Journal of Human Sport and Exercise
E-ISSN: 1988-5202
jhse@ua.es
Universidad de Alicante
España

Pérez-Soriano, Pedro; Llana-Belloch, Salvador; Cortell-Tormo, Juan M.; Pérez-Turpin, José A.

BIOMECHANICAL FACTORS TO BE TAKEN INTO ACCOUNT TO PREVENT INJURIES AND IMPROVE SPORTING PERFORMANCE ON ARTIFICIAL TURF

Journal of Human Sport and Exercise, vol. IV, núm. II, 2009, pp. 78-92
Universidad de Alicante
Alicante, España

Journal of Human Sport and Exercise *online*
J. Hum. Sport Exerc.
Official Journal of the Area of Physical Education and Sport
Faculty of Education. University of Alicante. Spain
ISSN 1988-5202 / DOI 10.4100/jhse
An International Electronic Journal
Volume 4 Number 2 July 2009

Review Article

BIOMECHANICAL FACTORS TO BE TAKEN INTO ACCOUNT TO PREVENT INJURIES AND IMPROVE SPORTING PERFORMANCE ON ARTIFICIAL TURF

Pedro Pérez-Soriano[1] , Salvador Llana-Belloch[1], Juan M. Cortell-Tormo[2], José A. Pérez-Turpin[2]

[1]Department of Physical and Sports Education, University of Valencia, Spain. [2] Faculty of Education, University of Alicante, Spain.

Received: 16 January 2009; received in revised form: 15 March 2009; accepted: 20 March 2009

ABSTRACT

This article reviews existing knowledge concerning the epidemiology, instruments and regulatory criteria currently used to evaluate artificial turf soccer pitches. Recent years have seen tremendous growth in the use of artificial turf as a playing surface for sports (rugby, soccer, American football…) and the problems traditionally associated with artificial turf and its relationship with a higher percentage of injuries seem to be disappearing. The contribution of biomechanics to the development of new techniques and instruments for analysing the properties and characteristics of grass pitches has contributed towards close collaboration with the regulatory bodies of different sporting organisations to define standards and criteria that guarantee not only the safety of the sportsmen and women, but also ensure performance and entertainment. Absorption of impacts, friction and traction, abrasion and factors associated with the mobile element and its interaction with artificial turf are the properties evaluated using a wide range of methodologies and instruments. In this sense, instruments such as the “Artificial Athlete” and the “Stuttgart Skiddometer” have helped different standards (DIN, BSI, AENOR, AFNOR, FIFA…amongst others) to define criteria for the homologation of a certain artificial turf surfaces.

Key words: *Artificial turf, Epidemiology, Biomechanics, Regulation, Football.*

Reference Data: Pérez-Soriano P, Llana-Belloch S, Cortell-Tormo JM, Pérez-Turpin JA. Biomechanical factors to be taken into account to prevent injuries and improve sporting performance on artificial turf. *J. Hum. Sport Exerc.* 2009; 4(2):78-92.

Corresponding author. Department of Physical Education and Sports. Faculty of Physical Activity and Sport Sciences. University of Valencia. c/Gascó Oliag, 3 - 46010 - Valencia (Spain).
Tel. +34 96 3864352.Fax. +34 96 3864353
E-mail: pedro. perez-soriano@uv.es

DOI:10.4100/jhse.2009.42.02

INTRODUCTION

The first artificial turf surface was laid for the American Football League at the Houston Astrodome (Texas) in 1966. The first artificial turf pitch in Europe was laid at Caledonian Park (England) in 1971, with their use expanding rapidly over the next 10 years. The use of artificial turf for hockey at the Montreal Olympics (1976) and for football at Queens Park Rangers F.C (1981) encouraged its expansion and showed that it could attract large crowds (Gordon, 1993). However, both players and clubs are still somewhat reluctant to use these artificial surfaces, as they believe that they cause more injuries.

The evolution of sporting surfaces since the early 1960s (initially because of the need to improve maintenance and strength) led to the development of the first synthetic surfaces. A decade later, several studies showed that the modern surfaces were a major etiological factor in sports injuries. Here, Biomechanics and epidemiology (based on identifying the type and distribution of different sports injuries) propose establishing procedures to prevent injuries and, to a certain degree, their occurrence on artificial surfaces.

As with all innovations, artificial turf brings a number of advantages and drawbacks, the latter derived from the impact absorption, abrasion and friction characteristics associated with the surface. Biomechanics thus focuses on aspects related to said sporting properties, which not only affect epidemiology but also sports technique and therefore sporting performance. However, the task facing Biomechanics is not simple as sporting properties (more related with execution and prevention of injuries) and technical properties (more related with the durability of the surface) are in opposition to each other, as by giving more importance to aspects associated with protection and maintenance of the artificial playing surface we can reduce sporting performance and vice versa.

