LOWER LIMB LANDING BIOMECHANICS ON NATURAL AND FOOTBALL TURF

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The aim of the study was to investigate variation in lower limb kinematics during jump landings on natural (NT) and artificial Football Turf (FT). One footballer performed 30 single leg jump landings, following a ball heading movement on NT and FT and immediately continued into a two-step forward run. Landing limb kinematics were recorded (200Hz) using CODA™ and cluster markers. There were similar knee and ankle touchdown kinematics and differing joint angle profiles throughout. FT landings showed greater knee flexion, adduction and internal rotation and reduced ankle eversion. During early impact, the ankle showed a tendency for greater plantar-flexion and inversion using FT compared to NT. These observations highlight a potential for altered lower limb kinematics on NT and FT which may be exaggerated during more demanding tasks and warrant further investigation.

KEY WORDS: artificial turf, injury, landings.

INTRODUCTION: Football Turf (FT), as described by the Fédération Internationale de Football Association (FIFA), is a third generation artificial surface developed specifically for football performance. Alterations to the Laws of the Game in 2004 acknowledged FT as an official surface for competitive football. The use of FT surfaces in professional competition continues to rise, but its suitability remains in question by the football community, based largely on the limitations of previous generations of artificial turf (Baker, 1990). Research in running has highlighted the potential for surfaces to impact on movement technique, altering performance, joint loading and subsequently injury risk (Dixon *et al*., 2000). Epidemiological investigations have highlighted a high incidence of lower limb injuries in professional football, often linked to landings (Murphy *et* al., 2003) and so differences in lower limb kinematics during landings as a function of playing surface may influence injury potential. This preliminary investigation aimed to identify whether lower limb kinematics differed when performing game specific jump landings on natural turf (NT) and FT.

METHODS: Data Collection: A female footballer (age 24 yrs, height 1.64 m and mass 56.8 kg) provided informed consent to participate in the study, with all procedures approved by the University's Ethics Committee. The participant was deemed experienced on natural turf having played competitive senior football for 10 years whilst inexperienced on FT having never played a competitive match on this novel surface. The An automated motion analysis system CODA, (Charnwood Dynamics Ltd, Leicestershire, UK) was used to collect the trajectories of 24 active LED markers at 200 Hz for 5 seconds per trial. Cluster marker sets were utilised with additional markers placed on anatomical landmarks of the lower limb for 10 static trials (2-6 s duration). The anatomical reference markers were removed for the movement trials. Ground reaction force data were collected for the landing leg using a force plate (Kistler 9287BA, Switzerland) sampling at 1000 Hz. Turf samples, housed in purpose built metal trays (900 mm x 600 mm x 50 mm) were mounted on the force plate and changed between trials. The participant performed 15 landings on each surface in a randomized order, wearing her own football boots (Predator Pulse II FG, Adidas). Trials were separated with a 5 minute interval to reduce the effects of fatigue on performance. Each trial comprised a single step approach into a jump to head a suspended size 5 official football followed by a single leg landing on turf and a two-step forward run (Figure 1).

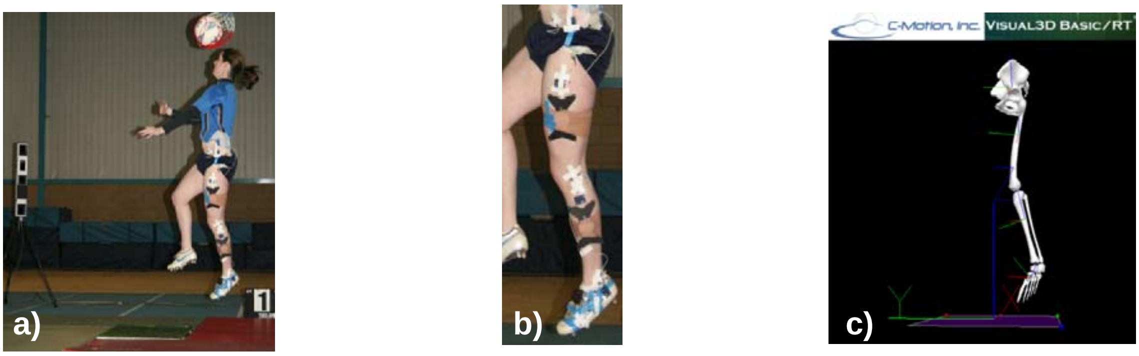

Figure 1: a) Participant performing experimental protocol and b) cluster set used to enable c) skeletal representation of lower limb during movement using Visual 3D software

