INFLUENCE OF PLAYING SURFACE ON KNEE LOADS DURING RUNNING, SIDESTEP CUTTING AND DROP JUMPING

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The purpose of this study was to analyse the influence of 3 different playing surfaces on knee load during sport tasks. 15 young skilled rugby players (17-19 year old) performed running, sidestep cutting and drop jumping tasks on 3 different tracks; i.e. a natural turf, an artificial turf and an hybrid turf (natural grass rooted in artificial rootzone). Kinematic analysis and inverse dynamic methods were applied to assess the knee loads during these exercises. A special attention was paid to knee valgus and internal rotation moments related to ACL injury risk. Results showed that moment of knee valgus during running and sidestep cutting were significantly higher on artificial turf compared with natural ones (3.73 ± 1.13 vs. 1.98 ±. 0.83 N.m.kg^{-1}). In the same way, internal rotation moments in sidestep cutting displayed higher values on artificial track than natural grass (2.97 ± 1.21 vs. 2.51 ±. 1.15 N.m.kg^{-1}). Furthermore, hybrid turf exhibited the lowest knee moments except for the running task. In conclusion, the type of the playing surface play an important role in knee loads related to ACL injury risk.

KEY WORDS: artificial turf, natural grass, anterior cruciate ligament, sport movement analysis.

INTRODUCTION: Sports that involve sudden stops and direction changes such as football, soccer or rugby are associated with high injury rates especially in the lower limbs (Arnason et al. 2004, Williams et al. 2011). The influence of the playing surfaces on the injury rate has been highly studied mostly through retrospective epidemiological studies (Williams et al. 2011, Dragoo et al. 2012). The injuries to the anterior cruciate ligament (ACL) are frequently cited as a significant risk to athletes on artificial turf because of the changes in shoe-surface interaction, however there is still no consensus regarding the literature depending on the sports concerns (Williams et al. 2011, Balazs et al. 2014). The aim of this study was to analyse the effect of different playing surfaces on knee loads during sport tasks. The quantification of knee loads through inverse dynamic method could help to understand the realtion between injury mechanisms and the type of the playing surface. It was hypothesized that playing surface plays a significant role on knee three dimensional loads and could influence the risk of ACL injury.

METHODS: Three tracks (15m x 2m) were built in a greenhouse (Figure 1). Tracks were built in accordance with ISO standards (NF P90-112 & NF P90-113). The natural track (NA) was composed of Lavaterr substratum (Cargo-Green AG, Bassel, Switzerland). The hybrid track (HY) is composed of artificial rootzone of sand, cork and synthetic fibres in which natural lawn grows (AirFibr, Natural Grass, Paris, France). The artificial track is a third generation artificial turf (AT). All tracks have been maintained following the same program. Watering for NA and HY tracks was provided uniformly by sprinklers.
Fifteen young high-school rugby players (mean ± SD; age: 17.7 ± 1.3yr; height: 1.75 ± 0.05m; mass: 83.4 ± 17.0kg) with no history of long term lower limb injury were recruited. Ethics committee approval was obtained before data collection.
The subjects were required to perform running and sidestep cutting trials randomly in a first phase. Secondly they performed 5 drop-jumps in a row from a 70cm high box. Kinematics during trials were recorded at 300Hz using an infrared optoelectronic system (VICON Peak, Oxford, United Kingdom). Subjects were fitted with reflective markers following pattern

derived from ISB recommendations. 13 segments were considered: head, trunk, pelvis, upper arms, forearms, thighs, shanks and feet. Static trial was used to build a subject's specific inertial model. Ground reaction forces (GRF) were recorded synchronously by 2 force plates at 1200 Hz (AMTI, Watertown, Massachusetts). For each track, both force plates were placed under a 17cm thick layer of the corresponding playing surface (Figure 1). The first force plate recorded GRF for a right stance during running and drop jumping and the first stance (right foot) during sidestep cutting. The second force plate recorded GRF for the second stance (left foot) during sidestep cutting task. Sport tasks were performed randomly for each subject during each recording session for each track.

Peak valgus (PV), peak internal rotation (PI) moments were quantified as they are considered as good predictors in the evaluation of ACL risk injury. Results of the different tracks were statically improved by repeated one-way Anova. Multiple comparisons of the track were made using Holm-Sidak test when significant effect was observed.

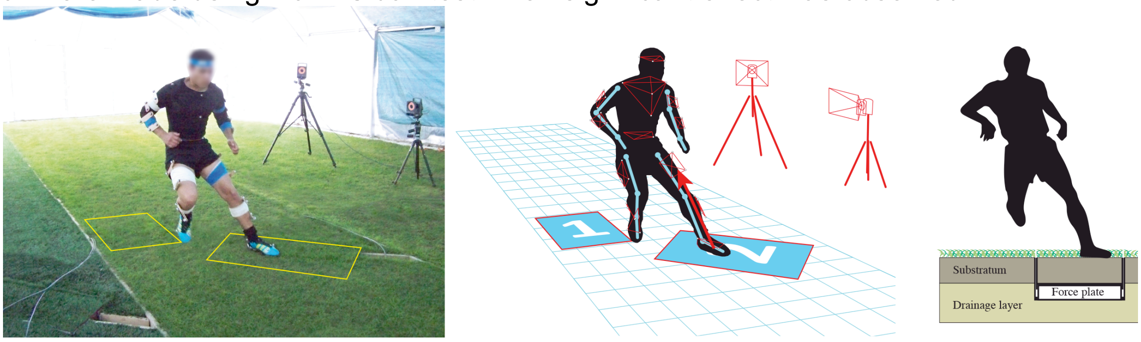

Figure 1: Experimental design of the 3 tracks.

