Original article

Effect of turf on the cutting movement of female football players

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Abstract

\textbf{Purpose:} The globalisation of artificial turf and the increase in player participation has driven the need to examine injury risk in the sport of football. The purpose of this study was to investigate the surface—player interaction in female football players between natural and artificial turf.

\textbf{Methods:} Eight university level female football players performed an unanticipated cutting manoeuvre at an angle of 30° and 60°, on a regulation natural grass pitch (NT) and a 3G artificial turf pitch (AT). An automated active maker system (CodaSport CXS System, 200 Hz) quantified 3D joint angles at the ankle and knee during the early deceleration phase of the cutting, defined from foot strike to weight acceptance at 20% of the stance phase. Differences were statistically examined using a two-way (cutting angle, surface) ANOVA, with an \textit{a} level of \textit{p} < 0.05 and Cohen’s \textit{d} effect size reported.

\textbf{Results:} A trend was observed on the AT, with a reduction in knee valgus and internal rotation, suggesting a reduced risk of knee injury. This findings highlight that AT is no worse than NT and may have the potential to reduce the risk of knee injury. The ankle joint during foot strike showed large effects for an increase dorsiflexion and inversion on AT. A large effect for an increase during weight acceptance was observed for ankle inversion and external rotation on AT.

\textbf{Conclusion:} These findings provide some support for the use of AT in female football, with no evidence to suggests that there is an increased risk of injury when performing on an artificial turf. The ankle response was less clear and further research is warranted. This initial study provides a platform for more detailed analysis, and highlights the importance of exploring the biomechanical changes in performance and injury risk with the introduction of AT.

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\textbf{Keywords:} Artificial turf; Football-specific movement; Gender; Injury risk; Kinematics

1. Introduction

Over the last decade artificial turf (AT) has been promoted as a viable alternative to natural turf (NT) by the major sporting international governing bodies, which utilise these playing surfaces (e.g., Fédération Internationale de Football Association (FIFA), International Rugby Board (IRB), Rugby League (RL), National Football League (NFL), International Hockey Federation (FIH)). The rationale behind this promotion is based on, firstly economic reasons: AT reduces the cost of maintaining a grass-based surface, which is particularly challenging across diverse environmental and climatic conditions. Secondly, consistency of playing surface will provide a more congruent playing surface globally. Finally, providing longer playing hours, as well as a multi-purpose application support the global health agenda.

These surfaces have been particularly promoted and installed in professional football communities, with the 3rd generation (3G) AT being the most common system.\textsuperscript{1} A 3G...
AT system is typically installed on a rigid base layer and consists of an elastic layer, an artificial grass carpet and infill material between the grass fibres. Against the benefits stands the generally negative perception of male players on playing on AT with a subjective feeling of poorer ball control and greater physical effort and greater difficulties in cutting. Female football players in this Swedish study demonstrated a different response pattern. Both regular AT and NT players reported, no general influence of AT on the game but felt that running with the ball and passing was easier on AT.

Independent of gender, the players psychological perceptions identified a perceived higher injury risk when playing on AT. These psychological observations were partly supported by epidemiological research exploring football injuries on 3rd and 4th generation AT, which suggested an increased risk of ankle injury on AT. However, a recent epidemiological meta-analysis of football injuries, summarised the risk of injury by playing on different surfaces (AT–NT) from eight published studies drawing the conclusion that competing or training on AT generally reduces the risk of injury compared to NT. Another recent study identified generally no differences in acute injury rates when playing on AT compared with NT, but demonstrated, that clubs with AT at their home venue had higher rates of acute training injury and overuse injury compared with clubs that play home matches on NT.

Additionally the role of gender and the surface effects are inconsistently reported in the literature. Generally, knee and ankle injuries are the most common injuries for female football players. Additionally they sustain a 2–3 times higher risk of ACL–rupture than their male counterparts. While Fuller et al. and Meyers identified a lower injury risk for women on AT, Steffen et al. found a trend towards higher risk of ankle sprains for female football players below the age of 17. Additionally, young female football players were very likely to sustain severe injuries on AT. During training Fuller et al. reported a higher risk of ankle sprains in men on AT, but no differences for women. Over a 5-year period, Soligard et al. reported no difference in overall injury risk between AT and NT for male and female players.