Biomechanical research into artificial playing surfaces has therefore allowed us to reduce the number of injuries, focusing primarily on sporting and technical factors, while establishing criteria and standardised tests that allow us to guarantee safety when using said playing surfaces. In this way, federations such as Field Hockey have made said artificial playing surfaces obligatory for this sport, not only accepting the sporting properties (which allow the ball to behave in more uniform fashion on the playing surface), but also trusting in the injury prevention characteristics of said playing surfaces.

In this article, the biomechanical aspects of artificial turf playing surfaces in different sports will be described, along with the methods currently used by different standards to establish criteria regarding the behaviour required by artificial turf used as a playing surface, more precisely a surface designed for playing soccer. We will also show the relationship that exists between the properties of artificial turf and the associated epidemiology in certain sports, describing the most frequent injuries in sports played on artificial turf, such as American football, soccer, rugby, etc.

CHARACTERISTICS OF ARTIFICIAL TURF AND ITS RELATIONSHIP WITH INJURIES

The different studies on artificial turf provide a wide range of opinions as regards the greater or lesser incidence of injuries on artificial turf pitches. Here, certain writers believe that several injuries such as abrasion, traumas and sprains are associated with artificial turf playing surfaces, while other kinds of injury are more related to natural playing surfaces.

The two main kinds of injury that occur on artificial turf playing surfaces are; a) foot locking injuries, such as the sprained knees and ankles that occur when a player's foot is locked on the surface while the rest of the body keeps moving, b) turf toe injury, this being a pain in the big toe (between the phalanges) caused by hyperflexion or hyperextension of the joint (Pine, 1991). Said injury is not normally exclusive to artificial turf surfaces, indeed the study carried out by Rodeo et al. (1990) of this type of injury found no significant differences between the percentage of injuries suffered by footballers playing on natural grass and those playing on artificial turf. However, the literature has shown that this kind of injury is more common on artificial turf because of an increase in rigidity and a reduction in impact absorption on artificial surfaces, adding that most players suffered turf toe for the first time on an artificial turf playing surface.

Most injuries occurring on artificial turf are associated with the adaption of movement to hard surfaces, with an increase in eccentric muscle activity and changes in knee and ankle movement patterns. In addition, with artificial surfaces, traction forces are greater and aggravated by heat absorption and the resulting lack of humidity that is finally transmitted to the foot of the sportsman/woman. As well as this, blisters are quite often formed if the player's feet slip within their footwear. In contrast, natural grass absorbs humidity through its roots, cooling the playing surface (González & Payán, 2001). However, it should be mentioned that the latest watering systems installed on artificial turf playing surfaces reduce the coefficient of friction and associated injuries. From a biomechanical point of view, many of the injuries that occur while running happen during the deceleration stage, with the friction established between the footwear and the surface being an important factor (Andréasson et al., 1986), fundamentally when the playing surface is dry.

The literature also shows that artificial playing surfaces allow for faster running, something that may be due to the uniformity of synthetic surfaces allowing higher speeds to be reached as adjustments do not have to be made to compensate for the irregularities existing on natural playing surfaces (González & Payán, 2001).

Despite having more or less adequate information about the injuries that are associated with artificial turf playing surfaces, it should be mentioned that the kind of sport being played is associated with one kind of injury or another. However, as we have described above, there are certain injuries which could have a common origin and which are closely related to the sporting properties of the playing surface. This is why biomechanics attempts to analyse how the playing surface affects the movement during sport on the basis of its materials and how it has been built, so that identifying the characteristics that artificial turf playing surfaces should have allows us to improve it and progressively reduce the number of injuries associated with said playing surfaces.

In general terms, in soccer there are two factors associated with injuries on artificial turf playing surfaces, these coinciding with the factors that the literature identifies as the surface design aspects that have most influence on epidemiology - shock absorption and friction (Figure 1).

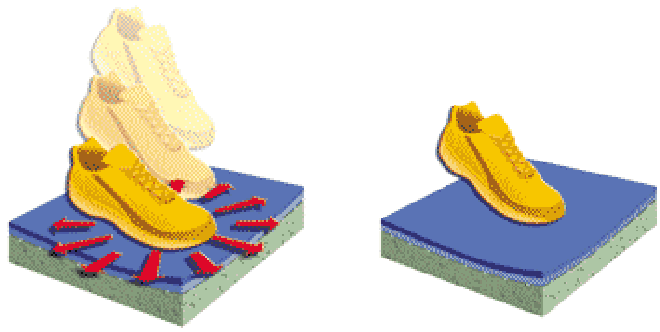

Figure 1. *Shock absorption and friction (Pérez et al., 2003)*

a) *The capacity to absorb impacts caused by the interaction of the foot with the surface while running and jumping*. This is normally a constant value that varies according to the percentage force and magnitude applied (Nigg & Yeadon, 1987). Impact forces may lead to overload due to many successive impacts on the playing surface.

