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Original article

The effects of artificial surface temperature on mechanical properties and player kinematics during landing and acceleration

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Abstract

Background: Artificial turf is considered a feasible global alternative to natural turf by many sports governing bodies. Consequently, its ability to provide a safe and consistent playing surface regardless of climate becomes essential. The aims of this study were to determine the effects of artificial surface temperature on: (1) mechanical properties of the turf and (2) the kinematics of a turf-sport related movement.
Methods: Two identical artificial turf pitches were tested: one with a cold surface temperature (1.8°C–2.4°C) and one with a warm surface temperature (14.5°C–15.2°C). Mechanical testing was performed to measure the surface properties. Four amateur soccer players performed a hurdle jump to sprint acceleration movement, with data (contact time, step length and hip, knee and ankle kinematics) collected using CODASport (200 Hz).
Results: The temperature difference had a significant influence on the mechanical properties of the artificial turf, including force absorption, energy restitution, rotational resistance, and the height where the head injury criterion was met. Both step length ($p = 0.008$) and contact time ($p = 0.002$) of the initial step after the landing were significantly longer on the warm surface. In addition, significant range of motion and joint angular velocity differences were found.
Conclusion: These findings highlight different demands placed on players due to the surface temperature and suggest a need for coaches, practitioners, and sports governing bodies to be aware of these differences.

Keywords: Artificial turf; Biomechanics; Rugby; Soccer; Temperature

1. Introduction

The use of artificial turf in sport is becoming more common, especially in areas that offer suboptimal climatic conditions for the growth and maintenance of good quality natural turf.[1] Andersson et al.[2] highlighted that movement and tactical play on artificial turf are different from natural turf. For example, soccer (football) players performed fewer tackles and more short passes on artificial surfaces.[2] Additionally, injury patterns have been shown to differ between natural and artificial turfs, although overall injury incidence is similar on both surfaces.[3–5] However, these studies are epidemiological in nature and less is known about the effect of artificial surfaces on the biomechanics of a performer, and specifically how this relates to the mechanical properties of the surface.

Artificial pitches must achieve certification before being used, ensuring the surface is not detrimental to the game-play or the players. The surfaces are required to meet regulatory standards regarding shock absorption, vertical deformation, energy restitution, and linear and rotational traction.[6,7] In addition, some sports require a shock pad underneath the surface and a head injury criterion (HIC) score to be met (including rugby[6]). The HIC is a measure of the likelihood of an impact causing a serious head trauma. The standards differ slightly between sports (e.g., soccer, rugby, American football, and Gaelic football) and were developed based on mechanical data collected from natural turf.[8] Laboratory and field mechanical tests are used to verify surfaces for soccer and rugby worldwide.[6,7] The application of mechanical testing is undoubtedly important for the identification of surface properties, to validate surfaces and

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to inform the surface maintenance.[8,9] However, how representative the mechanical criteria tested are of the human–surface interaction is questionable. For example, although a stiffer surface increases the impact force measured mechanically, peak ground reaction forces are not influenced by surface stiffness.[9–11] In addition, little is known about how players respond biomechanically on artificial surfaces with different properties. It is desirable, and expected, that artificial turf exhibits similar mechanical and performance characteristics in different environmental conditions; one of the perceived advantages of artificial turf over natural turf.

One environmental factor that may affect surface properties is surface temperature. Knowledge of the influence that surface temperature can have on the mechanical properties of the artificial turf is necessary for coaches, ground keepers, and facility managers in order to make informed decisions about the use of artificial turf. A number of studies have highlighted that artificial surfaces have a greater surface temperature than natural surfaces. Williams and Pulley[12] compared 2 types of artificial surface (American football and soccer pitches) with natural grass, concrete, and soil surfaces. The artificial surfaces reached maximum surface temperature of 69.4°C, whilst the natural grass pitch reached only 31.4°C on the same day. This underlines the importance of investigating how climatic changes influence the mechanical properties of artificial surfaces. In this regard, Torg et al.[13] found that an increase in surface temperature resulted in greater rotational resistance, which potentially increases athletes' lower limb injury risk. However, it should be noted that artificial surfaces have undergone great technological advances since 1996 and are now regularly used in Fédération Internationale de Football Association (FIFA) regulated competitions.

