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Introduction

The Astrodome in Houston, Texas, completed in 1965, was the first of the huge covered arenas for professional sports. Its domed roof had plastic windows that allowed sunlight to reach the grass on the enclosed field. Baseball fielders hated to play day games in the Astrodome because fly balls became invisible against the roof's mosaic of sunlit windows and dark supporting beams. The players missed routine catches and risked being hit on the head by the ball. To correct this problem, the windows of the dome were painted black, providing a uniform background. Without the sunlight, the interior grass died.[1]

To solve that problem, in 1966 the Astrodome's field was covered with a nylon rug-like "grass" that had been developed by the Monsanto Chemical Company as a low-maintenance surface for inner-city playgrounds. Monsanto promptly renamed its product "AstroTurf". Although some players disliked it from the outset, there were obvious advantages in reduced maintenance costs, durability, and ease of changing for different sports. Because of this, other professional, collegiate and high school arenas followed suit. AstroTurf® remains one of the most widely used synthetic surface on athletic fields.

In 1968, Monsanto released statistics suggesting that the use of artificial turf could reduce football injuries by 80%, a plausible claim considering that natural grass hides holes and other field irregularities that can trip an athlete. Detractors charged that synthetic turf, despite its smoothness, heightened the risk of injuries among high-impact

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1 *See* Edward Lawless, Technology and Social Shock (1977); Martin Levy et al., *Living With Artificial Grass: Part 1*, 18 Am. J. Sports Med. 406 (1990).

football players. The controversy became public near the beginning of the 1971 season when The New York Times reported the claim of Dr. James Garrick, an orthopedic surgeon and physician for the University of Washington football team, that increased friction made these fields more dangerous than grass. Garrick had conducted a one-year study of 139 injuries in 228 high school games (80 on AstroTurf and 148 on grass) showing, per game, 0.76 injuries on the synthetic surface vs. 0.52 injuries on grass. The artificial turf had nearly a 50% higher injury rate for the same weather during the same period. Garrick thought that knee sprains, especially torn ligaments and cartilage, were more likely when players' feet "hung up on the artificial turf," and that players ran faster and hit people harder on a surface that offered more traction.[2]

Monsanto immediately challenged Garrick's results, and an inconclusive Congressional investigation was instigated. By then, artificial surface was being used in twelve National Football League (NFL) stadiums, and the Players' Association formally demanded a moratorium on installations until the question of injuries was settled.[3]

Risk Assessment

A spate of studies during the 1970's compared injuries on artificial turf and grass but gave inconsistent results because of small numbers of injuries and often failing to control adequately for amounts of player time on surfaces. A 1988 review of 32 such studies from this period concluded that minor injuries (e.g. abrasions or bruises) were more common on synthetic turf, but with regard to severe injuries results were equivocal.

The knee and ankle are the most common sites of serious football injury. Nearly half the studies found the rate of knee and ankle damage to be at least 10% higher on turf than grass, and about half the studies found injury rates virtually equal (i.e., less than 10% difference) on the two surfaces. By this time, no one seriously entertained Monsanto's initial claim that AstroTurf reduced injuries.[4]

2 Lawrence Altman, *Football Injuries Are Linked to Synthetic Turf,* N. Y. Times, Sept. 1, 1971 at 39.

3 *See* Lawless, *supra* note 1.

4 *See* B. Nigg & B. Segesser, *The Influence of Playing Surfaces on the Load on the Locomotor System and on Football and Tennis Injuries,* 5 Sports Med. 375 (1988).

Some controversies over risk assessment seem endless, with "truth" characterized as at the bottom of a bottomless pit. In this case, truth was rising toward the surface with increasing experience, especially as the NFL continued to accumulate injury statistics on turf and grass. In 1988 an article reported game injuries, usually to the knee or lower leg, suffered by the New York Jets professional football team during 1968-85, when about two-thirds of their games were played on grass. Counting only injuries serious enough for a player to miss at least two consecutive games, the Jets suffered 0.70 injuries per game on turf, and 0.59 injuries per game on grass. Injuries serious enough for a player to miss eight consecutive games occurred 0.36 times per game on turf, but only 0.23 times per game on grass.[5]

In 1990 Skovron and her associates studied research concerning football injuries on turf versus grass, and selectively focused on the methodologically strongest studies and data bases from high schools, colleges, and the NFL. Their research concluded that "play and practice on artificial turf are associated with an increase in risk of time-loss injuries to the lower extremities...[i]ncreased injury risks for other parts of the body have not been consistently demonstrated."[6]

Concern was now focusing on the lower leg. New research by Powell and Schootman examined knee injuries in NFL games during 1980-89, when 2572 games were played on grass, and 2604 were played on AstroTurf. There were 1081 knee sprains during these games, involving 860 players. On AstroTurf there were 0.223 sprains per game, on grass there were 0.196 sprains per game.[7] Thus, the sprain rate was 13% higher on AstroTurf than grass. This is a reliable difference, based on many games, but one that is small in magnitude.

Significance Tests

Why was there so much confusion and disagreement among the earlier risk assessors? Leaving aside those studies that were simply sloppy or highly biased, the main source of ambiguity may be

5 *See* James Nicholas, et al., *A Historical Perspective of Injuries in Professonal Football,* 260 JAMA 939 (1988).

6 *See* Mary Skovron et al., *Living With Artificial Grass: Part 2,* 18 Am. J. Sports Med. 510 (1990).