The shock absorption capacity of playing surfaces is difficult to analyse for several reasons:

- Bone and joint injuries associated with the use of excessively rigid surfaces with low impact absorption capacity appear at a later date.
- The body has mechanisms to protect itself against impacts caused during running or jumping that act as shock absorption systems (musculoskeletal system).
- It is also important to take into account other factors that can have an effect on the reaction forces acting on the skeletal structures of sportsmen/women while playing, such as: type of movements and frequency of execution in each sport, injury mechanisms (besides injuries caused by interaction with other players), footwear used, the individual physiology of each player, etc.

b) *Friction force:* friction is commonly divided into two components, translational and rotational (Nigg & Yeadon, 1987). The first is needed for athletes to move quickly, stop and make sudden changes in movement. The coefficient of friction (μ) depends on the materials and roughness of the surfaces in contact and relative speed between the surface and the footwear.

With regard to *friction*, there is abundant epidemiological information available on its associated pathologies, given the significant problems that derive from the use of surfaces with a high coefficient of friction, as the injuries are normally serious. Inappropriate friction of the surfaces used has been linked to ligament problems (sprains) and muscle overload. Other studies point to a possible relationship between the greater friction of synthetic surfaces and the increase in ankle sprains and knee cruciate ligament injuries.

Epidemiological aspects of two sports (American football and soccer) played on artificial turf

1. American Football

A study based on over 5,000 NFL matches showed a 13% greater frequency of injury on artificial turf than on natural grass (taking the matches as the unit for analysis). The database of football, specifically that of the NFL, is large enough to show that artificial turf increases the risk of knee injuries and perhaps other injuries, although the percentage increase is still in doubt and may be minimal (Mazur & Bretch, 1999). However, the literature (Powell & Schootman, 1992; Skovron et al., 1990) also shows how less serious injuries are less common on artificial turf, underlining the fact that serious injuries can occur on both natural and artificial turf.

Knee and ankle injuries seem to be the most common in this sport, as stated by Powell et al. (1992), who classify two kinds of knee injuries: lateral knee ligament injury and anterior cruciate knee ligament injury (Figure 2). Anterior cruciate knee ligament injury shows a statistically significant difference in the percentage of injuries on natural grass (Astroturf) under the same special playing conditions.

Figure 2. *Knee injuries (Pérez et al., 2003)*

Labson et al. (1990), included one more analysis variable in their study, taking into account an important factor concerning the mechanics of and injury and one that Nigg & Segesser (1988) had already taken into account to a degree – the interaction between the boot on the playing surface and the shape of the studs. Where the boots had longer studs, there was greater traction on the artificial turf and there were more anterior cruciate ligament injuries (0.017%) than with other types and shapes of studs.

2. Soccer

Despite the fact that few studies have been carried out on the epidemiology of soccer played on artificial turf playing surfaces, most of them deal with different factors that could have an effect on the mechanism of the injury, as well as the playing surface itself. In this sense, taking into account the position players take up on the pitch, Rodeo et al. (1990) state that 60% of players occupying an attacking position on the pitch suffer from turf toe", compared with 32% of defenders. The literature also shows how the number of studs on the boots is one of the possible causal factors of injuries, where players with between over 6 and less than 10 studs have a lower frequency of injury on natural grass playing surfaces. However, players using boots with 13 to 17 studs on artificial turf playing surfaces have a lower percentage of injuries.

Ekstrand & Nigg (1989) consider lack of adaptation to the playing surface to be one of the possible factors behind injuries, suggesting that players need about 6 training sessions to familiarise themselves with artificial turf playing surfaces.

As regards monitoring the incidence of injuries on artificial turf playing surfaces, the study carried out by González & Payán (2001) should be highlighted, in which they monitored soccer players for two seasons, one of them on natural grass and the other on artificial turf. In this study, the injuries that, etiologically speaking, accounted for the highest percentage on the artificial surface corresponded to a pathology of overuse (tendonitis in most cases), which accounted for 46.3% of the cases, followed by muscle injuries with 25.6%, osteoarticular injuries with 12.8%, ligament injuries with 12.8% and, finally, back injuries with 5.2%. However, with natural grass, muscle injuries accounted for 37.8%, followed by osteoarticular injuries with 31%, ligament injuries with 13.8%, overuse injuries with 3.4%, back injuries with 3.4% and other injuries with 10.3%. The ankle is the most frequently injured joint with 72.1% of total injuries on a natural playing surface and 40.9% on an artificial playing surface. Other joints affected were: knee (14.3%/13.6%), shoulder (5.4%/4.5%), hands (3.6%/18.2%), pubis (2.4%/13.6%) and back (2.2%/9.1%).