These epidemiological studies provide useful information about the frequency and trends in injury occurrence. However, there is still a gap between these descriptions and the aetiology of injury risk, with considerations for gender, age, and turf still under represented. Some evidence exists that surface changes lead to alterations in football-specific movement patterns of male football players, but to date no research was found by the authors, which investigates surface-induced effects on the movement of female football players. Playing on AT includes, for example, increased peak torque and different rotational stiffness properties of shoe–surface interaction, decreased impact attenuation properties of surfaces and differing foot loading patterns. While the approach velocity remained constant, the last step to a kick was decreased on a rubber and sand filled artificial surface leading to a “more cautious braking behavior”. Since female football players respond differently to football injury and perception of the AT than their male counterparts, investigating the female specific movements on different surfaces could enhance the understanding of injury risk and improve the quality of these surfaces. As approximately 50% of all season ending injuries during match play in female football are ACL-tears, it seems worthwhile investigating a movement task that is commonly representative for this injury. Female athletes tend to demonstrate less knee flexion, more knee valgus angles, greater quadriceps activation, and lower hamstring activation in cutting and running tasks than male athletes. In non-contact situations an extended knee position (up to 30°) as well as an anterior tibial draw combined with valgus and internal rotation moments could induce excessive loads on the ACL causing it to rupture. Thirty-seven percent of the non-contact ACL injuries occur during cutting manoeuvres, followed by 32% in landings, 16% land and steps, 10% stopping/ slowing, and 5% crossover-cut manoeuvres. Further, unanticipated cuttings are more likely to represent the movements during a game situation and are described with an increased risk of injury compared to anticipated cuttings.

Therefore, the purpose of this study was to investigate the lower limb kinematics on different surfaces in female football players during an unanticipated cutting manoeuvre. This could lead to a more comprehensive knowledge of player–surface interaction and provide further understanding of the mechanism of injury risk and enhancement of artificial surfaces in football. It was hypothesised that AT would lead to increased contact times, no alterations in knee positions but higher ankle dorsiflexion, inversion, and rotational angles.

2. Materials and methods

2.1. Participants and surfaces

Eight female university level football players (age: 21.5 ± 2.1 years; height: 162.8 ± 7.1 cm; weight: 66.0 ± 8.5 kg; football experience: 13.3 ± 4.1 years) participated in the study. The institutional ethical review board approved the study and additionally a written consent form prior to participating was signed by all athletes. Athletes were free from injury over a 6-month period prior to testing. Leg dominance was determined by the leg instantaneously used for a single-legged forward jump and only right-leg dominant players were included in the study. Participants used their individual football shoes, which they would use on both AT and NT.

The data collection was performed on two neighbouring pitches: the natural surface pitch (NT) was a natural grass pitch approved for national competition, and the AT pitch was a 2-star FIFA approved 3G AT pitch. As this was an outdoor testing, each participant underwent data collection for both surfaces in one session to keep the influence of weather and temperature change at a minimum.

2.2. Data collection

A testing session consisted of an individual warm-up, habituation phase and data collection on surface A followed
by data collection on surface B, whereas the order of the surfaces (NT, AT) was randomized. The habituation phase consisted of 5–10 cutting trials to familiarize the participants with the movement and the predetermined approaching speed of 4–5 m/s.17 The movement contained an acceleration phase of maximum 8 m before cutting with a change of direction in a 30° or 60° angle, followed by a 5-m acceleration phase before decelerating and finishing the manoeuvre. The angle of the cut was predetermined and visually displayed by cones, but as the cutting direction (to the right or left side) was desired to be unanticipated, the participants received the direction of the cut in the acceleration phase by light signals in a randomised order. The data collection consisted of eight unanticipated cuts at 30° and 60° angle on each surface, leading to four cuts to the left and right side for each cutting angle and surface. A trial was declared successful when the predetermined speed and cutting point was hit.

Kinematic data were collected by an outdoor 3D motion capture analysis system (CodaSport CXS System; Charnwood Dynamics Ltd., Rothley, Leicestershire, UK) which collected data of active markers by two scanners with a sampling frequency of 200 Hz. Thirty active markers were placed on anatomical landmarks of the left lower limb and pelvis according to the Cleveland Clinic Lower Body Markerset (Motion Analysis Corp, Santa Rosa, CA, USA) to calculate knee and ankle joint angles in the sagittal, frontal, and transverse planes. Scanners were positioned to detect each marker by at least one scanner throughout the entire contact phase of the cutting movement. Approach velocity was determined via two pairs of infrared velocity timing gates (SMARTSPEED, Fusion Sport International, Coopers Plains, Australia), placed at the fifth meter before the cutting point (Fig. 1).