Data Processing: The kinematic data were processed using motion analysis software (Visual 3D, C-motion Inc., USA) which enabled three dimensional kinematics and skeletal illustrations for each movement trial (Figure 1). The local coordinates for the thigh, shank and foot segments of the landing leg were defined from the static trial data and assigned to the 30 movement trials. Each trial was normalised to 100% from the instant when vertical ground reaction force (Fz) exceeded 10 N and the instant when Fz dropped below 10 N. The raw data were filtered at a cut off frequency of 19 Hz, determined by a Residual Analysis and the rotations about the three axes (flexion-extension, adduction-abduction and internal-external rotation) of the hip and knee joint and the two axes (plantar-dorsiflexion and inversion-eversion) of the ankle joint were exported from Visual 3D.

Data Analysis: Mean (±SD) curves were calculated for knee flexion/extension, adduction/abduction and internal/external rotation under NT and FT conditions, with percentage root mean squared differences (%RMSD) calculated for each joint angle profile. Variability was quantified by calculating %RMSD between the standard deviation profiles under each condition. Mean (±SD) joint angles were calculated for the instant of touchdown under each condition (Table 1).

RESULTS: The two greatest overall percentage difference (%RMSD) between the average NT and FT angle profiles for the hip, knee and ankle were found in ankle inversion-eversion and knee adduction-abduction (Table 1). The greatest variability between conditions was found in knee flexion-extension (Table 1). Percentage difference found between movement variability at the hip, knee and ankle were greater than the differences found between the mean angle profiles (Table 1). Similar joint angles were demonstrated under NT and FT at touchdown (Table 1).

Table 1 Overall percentage difference between the mean and the standard deviation angle profiles between NT and FT conditions

	Movement	Mean profile RMSD (%)	SD profile RMSD (%)	Mean (±SD) Angle at Touchdown NT (°)	Mean (±SD) Angle at Touchdown (FT)
Hip	Flexion-extension	4	45	12 (5)	10 (3)
	Adduction-abduction	18	35	9 (3)	9 (4)
	Internal-external rotation	5	49	-10 (4)	-10 (5)
Knee	Flexion-extension	9	82	-14 (5)	-13 (4)
	Adduction-abduction	22	40	-6 (3)	-5 (2)
	Internal-external rotation	13	34	15 (5)	15 (4)
Ankle	Plantar-dorsiflexion	5	9	-20 (10)	-26 (9)
	Inversion-eversion	25	33	0 (7)	-2 (4)

The angle profiles for the hip, knee and ankle when landing on NT and FT are presented in Figure 2. At touchdown under both surface conditions the hip was flexed, abducted and internally rotated, the knee was flexed, adducted and externally rotated and the ankle was plantar-flexed (Figure 2). A tendency towards greater knee flexion, adduction and internal rotation was observed under NT compared to FT (Figure 2). A tendency was also noted for additional plantar-flexion and inversion at the ankle joint during early contact and less ankle eversion throughout the landing under NT compared to FT.