Biomechanical characteristics of artificial turf playing surfaces

The sporting properties that should be taken into account with artificial playing surfaces should not only include those affecting epidemiology (only affecting the players), as the properties of the playing surface can also alter the mobile elements (ball, soccer, etc.) used to play the sport. In this respect, the regulations of certain countries (including Spain, France, England, Germany, etc.) and the FIFA regarding artificial playing surfaces already include criteria that cover the playing surface, player and ball. This means that analysis of the behaviour of the playing surface is carried out on the basis of the different factors that play a role in the sport.

Focusing most of the characteristics described below on soccer, the following sporting properties should be taken into account for artificial turf playing surfaces:

1. Impact absorption
2. Friction and traction
   - Abrasion
3. Ball-related aspects:
   - Absorption of ball bounce
   - Resistance to ball progress
   - Effects on the ball

1) Impact absorption

This is the property of the artificial surface to reduce the forces transmitted to the player after impact, so that the magnitude and speed of the force transmitted is not as traumatic as that generated from a rigid surface (Figure 3). According to Milhurn & Barry (1998) insufficient reduction in impact absorption has been linked to the degeneration of cartilages, the development of osteoarthritis and lumbar pains.

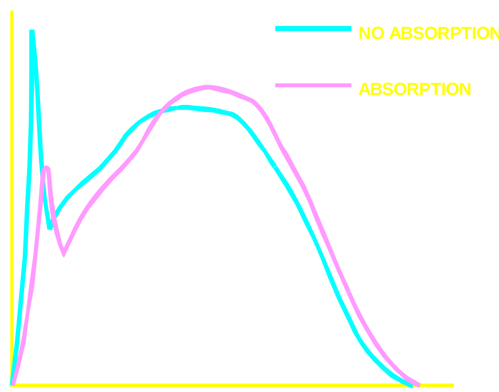

Figure 3. *Impact absorption*

The factors required to measure the density and flexibility of a surface completely are (Bell et al., 1985):

- Total duration of the impact
- Time to reach maximum deceleration, maximum deceleration, average deceleration and % deceleration.
- The area below the deceleration curve vs. time.
- Maximum force.
- Deformation of the surface.
- Recovery capacity.

• *Test methodology*

The artificial athlete is the instrument most commonly used to measure impact absorption (Figure 4). The "Stuttgart" and "Berlin" athletes used to be the most popular versions, although the current athlete combines the properties of both and is the method currently used by DIN and FIFA, as well as being proposed by AENOR, to analysis the impact absorption properties of artificial turf surfaces.

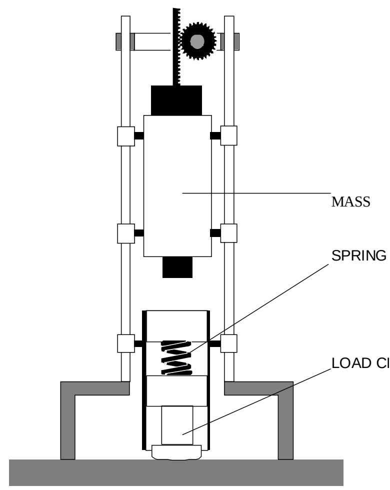

Figure 4. *Artificial Athlete.*

We should highlight that observed in certain studies (Winterbottom 1985; Baker 1990), where they state the need to design a new analysis foot that includes studs to test on grass, as their influence could alter the results obtained on the basis of stud penetration.

Amongst other methods of analysis we should mention that used by Stanitski et al. (1974), using video cameras and different loads released from particular height, the "Sportest" proposed by AFNOR, the methodology used by BSI, etc.

• *Criteria for impact absorption*

The different standards lay down the following criteria for force reduction (FR):

$$RF = 1 - \left(\frac{Fmax}{Fmax.Hormigón} \right) x100$$

- AENOR classifies impact absorption into: rigid (<20%), low (20%≤RF≤35%), moderate (35%≤FR≤50%), high (50%≤FR).
- DIN specifies that the artificial turf must be able to absorb between 50% and 65% of the impact.
- FIFA requires an absorption of 55-70% (for both laboratory and field trials, carried out three months before being installed).

2) Friction and Traction

Friction and traction (Figure 5) are the properties that enable players to carry out movements without slipping or falling.