2.3. Data analysis

Processed (labelled and gap filled) trajectory data were inserted in Visual 3D software (V3D, C-motion, Rockville, MD, USA) for further analysis. The trajectory data were filtered using a 4th order Butterworth filter implemented in the V3D software with 20 Hz. Stance phase was defined as the period from initial contact of the foot to toe off. These events were determined using acceleration data of active marker placed on the 5th metatarsophalangeal joint and 2nd interphalangeal joint following a procedure described by Ast et al.26 Early deceleration of the cutting movement was defined as beginning with foot strike (FS) at initial contact until weight acceptance (WA) at 20% of the stance phase.27 The 3D ankle and knee angles were calculated via the 6° of freedom model inserted in the V3D software.29 Data were time normalised during the early deceleration phase, as the majority of non-contact ACL injuries are reported to occur during this phase.23,27 As parameters the sagittal, frontal, and transversal ankle and knee angles at FS and WA were determined.

Statistical analysis was calculated via a two-way (cutting angle, surface) ANOVA with repeated measurements, using SPSS 20 statistical software (IBM SPSS Statistics, 20.0, Chicago, IL, USA). Significance levels were set at \( p < 0.05 \). Effect sizes were calculated using the partial eta squared (small: \( \eta_p^2 < 0.05 \); medium: \( 0.06 < \eta_p^2 < 0.13 \); large: \( \eta_p^2 > 0.14 \)) for main effects and Cohen’s \( d \) value (small: \( 0.20 < d < 0.49 \); medium: \( 0.50 < d < 0.79 \); large: \( \geq 0.80 \)) for interaction effects. Due to the low sample number medium and large effect sizes will also be discussed as indicator for movement changes.

3. Results

3.1. Global effect turf and interaction with cutting angle

The ground contact times did not reveal a significant effect of the surface (\( p = 0.465 \)) and were on average for the 30° cut 0.180 ± 0.020 s and 0.180 ± 0.015 s on NT and AT, and for the 60° cut 0.185 ± 0.015 s and 0.190 ± 0.015 s on NT and AT, respectively.

At the ankle (Table 1) no significant effects were found for the main surface effect at FS and WA. However, large effect sizes appeared at FS for the ankle dorsiflexion angle (increased (mean over both cutting angles = factor surface) on AT compared to NT by 2.8°, \( \eta_p^2 = 0.15, p = 0.303 \)) and ankle inversion angle (increased on AT compared to NT by 2.4°, \( \eta_p^2 = 0.19, p = 0.243 \)). At the point of weight acceptance large effect sizes remained for the ankle inversion angle (increased on AT compared to NT by 2.7°, \( \eta_p^2 = 0.16, p = 0.284 \)) and occurred for the ankle external rotation angle (decreased on AT compared to NT by 1.3°, \( \eta_p^2 = 0.35, p = 0.091 \)). Additionally, the interaction effect of the surface with the cutting angle demonstrated that the ankle inversion position at the 60° cut was decreased for both FS (by 5.4°) and WA (by 5.0°), on the AT compared to the NT, while at the 30° cut no effect became evident. This reached significance level with high
effect size at FS ($d = 0.54$, $p = 0.004$) and a medium effect size at WA ($d = 0.52$, $p = 0.115$).

At the knee (Table 1) comparison of the surface showed a significant effect of surface type on the internal knee rotation angle of the knee (decreased on AT compared to NT by $5.4^\circ$, $\eta_p^2 = 0.44$, $p = 0.050$) at FS. At weight acceptance a large but insignificant effect remained (by $2.3^\circ$, $\eta_p^2 = 0.19$, $p = 0.092$). Additionally large effect sizes without reaching significant difference occurred for the knee valgus position at FS (decreased on AT compared to NT by $1.6^\circ$, $\eta_p^2 = 0.21$, $p = 0.217$) and WA (decreased on AT compared to NT by $3.2^\circ$, $\eta_p^2 = 0.35$, $p = 0.084$). The interaction effect of the surface with the cutting angle revealed medium and large but insignificant effect sizes for the knee valgus angle at FS by $3.1^\circ$ ($d = 0.77$, medium effect, $p = 0.094$) and at WA by $5.1^\circ$ ($d = 0.97$, high effect, $p = 0.114$), indicating an increased valgus positions at the $30^\circ$ cut on NT compared to AT. The $30^\circ$ cut on NT additionally seemed based on a medium effect to lead to a higher knee internal rotation by $5.6^\circ$ ($d = 0.51$, medium effect, $p = 0.235$) at FS.