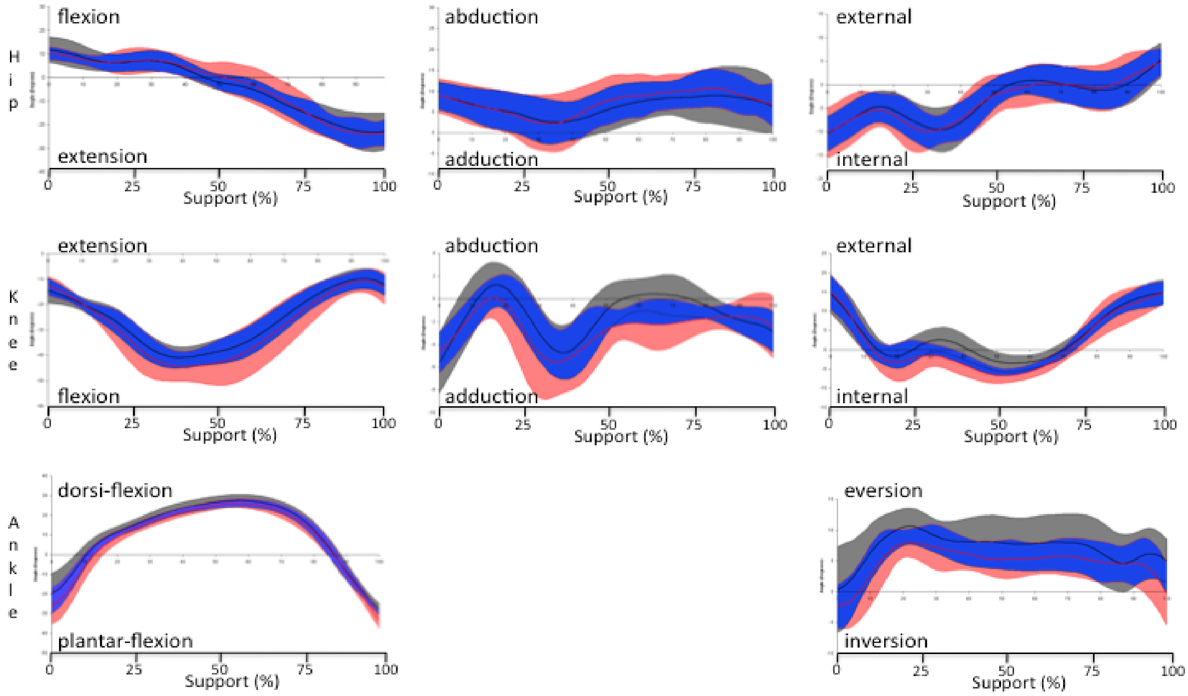

Figure 2: Mean (n=15) ±SD joint angle profiles for hip, knee and ankle under NT (black) and FT (red). Blue areas indicate overlapping standard deviation whilst the black indicates variability in NT alone and red indicates variability in FT alone

DISCUSSION: This preliminary investigation aimed to identify whether lower limb kinematics differed when performing game specific jump landings on NT and FT. Similar hip, knee and ankle angles at the instant of touchdown suggest similar preparatory landing strategies and force generation at touchdown under both surface conditions (Decker *et al*., 2003). However, differences in knee and ankle joint kinematics highlighted potential alterations in landing strategy when performing on NT and FT which warrants further investigation.

Knee Landing Strategy*:* The tendency towards additional knee flexion under FT compared to NT (Figure 2) suggests an increased ability to dissipate force (Decker *et al*., 2003), however, no difference was found in peak Fz between conditions. Previous authors (McNitt-Gray *et al*., 1993) noted greater knee flexion during landings as a function of additional surface stiffness, suggesting differing surface characteristics between NT and FT which may require further investigation. Landings under FT produced a tendency towards greater adduction and internal rotation of the knee compared with NT (Figure 2). Additional lateral movements of the knee may have induced similar lateral movements at the ankle (Andrews *et al*., 1996) providing rationale for the apparent tendency towards reduced ankle eversion under FT (Figure 2).