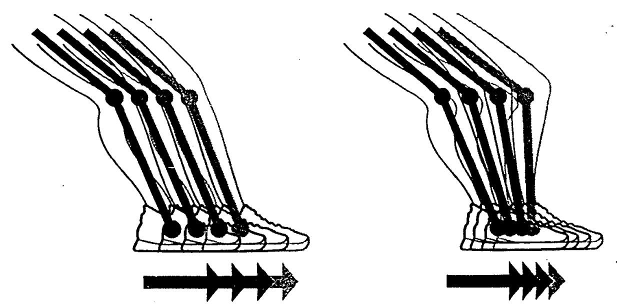

Figure 5. *Friction on the surface (Pérez et al., 2003)*

The concept of friction is applied when one surface slides over another, for example the shoe over the surface, although when the shoe has studs that dig into the playing surface the concept of friction is not applicable, with the concept of traction being used to describe said interaction. We have to distinguish between static friction and dynamic friction, with the static friction coefficient (μ) being the quotient between the minimum force needed to produce sliding and the normal force at the surface. The dynamic friction coefficient is the force parallel to the surface needed to maintain a certain sliding speed divided by the normal force at the surface (the latter being the most important from the point of view of sport). Adequate friction could be regarded as that allowing adequate traction, so that sportsmen/women can accelerate and decelerate while maintaining balance, rhythm and coordination of all their body movements. However, while playing sport there are frequent changes in direction that cause circular frictions known as torques. These must be such that the knee and ankle ligaments are not subject to excessive stress during rapid changes of direction, thus avoiding the possibility of injury.

Water and temperature can affect the friction properties. Here, the research carried out by Torg et al. (1974) shows that an increase in temperature, combined with the characteristics of the stud, affects the friction generated between the shoe and the surface, as well as the possibility of injuring the knee and ankle.

• *Test methodology*

The test methodology should simulate conditions that are as similar to real game conditions as possible, meaning that we have to take into account (Lloyd & Stevenson, 1990) the contact time and increase in the vertical force component, the angle between the shoe and the contact surface, the magnitude of the vertical force at the time of maximum friction and the sliding speed between the stud and the surface.

No single one of the methods described in the literature and the standards laid down in different countries for analysing friction on surfaces can be described as ideal for artificial turf tests. The tests used are: the friction pendulum (Bonstingl et al., 1975; Majid & Bader, 1993) used by DIN, which also uses the Stuttgart sliding apparatus (Figure 6) (not used for grass, however it could be adapted for this purpose with a new foot design), the "Studded Foot" (Torg et al., 1974; Winterbottom, 1985; Canaway & Bell, 1986; Lambson et al., 1996) used by FIFA and BSI, which also uses another method involving a sliding apparatus, the method used by Stanitski et al. (1974) that drags several boots over the grass, using a pneumatic device (Andréasson et al., 1986; Heidt et al., 1996), measuring friction with a graduated pendulum (AFNOR), etc.

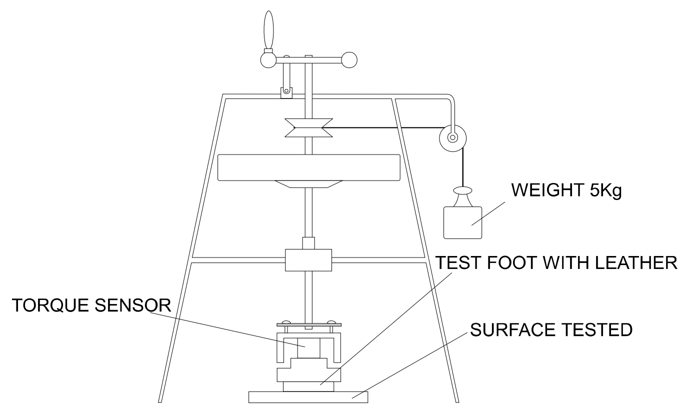

Figure 6. *Stuttgart sliding apparatus*

• *Criteria for Friction – Traction*

It should be borne in mind that weather conditions influence friction properties, with this influence being observed in the results obtained by Heidt et al. (1996) when comparing dry and wet artificial surfaces. With the dry artificial turf surface, the traction force was 413.69N (±238.88) at the axis of movement and a torque of 20.539 N.m (±6.96) on the axis of the tibia. With wet artificial turf, the average was 301.97N (±129.17) with a torque of 15.27N.m (±5.84).

Valiant (1990) states that the minimum traction required for a soccer boot on artificial turf should have a traction coefficient of between 22 and 30 N.m, while also stating that the injury rate could be reduced with values lower than 30N.m. However, FIFA suggests values of 25-50 N.m. while using the same test.

• ***Abrasion***

This is a concept related to the friction surface and associated with injuries caused by burns. However, the importance of this factor has not been dealt with in detail in the literature, where no method for analysing it has been found, although some friction instruments are able to measure the temperature of the material being analysed (pending homologation).

3) Characteristics of artificial turf as regards the ball

- Absorption of ball bounce

From the point of view of standards, it is necessary to calibrate the ball being used for analysis with reference to a rigid surface (ground). After establishing the drop height, the results are given as a percentage with relation to the reference surface:

$$100 \times \frac{\text{Bounce height on other surfaces}}{\text{Bounce height on the reference surface}}$$

Certain factors affect bounce, including: the base on which the grass is laid (Bell et al., 1985), ball pressure and ball type, reducing the height in the same proportion as the pressure, this being from 5.1% of 1.1 to 0.6 bar (Holmes & Bell, 1984).