3.2. Global effect of the cutting angle

The ground contact times for the cut were with $0.190$ s significantly higher for the $60^\circ$ cut than for the $30^\circ$ cut ($0.180$ s) ($\eta_p^2 = 0.51$, $p = 0.03$). The kinematic comparison of the effect of the cutting angle revealed for the $30^\circ$ cut a significantly increased ankle dorsiflexion angle at FS by $2.8^\circ$ ($\eta_p^2 = 0.53$, $p = 0.027$) and WA by $2.1^\circ$ ($\eta_p^2 = 0.45$, $p = 0.048$). The $30^\circ$ cut indicates with large effect sizes an increased ankle inversion at FS by $1.4^\circ$ ($\eta_p^2 = 0.20$, $p = 0.222$) and WA by $1.6^\circ$ ($\eta_p^2 = 0.27$, $p = 0.149$), as well as a decreased external ankle rotation at FS by $0.8^\circ$ ($\eta_p^2 = 0.20$, $p = 0.135$) (Table 1).

Similarly to the ankle dorsal flexion angle the knee was significantly more flexed for the $30^\circ$ cutting angle at FS by $4.4^\circ$ ($\eta_p^2 = 0.69$, $p = 0.005$) regardless of surface.

4. Discussion

The globalisation of AT across many football codes, with the combined increase in participation, has driven the need to examine the influence of surface on the injury risk. The purpose of this study was to investigate the surface–player interaction in female football players for an unanticipated cutting manoeuvre. Due to the low population number, medium and large effect sizes are discussed as a tendency towards a difference. Female athletes displayed a tendency to alterations mainly in the frontal and rotational plane of the knee and ankle with increased ankle inversion and external rotation angles and increased knee valgas angles as well as knee internal rotation angles for the AT in comparison to the NT. The only effect showing in sagittal plane was an increased ankle dorsiflexion at initial contact on AT. The ankle and knee joint angle strategies demonstrated by the female participants of this study revealed a movement strategy, which might be beneficial towards a lower risk of ACL injury on AT.

Ground contact times for the cut did not differ between the two surfaces. As the participants approached the cut with the same velocity, this could give some indication of similar grip properties.29

Non-contact ACL injuries are often described to occur in a position at which the knee is in a low flexion angle in combination with an increased knee valgas and internal rotation angle.19–22,24,30 An increased ankle eversion and pronation may further preload the ACL.31 However, the cause and effect of the kinematics and ligament rupture are not yet fully understood. Current evidence attained by investigating in vivo loading patterns of the ACL suggests that the low flexion angle in combination with a posterior orientated ground reaction force is the primary cause of overloading the ACL.19,20 The additional valgus and internal rotation position have the potential to slightly increase this load,20,30,32 but play a minor role in terms of ACL-rupture.19,20 A more recent study even suggests that the addition of a valgus collapse pattern to a knee flexion angle of $30^\circ$ does reduce the length of the ACL compared to the $30^\circ$ flexed position only, indicating a lower strain on the ACL.21

Difference between female and male valgas angle during cutting on NT has been reported to be approximate $11^\circ$.17 Additionally, Hewett et al.15 identified an $8^\circ$ difference in valgas angle during a jump-landing task between participants with an ACL-injured knee and participants with a healthy knee. The current study showed that there was a tendency towards a lower knee valgas angle by $1.6^\circ$–$3.2^\circ$ between different surfaces. Keeping in mind that the knee flexion angle did not significantly change between AT and NT, the