To identify the effect of different surfaces, Potthast et al.[14] investigated the biomechanics of soccer players performing a free kick on 3 surfaces composed of different materials. The authors found that soccer players' decelerations, shot velocities, and shot accuracy were all lower when performing on an artificial turf with a combined sand and rubber infill, compared to performance on natural turf or artificial turf with an entirely rubber infill. As a result, Potthast et al.[14] highlighted that consideration should not only be given to describe differences between artificial and natural turfs, but also differences among artificial turf surfaces.

Other studies examining player responses on different surfaces have largely investigated hard court surfaces or natural turf.[15–17] When investigating the properties of 3 different natural turfs, Stiles et al.[16] found running on the hardest surface only resulted in the second highest peak loading rate, whilst the surface that was ranked joint-lowest in terms of hardness showed the highest peak loading rate. Although McMahon and Greene[18] found surface stiffness influenced contact time and step length, other studies found no significant effect on sprinting time, ground contact time, or step length.[19,20] These findings add to the theory that athletes adapt their leg stiffness to the stiffness of the surface on which they move.[21,22] Athletes' ability to adjust their leg stiffness through flexion/extension changes[23] indicates that fixed energy devices, such as the Artificial Athlete or Clegg Hammer, should not be seen as substitutes for human movement testing.[1] In addition, as McMahon and Greene[18] originally found in their study of the influence of track compliance on running, artificial surface properties can be engineered to optimise technique and movement efficiency. Collectively, these studies conclude that the mechanical characteristics of the surface influence the player–surface interaction. Therefore, in the interests of ensuring athlete safety and preserving the integrity of the sports in question, it is critical to determine the specific effects of surface properties on athletic performance. The aims of this study were to determine the effects of artificial surface temperature on: (1) mechanical properties of the turf and (2) the kinematics of a turf-sport related movement. The movement chosen to investigate this issue was a landing with forward momentum followed by acceleration. The landing and the first step were of particular interest as landings followed by acceleration are a commonly used dynamic movement in soccer and rugby.[2]

2. Materials and methods

2.1. Participants

Four amateur soccer players (1.85 ± 0.22 m; 79.3 ± 9.1 kg; 20.8 ± 0.5 years) gave written informed consent to participate in the study, which was approved by the Cardiff Metropolitan University's Ethics Committee. Three players were left foot dominant and 1 was right foot dominant. Dominance was defined as the leg that the players would use to push off into the sprint following the landing. All players were free from injuries at the time of testing and had no serious lower limb injuries in the past 12 months. The participants all wore standardised soccer boots (Copa Mundial; Adidas, Herzogenaurach, Germany) in their size and their own soccer clothing. A standardised soccer-specific warm-up that the players were familiar with was used prior to both testing sessions. Between trials the players wore substitute (bench) coats to limit the effect of the cold air temperature on their subsequent performance.

2.2. Data collection

All testing was performed on 2 identical third generation (3G) artificial turfs (65 mm pile height; White Horse Contractors, Abingdon, UK), 1 outdoor and 1 indoor. Both surfaces were regularly used for elite rugby and soccer training. The mechanical and biomechanical testing took place on 2 consecutive days; the outdoor surface on Day 1 and the indoor surface the following day. Both artificial turfs had fulfilled the standards and regulations for rugby and soccer training and competitive use when installed and were both maintained according to FIFA[7] and World Rugby[6] guidelines.

2.2.1. Mechanical testing

An independent, regulated surface testing institution (Labosport Ltd., Nottingham, UK) performed the standardised mechanical tests[6,7] to determine the surface mechanical properties. For all surface properties, the data were collected at 6 different locations on each surface. During testing, the outdoor artificial turf had a surface temperature between 1.8°C and 2.4°C, whilst the indoor turf ranged between 14.5°C and 15.2°C. The