It must be taken into consideration that ball bounce increases over time, with surfaces becoming more compact and harder as a result of one or more factors, such as flattening of the grass fibres, compaction of the sand or other base materials, etc.

- *Test methodology*

Different systems can be used to measure the height of bounce: visual methods (camera recordings), photocells and acoustic methods, and analyse the properties of the playing surfaces and the type of ball.

The method proposed for use by BSI, DIN, EN (Appendix 8) and FIFA consists of dropping a ball repeatedly from a certain height (this varying from one standard to another), obtaining the bounce percentage with regard to the average on a rigid surface. The BSI standard also specifies that the analysis should be carried out for both wet and dry surfaces.

The type of ball and its pressure have a significant effect on bounce, with a study carried out by Baker (1990) setting the bounce at 57%-59% when the pressure of the ball is 70 Pa. It should be pointed out that the pressure of the ball is not taken into account in the different standards, making it an important factor to be looked at in future studies.

- *Criteria*

In soccer, the general criterion accepted by the different standards (including FIFA) consists of dropping the ball from a certain height (measured from its lowest point) and reaching a given bounce height, measured from the bottom of the ball. The EN calibrates ball bounce height on a rigid surface from a drop height of 2 metres and ball bounce height must reach 1.35±0.05m. The bounce percentage laid down by the EN for artificial turf is 80% ≥ B ≥ 35%. FIFA state that the bounce should be from 30% – 50 %. The difference in bounce percentage between FIFA and the EN is due to the fact that FIFA lays down the ball bounce percentage on the basis of the 2 metre drop height, while EN does so with regard to the 1.35 metre drop height onto a rigid surface.

- **Resistance to ball advance**

Resistance to ball advance can be defined as the force that acts at the point of contact between the ball and the surface whose direction is contrary to the direction of the ball, causing the ball to decelerate as it advances. This is important for sports such as golf, bowls, hockey and, of course, soccer. It has also been called the "speed" of the surface.

- *Test methodology*

Several techniques have been used to analyse ball behaviour on the surface, including those used by Baker (1990): rolling distance, deceleration and changes caused to speed.

Resistance to ball advance is not dealt with by AFNOR, although FIFA (following the method proposed by EN 12235), DIN and BSI do use a method for analysing this factor, measuring the resistance to advance using a ramp down which the ball is rolled. This allows two types of measurement to be made: the speed of movement between two points 1 metre apart (using photocells) and the distance covered by the ball until it stops.

- *Criteria*

In the analysis of resistance to ball advance on different soccer surfaces with different bases, the average rolling distances were (Bell et al., 1985): artificial turf on asphalt (14-20 metres), artificial turf on dynamic base (wet – 10 metres and dry – 17 metres).

BSI suggests changes in speed of 0.1 to 0.35 metres/second and a final ball distance of 5 to 15 metres. DIN specifies that the delay should be between 0.3 and 0.6 metres/second and the final distance from 10 to 20 metres. FIFA sets a final distance of 4 to 10 metres.

In the comparative study of natural and artificial turf, differences were seen between both surfaces for ball deceleration and final distance values (Winterbottom, 1985) (Figure 7), with the ball travelling farther over the artificial surface.

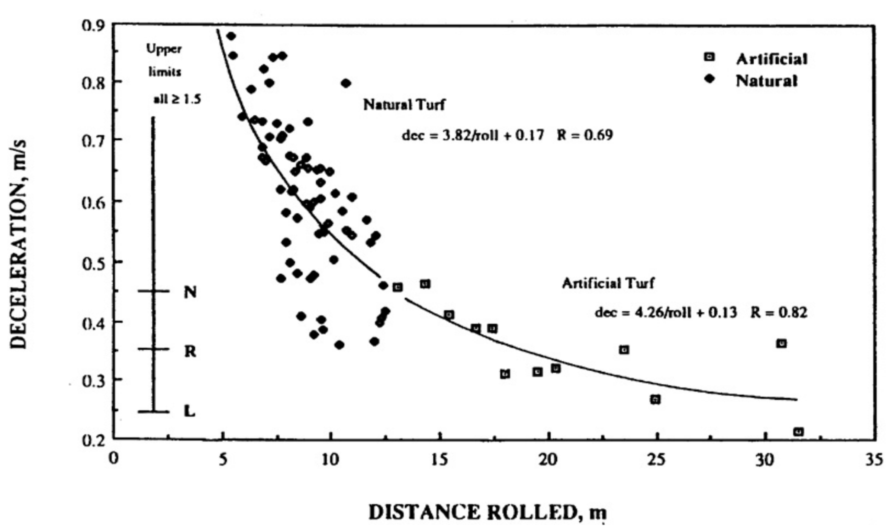

Figure 7. *Deceleration and distance of the ball on natural and artificial turf (Winterbottom, 1985)*

Effects on the ball

Friction between the ball and the surface is responsible for changes in the speed, direction and rotation of the effect on the ball after coming into contact with the surface. Although this factor does not seem to be very important in soccer, it does become more important in such sports as tennis, golf and cricket.