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Ankle and knee angles ($^\circ$) (mean ± SD) in 3D at foot strike and weight acceptance for two surface conditions (artificial (AT) and natural (NT)) and two cutting angles ($30^\circ$ and $60^\circ$).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foot strike</td>
<td>Weight acceptance</td>
</tr>
<tr>
<td>NT-30</td>
<td>AT-30</td>
</tr>
<tr>
<td><strong>Ankle</strong></td>
<td></td>
</tr>
<tr>
<td>Dorsiflexion</td>
<td>5.4 ± 5.2</td>
</tr>
<tr>
<td>Inversion</td>
<td>−11.0 ± 7.1</td>
</tr>
<tr>
<td>External rotation</td>
<td>5.1 ± 6.7</td>
</tr>
<tr>
<td><strong>Knee</strong></td>
<td></td>
</tr>
<tr>
<td>Flexion</td>
<td>32.0 ± 4.8</td>
</tr>
<tr>
<td>Valgus</td>
<td>15.0 ± 2.9</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>−13.8 ± 8.9</td>
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</table>
implications of these results are that cutting on AT does not appear to yield an increased ACL-injury risk for the female knee. The decrease in varus angle in combination with the observed decreased knee internal rotation angle and tendency toward an increased ankle inversion could further indicate that cutting on AT might even bear a slightly lower injury potential than cutting on NT. The findings of this study support the literature demonstrating equal7,9,13,14 and lower knee injury than cutting on NT. The findings of this study support the observations of the valgus angle during the early deceleration phase corresponds well with these previous studies. Additionally, the reported intra-individual changes on knee valgus motion between AT and NT are consistent for each participant, which strengthens the confidence, that the demonstrated surface effects occur. The effect of the different surfaces on the ankle is less evident. Even though ankle sprains are among the most common ankle injuries, the mechanisms leading to the injury are unclear. The primary risk factor seems to be having sustained a previous ankle sprain35,36 and the majority of ankle sprains present an increased inversion or supination mechanism.37 An increased plantar flexion at touchdown might also bear an increased risk.38 However, as reported by Arnason et al.,38 it was not possible to identify football-specific screening tests to identify an increased risk of ankle sprain pre-injury, apart from having sustained a previous ankle strain. This study revealed on AT a tendency towards an increased dorsiflexion angle at touchdown, a trend towards higher external rotation at weight acceptance and for the 30° cut an increased inversion at the beginning and end of the early acceleration phase. Hence, no clear strategy to support or refute increased ankle injury risk derived out of this study, and further research is needed to fully understand the surface—player effect on the ankle joint.

The current study has shown surface-induced alterations occurred in the kinematics of female football players, a more indepth analysis including ground reaction forces, joint kinetics, and EMG could reveal additional information and increase our understanding of the interaction between the female player and the different surface systems in football-specific situations. It has to be noted that a variety of 3G AT systems exists and the differences in movement between ATs could become greater than between AT and NT.2 Therefore the results of this study can only be applied to the differences between the specific AT and NT used.

Athletes wore the same football boot, which they would wear on both surfaces, which might not be the football boot used in match play. However, boot type (studded vs. bladed) did not seem to impart differences in knee loading when used on AT,39 and this approach allowed an investigation on surface-induced rather than shoe-induced effects. As the movement changes induced by AT are not well understood, and gender related responses might be affected by a variety of different aspects, such as climatic exposure, boot type, or playing experience, a number of key research questions remain unanswered, and our understanding of the influence of artificial surfaces needs to be further developed. These investigations should address more factorial approaches as including males and different soccer relevant movements (e.g., straight running vs. cutting with different angles). Finally, the present study investigated only a small sample size, as such, the findings should be interpreted with care and only can point out tendencies towards the discussed kinematic changes. Using a higher sample size could possibly lead to not only similar or decreased effect sizes, but also current non-significant differences could become significant.

5. Conclusion

The overall purpose of this study was to investigate the lower limb kinematics on different surfaces in female football players during an unanticipated cutting manoeuvre. The major finding of this study was that there was no evidence to suggest that there is an increased risk of injury when performing with the same movement speed on an AT. The knee kinematics suggested that the ACL risk factors were reduced in some cases. The ankle response was less clear and further investigation into this specific joint is needed. Significant changes in environmental conditions, as in this case through the playing surface, must occur in parallel to detailed biomechanics analyses, which can provide a mechanism of quantifying changes in performance and identifying whether there is a concurrent change in injury risk.

References


