Controlled environment
  – Mimic worst-case scenario (over-estimate)
  – Realistic?

• Field studies
  – Can be difficult to get permission
  – Other factors can affect results
Areas of Potential Concern

- **Water Quality**
  - Heavy metals
  - Aquatic life

- **Air Quality**
  - Organic compounds
    - Volatile organic compounds (VOCs)
  - Particulate matter
Environmental Impact Studies

- Most comprehensive study:
  - New York State Department of Environmental Conservation (2009)
  - Lab and field study
Environmental Impact Studies

- New York State DEC
  - 4 types of crumb rubber
    - Car
    - Truck
    - Car + truck
    - Cryogenic
  - Simulated precipitation and leaching (lab)
Water Quality Results

• Zinc (truck only), aniline, and phenol
  – Potential release above groundwater standards

• No significant impact on groundwater quality

• Zinc
  – Contaminant of most concern (similar to other studies)
  – Other heavy metals (lead, cadmium, etc.) – little concern
Zinc Levels

- Milone and MacBroom, 2008 (field study)
  - Maximum zinc concentration found: 0.031 mg/L
  - Connecticut DEP water quality standard: 0.065 mg/L
Water Quality – Field Study

- Samples collected from installed fields (surface and groundwater)
  - Surface – no organics, several metals at low levels
  - Groundwater – no organics or metals (zinc)
Aquatic Life

• New York State DEC - 2 test methods (lab)

• Test 1 – Simulated precipitation test
  – 100% truck tires – possible impact (zinc)
  – Other rubber – toxicity unlikely

• Test 2 – Column test – represents field conditions
  – No negative impacts for any rubber type
Aquatic Life

- Tire rubber on playgrounds (lab)
  - Toxicity immediately after installation

- Potential risk – zinc (Connecticut DEP)

- Zinc – site specific (depth to groundwater, pH, drainage, etc.)
Air Quality

- Milone and MacBroom, 2008
  - Tested during hot weather, calm winds, 3 days after grooming (worst case scenario)

- Any contaminants found common in urban air (background levels)
Other Environmental Concerns

• Heat island effect

• What about disposal?
  – Landfills?
  – Recycle?
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Traction

Goal: Maximize players’ actions without causing excessive stress to joints and ligaments
Swivel Football Shoe

- 1960s
- No cleats on heel
- Forefoot cleats – 360° rotation
# Traction

<table>
<thead>
<tr>
<th>Linear traction</th>
<th>Rotational traction</th>
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</thead>
<tbody>
<tr>
<td>– Performance</td>
<td>– Resistance that prevents the shoe from moving freely during twists and pivots</td>
</tr>
<tr>
<td>– Start/stop</td>
<td>– Excessive rotational traction – “foot fixation”</td>
</tr>
<tr>
<td>– Changes of direction</td>
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</table>

We cannot say what the safe level / peak performance levels are.
Techniques to Measure Traction

Mechanical Tests

Human Subjects (Biomechanical)
Mechanical Traction Measurement

Boise State TurfBuster
Boise State Research – Linear Traction

Multiple studs on the same path – less effective – “trench effect”
Mechanical Traction Measurement

Michigan State Traction Tester

Compressive Weights (Normal Force)
Dynamic Internal Leg Rotation
Release Mechanism
Normal Force
Torsion Drop Weights
Deformable Elastomer for Compliant Ankle
Football Shoe Mounted on a Rigid Foot Model
Resultant External Torque at the Shoe-Surface Interface
Michigan State Research – Rotational Traction

- Higher peak rotational traction on synthetic turf than natural grass
- Turf cleat – highest rotational traction
Mechanical Traction Measurement
Pennfoot

• Differences between Pennfoot and other devices
  – Linear and rotational
  – Fore-foot only stance
  – Rotational 45° vs. 90°
Traction Testing

- Synthetic turf research trial at Penn State
- Data from 2003 – 2010
  - Wear vs. no wear
  - Pre-grooming vs. post grooming
Traction Testing – NFL Fields
European Traction Testers
Human Subject Testing

- Biomechanics

- “Bridge the Gap”
  - Biomechanists: Human Performance studies
  - Turfgrass scientists: Surface testing / Manipulation
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Surface Testing - Durability

Outdoors

Indoors
Surface Testing - Hardness

- ASTM Gmax – F1936, F355
  - Drop weighted missile from standard height
  - Accelerometer in missile measures impact
Surface Testing - Hardness

- Missile – 20 lbs (human head, neck), flat faced

- Drop height – 2 ft.
  - 1960’s crash tests
  - Impact energy during football game
Surface Testing - Hardness

- $1 \ G = \text{acceleration due to gravity}$
- Measure magnitude of impact – peak deceleration
- $G_{\text{max}} = \text{maximum negative acceleration on impact}$
Surface Testing - Hardness

• How many G’s can the surface absorb?

• How much returned to athlete?
  
  – High Gmax = less absorption of force by surface
Surface Testing - Hardness

- 200 G
- >200 G = life threatening head injuries likely to occur
- 200 G – accepted by U.S. Consumer Products Safety Commission
Surface Testing - Hardness

- Test procedure – ASTM F1936
- 3 successive drops on each test point (8 total)
- $G_{\text{max}}$ – average of 2$^\text{nd}$ and 3$^\text{rd}$ drop
Surface Testing - Hardness

- No minimum standard

- Too soft =
  - Decrease in performance?
  - Increased injury risk?
Surface Testing - Hardness

- Synthetic turf research trial at Penn State
- Data from 2003 – 2010
  - Wear vs. no wear
  - Pre-grooming vs. post grooming
Surface Testing - Abrasion

- ASTM F1015
- Friable foam blocks pulled across surface
- Difference in mass of blocks before and after
Surface Testing - Abrasion
FIFA Quality Concept for Football Turf

- FIFA Recommended 2 Star & 1 Star
- Designed to ensure safety and performance
- Lab and field testing
- No tests for natural grass
### FIFA Quality Concept for Football Turf

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Features</th>
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<tbody>
<tr>
<td>Vertical ball rebound</td>
<td>Vertical deformation</td>
</tr>
<tr>
<td>Angle ball rebound</td>
<td>Rotational resistance</td>
</tr>
<tr>
<td>Ball Roll</td>
<td>Climatic resistance</td>
</tr>
<tr>
<td>Shock absorption</td>
<td>Durability</td>
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Similar Standards in USA?

- Different structure in Europe
  - Governing bodies

- Standardized testing is good, but must be science-based
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Perceptions of Athletes

- Survey of 1600 Italian amateur soccer players
  - 9 categories
  - Synthetic turf better than natural grass in 8 of 9 categories (abrasion)

- 2008 NFL Players Association Survey
  - 85% - synthetic turf more likely to contribute to injury
  - 72% prefer to play on natural grass
Does the Game Change?

- FIFA Technical Studies
  - Compare synthetic turf to natural grass
    - Touches
    - Passes
    - Dribbles per possession
  - Video/computer analysis

Result: Synthetic turf does not dramatically affect the pattern of soccer games
Comparisons with Natural Turfgrass
Comparisons with Natural Turfgrass
Future Research

• Surface temperature
• Infill alternatives
• Maintenance practices
• Disposal / Recycling
• Biomechanical testing
• Better understanding of injury mechanisms
• Develop relationships with shoe companies
Penn State’s Center for Sports Surface Research

Website: ssrcresearch.psu.edu

Facebook: “Like” Penn State’s Center for Sports Surface Research

Twitter: @PSUsportsturf