RESULTS: No significant between-tracks differences in speed were found for running and sidestep cutting (6.23 ± 0.40m.s^{-1} and 5.55 ± 0.40m.s^{-1} respectively). Concerning weight acceptance duration, NA and HY showed significant lower values compared to AT only for the right stance during sidestep cutting task (42.0 ± 13ms and 41.5 ± 19.3ms vs. 52.0 ± 21.4ms respectively; $p<0.05$).

For PV values (Figure 2), AT showed significantly higher values compared to NA and HY for right stance during running and left stance during sidestep cutting ($p<0.005$). NA presented higher values ($p<0.005$) for the two other stances (i.e. right stance during sidestep cutting and right stance during drop landing). The lowest values for all tasks were observed on HY track. PI values showed similar trends than PV (Figure 2). Higher values for NA track were found for both right stances during running and drop landing compared to natural ones ($p<0.05$). AT track showed also significant higher values for both stances during sidestep cutting ($p<0.01$). As observed for PV, HY track showed lowest values for all tasks but running right stance.

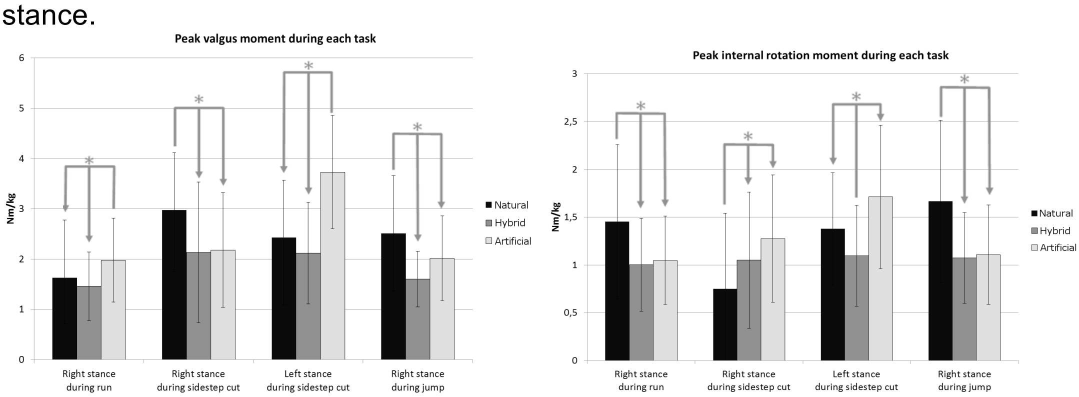

Figure 2: Peak valgus moment (left) and peak internal rotation moment (right) (mean ± SD) during the weight acceptance phase of the stance for running sidestep cutting and drop jumping on natural turf (NA), hybrid turf (HY) and artificial turf (AT). (*p<0.005)

DISCUSSION: The principal finding of this study is that playing surface has a significant effect on knee moments during running, sidestep cutting and drop landing tasks. The sidestep cutting, running and landing tasks have been chosen as they are met in multiple outdoor sports such as european and american football or rugby. They are tasks during which ACL injuries could occur as well during practice as during games. Furthermore, the results showed that the artificial turf exhibits the higher values for PV and PI contrary to the hybrid surface. Based on *in vitro* experimentations, Marklof et al. (1995) found that combining knee valgus and internal rotation moments increased ACL strain and could lead to ACL injury. Present results indicated that knee moments linked to ACL injury were significantly higher on artificial turf than on natural grass. ACL injury risk seems to be increased on artificial turf compared to the two other playing surfaces. These results are consistent with previous epidemiological studies on the major risk of ACL injuries incurred on synthetic turf compared to natural grass (Williams et al. 2011, Dragoo et al. 2012, Balazs et al. 2014). Our study shows also that hybrid surface display the lowest values of knee moments and seems to be safer regarding ACL integrity. To our knowledge, it is the first study assessing the mechanical parameters of a hybrid surface making the comparison difficult.
This study propose to analyse the influence of playing surface on user's risk injury using motion analysis and inverse dynamic methods. Motion analysis and inverse dynamic have proved their reliability for *in vivo* kinetic and kinematic sport movement analysis despite some limitations related to marker placement and skin movements. Other authors have already used this method to evaluate the influence of the whole body kinematic on non-contact ACL injuries during sidestep cutting, overhead catching and landing tasks (Dempsey et al. 2012). This study was also based on quantification of knee moments which are not equivalent to ACL loads. However valgus and internal rotation moments are closely linked to ACL strain. They are commonly used as good surrogate measures for non-contact ACL injury risk assessment. Further investigations could help developing detailed models to understand influence of different playing surface's mechanical behaviour.

CONCLUSION: Knee valgus and internal rotation moments were significantly influenced by the type of the playing surface during running, sidestep cutting and drop jump tasks. Artificial turf showed higher values of moment linked to ACL injury mechanisms whereas hybrid surface displayed the lowest values. This study improves understanding of playing surfaces' effect on anterior cruciate ligament injury risk. Additional analytic and functional studies will be necessary to support the results on player's injury risk and to evaluate the effect of playing surface on sport performance.

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