- *Test methods and criteria*

The FIFA standard includes a method that analyses the complex interaction between ball and surface by analysing the loss of speed of the ball after being shot from a cannon inclined at 25º. Limits for loss of ball speed after impacting against the surface have been set at 60-80% of the muzzle velocity (50Km/hr).

BSI standards include a method for measuring ball spin, however there is no clear criteria on acceptable ball behaviour.

CONCLUSIONS

The views held on artificial turf surfaces have changed over time. Despite the generally held view that more sports injuries occur on artificial turf playing surfaces, certain writers show a degree of disagreement with this, as well as with the type of injuries associated with said surfaces.

The associated idea is that more injuries were caused by the early generations of artificial turf, however the inclusion of new materials (with properties that allow us to obtain similar conditions to those of natural grass) and the incorporation of biomechanical research of said playing surfaces (allowing us to generate more reliable criteria), have allowed us to change preconceived ideas regarding artificial turf. This allows us not only to guarantee enhanced protection against injuries associated with playing on said surfaces but also guarantee an improvement in the conditions in which the sport is played (more homogenous surfaces, higher playing speed, etc.).

With regard to the epidemiology associated with artificial turf, it should be pointed out that that the methodologies used to identify the injuries and injury percentages have not followed the same criteria in the studies carried out, meaning that not clearly defining such variables as type and specifications of the footwear used, the skill level of the sportsman or woman, origin of the injuries, type of activity and movement, etc. can have a greater or lesser influence on the results obtained. As regards the different standards in existence, the need must be mentioned to consider the factors used by the methods for evaluating and analysing artificial turf playing surfaces, such as: ball pressure, the influence of studs used with the analysis boot, weather conditions, etc. These are all factors that have an influence when it comes to defining the criteria laid down for said playing surfaces.

Finally, mention must be made of the important work carried out by biomechanical research in guaranteeing and developing artificial turf playing surfaces by carrying out two main tasks:

- Developing new and different methods and instruments for analysing artificial turf playing surfaces.

- Collaborating with the different standards, federations and sporting bodies to establish criteria and standards that guarantee sports safety.

ACRONYMS

1. - N.F.L: National Football League (U.S.A.).
2. - F.I.F.A: International Amateur Football Federation.
3. - D.I.N: German Standard.
4. - A.E.N.O.R: Spanish Association for Normalisation and Certification.
5. - A.F.N.O.R: French Association for Normalisation and Certification.
6. - B.S.I: British Standard.
7. - E.N: European Standard.

REFERENCES

1. ANDRÉASSON G, LINDENBERGER U, RENSTRÖM P, PETERSON L. Torque developed at simulated sliding between sport shoes and an artificial turf. *Am J Sports Med*, 1986; 14(3):225-230. [Abstract] [Back to text]
2. BAKER SW. *Standards for the playing quality of artificial turf for association football*. In: Schmidt RC. Natural and artificial playing fields: characteristics and safety features, eds. Schmidt, Hoerner, Milner and Morehouse. Portland: Book News, Inc; 1990. p. 48-60. [Abstract] [Back to text]
3. BELL MJ, BAKER SW, CANAWAY PM. Playing quality of sports surfaces: a review. *J. Sports Turf Res. Inst.* 1985; 61:26-45. [Back to text]
4. BONSTINGL RW, MOREHOUSE AC, NIEBEL BW. Torques developed by different types of shoes on various playing surfaces. *Medicine and Science in Sports*. 1975; 7(2):127-131. [Abstract] [Back to text]
5. CANAWAY PM, BELL MJ. An apparatus for measuring traction and friction on natural and artificial playing surfaces. *J. Sports Turf Res. Inst*. 1986; 62:211-214. [Back to text]
6. EKSTRAND J, NIGG BM. Surface-related injuries in soccer. *Sports Med*. 1989; 8(1):56-62. [Abstract] [Back to text]
7. GONZALEZ JC, PAYÁN ML. Lesiones relacionadas con la superficie de juego en el fútbol. *Selección*. 2001; 10(1):58-61. [Abstract] [Back to text]
8. GORDON, S. Refurbishement of synthetic turf pitches at two national sports centres. *Sports Council. Datasheet*. 1993; 63:1-12. [Back to text]
9. HOLMES G, BELL MJ. Technical note: The effect of football type and inflation pressure on rebound resilience. *J. Sports Turf Res. Inst*. 1984; 61:132-135. [Back to text]
10. HEIDT RS, DORMER SG, CRAWLEY PW, SCRANTON PE, LOSSE G, HOWARD M. Differences in friction and torsional resistance in athletic shoe-turf surface interfaces. *Am J Sports Med*. 1996; 24(6):834-842. [Abstract] [Back to text]
11. LAMBSON RB, BARNHILL BS, HIGGINS RW. Football cleat design and its effect on anterior cruciate ligament injuries: A three-year prospective study. *Am. J. Sports Med*. 1996; 24:155-159. [Abstract] [Back to text]
12. LLOYD DG, STEVENSON MG. Dynamic friction measurements on artificial sports turf. *J. Sports Turf Res. Inst*. 1990; 66:149-159. [Back to text]
13. MAJID F, BADER DL. A biomechanical analysis of the plantar surface of soccer shoes. *Proc Inst Mech Eng.* 1993; 207(2):93-101. [Abstract] [Back to text]
14. MAZUR A, BRETSCH J. Looking back. Synthetic turf and football injuries. *Risk: Health, safey & enviorement*. 1999; 1:1-6. [Back to text]