7 *See* John Powell & Mario Schootman, *A Multivariate Risk Analysis for Selected Playing Surfaces in the National Football League: 1980-1989,* 20 Am. J. Sports Med. 686 (1992).

illustrated by the 1988 JAMA article, discussed above, which showed that major injuries-those serious enough for a Jet player to miss eight consecutive games-occurred 0.36 times per game on turf, but only 0.23 times per game on grass, a risk for turf that is over 50% higher than for grass. Remarkably, the authors of that study concluded that "there was no difference in the rates of...major injuries per game...between games played on grass or artificial turf...".[8] Obviously there is a difference in the rates; and the authors meant there was no "significant difference," using the conventional statistical criterion, p = .05.

"Significant difference" has a technical meaning in statistics that is perplexing to laypeople. It arises when we want to describe a population, for instance, all the voters of New York, but we have data only on a smaller sample, randomly drawn from that population, as a pollster might do in trying to forecast the result of an upcoming election. We have no interest in the sample per se, except as it tells us something about the larger population. If we had data on the full population, as we do on election night, there would be no point in examining a sample.

Suppose 55% of a sample of New York voters, interviewed on the eve of the election, say they will vote for Gore, and 45% favor Dole. Can we say that Gore will win in New York on Election Day? We cannot say that with certainty because any sample may give a misleading result. Significance tests allow statisticians to judge the probability that Gore will win the election in New York, given his majority in the sample result

By convention, if the statistician figures the probability of a tie vote, or a Dole win, to be less than five-out-of-a-hundred (p =.05) he will predict a Gore win. It is important to note that statisticians can use the sample result to calculate the probability of a Gore victory only if the sample has been randomly drawn from the population. If the sample is not truly random, or very nearly so, is it useless as the basis for a significance test.

The problem of comparing injuries on grass and turf is similar. If we have a total population of football games, there is no need–indeed, no point–for significance tests. We simply see whether injuries are more

8 Nicholas et al., *supra* note 5 at 939.

frequent on turf than grass. It is like looking at the Gore-Dole vote after the election is over. However, if we have only a sample of turf and grass games, randomly drawn from a larger population, then we must calculate with significance tests whether or not a turf-grass difference seen in the sample is likely to be true of the population.

The authors of the JAMA study regarded 18 seasons during which the Jets played on both grass and turf as a sample of seasons. Over those 18 seasons, injuries serious enough to miss eight games occurred 0.36 + 0.29 times per game on turf (mean + standard deviation), and 0.23 + 0.16 times per game on grass. Using a two-tailed test of significance, they calculated that the difference between turf and grass rates was just shy of a "significant difference" at the p = .05 level; they therefore concluded "there was no (significant) difference in the rates." [9]

The size of the sample is important: the larger the sample, the more likely an observed difference will be "significant" at the p = .05 level. Eighteen seasons is a small sample. Had the same Jets injury rates come from a somewhat larger sample of 26 seasons, they would have been "significantly different" (t-test, p = .05). Obviously, early studies, based on limited experience with turf, were less likely to show "significant" differences than later studies based on larger samples.

The sources of ambiguity run deeper. Statisticians have some freedom to choose assumptions for their significance tests. Had the JAMA authors chosen a one-tailed rather than two-tailed test (permissible under the hypothesis that injuries are more frequent on turf), then they would have found a "significant difference" even with 18 seasons of data. If they had used different units of analysis, such as games instead of seasons, then the far larger sample size would have produced a more "significant" result.

Are significance tests relevant? Are Jets seasons from 1968 to 1985 a random sample of a larger population, or do they comprise a whole population? If they are a random sample, from what population are they randomly drawn? To say that Jets seasons are a random sample of all NFL seasons would be no more defensible than saying that the New York State vote for Dole and Gore is a random sample of the national election. On the other hand, one might conceptualize Jets seasons

9 *Id.*

between 1968 and 1985 as an acceptable sample drawn from some imaginary population of all conceivable Jets seasons, in which case a significance test would be justified. This is a difficult issue that perplexes even statisticians.

With increasing experience on turf, this issue has become moot. Analysts who reject the appropriateness of significance tests can focus on the reliably higher injury rates on turf. Analysts who believe that significance tests are appropriate now have enough data to show a "significant difference" between turf and grass. Thus, the Powell and Shootman analysis, noted above, based on over 5000 team-games in the NFL, showed knee sprains to be 13% more frequent on turf than grass and also calculated this to be a "significant difference" (using team-game as the unit of analysis).

Conclusion

The football database, especially from the NFL, has grown sufficiently to reliably show that synthetic turf increases the risk of knee sprain, and perhaps other injuries, although the degree of increase remains in doubt and may be small.[10] Obviously, one should not assume that injury rates for the NFL would necessarily be the same for college or high school players. The National Collegiate Athletic Association (NCAA) has a large database on injuries from college sports but has not released an adequate analysis of the relationship between playing surface and football injury rate. The crude injury rate for NCAA football, combining practice and games, is six percent higher on artificial surfaces than on grass during 1988-1996, but this comparison has little meaning since confounding factors are not controlled.[11]

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[10] Sprains on the big toe may also be increased by synthetic turf. *See* Scott Rodeao, et al., *Turf-toe: An Analysis of Metatarsophalangeal Joint Sprains in Professional Football Players,* 18 Am. J. Sports Med. 280 (1990).

[11] *See* Randall Dick, *Injury Surveillance System: 1997-98 Football* 10, NCAA Report.