Ankle Landing Strategy*:* The participant demonstrated a tendency towards greater ankle plantar-flexion and inversion during early contact under FT compared to NT (Figure 2), with both movements believed to be key ankle injury mechanisms when landing (Renstrom and Konradsen, 1997). Landing in an extended ankle position is thought to improve force dissipation (Self and Paine, 2001) and increase lateral ankle ligament exposure (Caulfield and Garrett, 2004). Whilst this tendency appears minimal, a potential exaggeration may be evident during more demanding tasks. This concept may be particularly relevant to the suitability of FT due to the increased ankle injury incidence noted when performing on FT in comparison to NT (Ekstrand *et al*., 2006).

Knee Movement Variability: Substantial differences were reported in movement variability (MV) under NT and FT (Table 1), with landings on FT producing greater MV at the knee joint in comparison to NT. Optimal MV is believed to stem from experience (Wilson *et al*., 2008), which was believed to occur under NT conditions, reducing repetitive loading and increasing adaptability to perturbations (Hamill *et al*., 1999). In contrast, the greater MV produced at the knee under FT was deemed to be outside the functional limits of variability and coincided with the participant's lack of experience on this surface. The participant may have been attempting to acquire the appropriate characteristics of the landing movement, resulting in greater MV under FT (Wilson *et al*., 2008).

CONCLUSION: The present study has investigated the kinematics of the lower limb during football specific jump landings. Whilst being a preliminary investigation, tendencies towards greater knee flexion and internal rotation combined with additional lateral movements at the knee and ankle may highlight important differences in landing technique when performing on a novel FT surface. Future studies need to investigate how performers adapt to performing on FT incorporating greater sample sizes, inferential statistics and inter-subject comparisons across a range of turf types and sizes.

REFERENCES

Andrews, M., Hewett, T. and Andriacchi, T. P. (1996). Lower limb alignment and foot angle are related to stance phase knee adduction in normal subjects: A critical analysis of the reliability of gait analysis. Journal of Orthopaedic Research 14, 289-295.

Baker, S. W. (1990). Performance standards for professional soccer on artificial turf surfaces. *Journal of Sports Turf Research Institute*, 66, 83-92.

Caulfield, B. and Garrett, M. (2004). Changes in ground reaction force during jump landing in subjects with functional instability of the ankle joint. Clinical Biomechanics, 19, 617-621.

Decker, M. J., Torry, M. R., Wyland, D. J., Sterett, W. I. and Steadman, J. R. (2003). Gender differences in lower extremity kinematics, kinetics and energy absorption during landing. *Clinical Biomechanics*, 18, 662-669.

Dixon, S. J., Collop, A. C. and Batt, M. E. (2000). Surface effects on ground reaction forces and lower extremity kinematics in running. *Medicine & Science in Sports & Exercise*, *32*, 1919-1926.

Ekstrand, J., Timpka, T. and Hagglund, M. (2006). Risk injury in elite football played on artificial turf versus natural grass: a prospective two-cohort study. *British Journal of Sports Medicine, 40*, 975-980.

Hamill, J. R. E., van Emmerik, B. C., Heiderscheit, B. C. and Li, L. (1999). A dynamical systems approach to lower extremity running injuries. *Clinical Biomechanics, 14*, 297-308.

McNitt-Gray, J. L., Yokoi, T. and Millward, C. (1993). Landing strategy adjustments made by female gymnasts in response to drop height and mat composition. Journal of Applied Biomechanics, 9, 173-190.

Murphy, D. F., Connolly, D. A. and Beynnon, B. D. (2003). Risk factors for lower extremity injury: a review of the literature. *British Journal of Sports Medicine, 37*, 13-29.

Renstrom, P. A. and Konradsen, L. (1997). Ankle ligament injuries. British Journal of Sports Medicine, 31, 11-20.

Self, B. and Paine, D. (2001). Ankle biomechanics during four landing techniques. Medicine & Science in Sports & Exercise, 33, 1338-1344.

Wilson, C., Simpson, S. E., van Emmerik, R. E. A. and Hamill, J. (2008). Coordination variability and skill development in expert triple jumpers. Sports Biomechanics, 7, 2-9.

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