15. MILBURN PD, BARRY EB. Shoe-surface interaction and the reduction of injury in rugby union. *Sports Med*. 1998; 25(5):319-27. [Abstract] [Back to text]
16. NIGG BM, YEADON MR. Biomechanical aspects of playing surfaces. *J. Sports Sciences.* 1987; 5:117.145. [Abstract] [Back to text]
17. NIGG BM, SEGESSER B. The influence of playing surfaces on the load on the locomotor system and on football and tennis injures. *Sports medicine*. 1988; 5:375-385. [Abstract] [Back to text]
18. PÉREZ P, MARTINEZ A, GÁMEZ J, DUEÑAS L. Generación de criterios de calzado para la práctica del fútbol en campos de tierra; entrevista a expertos y estudio epidemiológico. II Congreso de Educación Física y Deportes. Nuevas aportaciones al estudio de la actividad física y el deporte; 2003. p. 293-305. [Back to text]
19. PINE D. Artificial vs natural turf: injury perceptions fan the debate. *Phys. Sports Medicine.* 1991; 19:125-128. [Back to text]
20. POWELL JW, SCHOOTMAN M. A multivariate risk analysis of selected playing surfaces in the National Football League: 1980 to 1989. An epidemiologic study of knee injuries. *Am J Sports Med*. 1992; 20(6):686-94. [Abstract] [Back to text]
21. RODEO SA, O'BRIEN S, WARREN RF, BARNES R, WICKIEWICZ TL, DILLINGHAM MF. Turf-toe: an analysis of metatarsophalangeal joint sprains in professional football players. *Am J Sports Med*. 1990; 18(3):280-285. [Abstract] [Back to text]
22. STANITSKI CL, MCMASTER JH, FERGRUSON RJ. Synthetic turf and grass: a comparative study. *J. Sports Med*. 1974; 2(1):22-27. [Abstract] [Back to text]
23. SKOVRON ML, LEVY IM, AGEL J. Living with artificial grass: a knowledge update. Part 2: Epidemiology. *Am J Sports Med*. 1990; 18(5):510-513. [Abstract] [Back to text]
24. TORG JS, QUEDENFELD T, LANDAU S. The shoe-surface interface and its relationship to football knee injuries. *J. Sports Med*. 1974; 2:261-269. [Abstract] [Back to text]
25. VALIANT GA. *Traction characteristics of outsoles for use on artificial playing surfaces*. In: Natural and Artificial Playing Fields: Characteristics and Safety Features, ASTM STP 1073. Eds.Schmidt R.C., Hoerner, E.F., Milner, E.M. and Morehouse, C.A. , American Society for Testing and Materials: Philadelphia; 1990. p. 61-68. [Back to text]
26. WINTERBOTTOM W. Artificial grass surfaces for association football - Report and recommendations. *The Sport Council*, London. 1985. [Back to text]

Biomechanical factors to be taken into account to prevent injuries and improve sporting performance on artificial turf. J Hum Sport Exerc Online 4: 78-92, 2009. Cited Here...Â This article has been saved into your User Account, in the Favorites area, under the new folder "". Related Articles. Article Tools. Information about the open-access article 'BIOMECHANICAL FACTORS TO BE TAKEN INTO ACCOUNT TO PREVENT INJURIES AND IMPROVE SPORTING PERFORMANCE ON ARTIFICIAL TURF' in DOAJ. DOAJ is an online directory that indexes and provides access to quality open access, peer-reviewed journals.Â Biomechanical factors to be taken into account to prevent injuries and improve sporting performance on artificial turf. Journal of Human Sport and Exercise. 2009;4(2):78-92. Journal Homepage. Journal Title: Journal of Human Sport and Exercise. ISSN: 1988-5202 (Online). Publisher: University of Alicante. Society/Institution: University of Alicante, Faculty of Education.