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OTRF Funded Research Project

■ Final Report

Title	**Contribution of Field Playing Surface Type and Quality to Potential Acute and Chronic Injury Rates**
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Executive Summary

The objective of this study was to investigate and compare the measured peak loads, moments (rotational forces) and moment variability at the major joints of the lower limb during movements over artificial turf, a natural grass and grass/weed mixture sporting surfaces. Plot boxes were manufactured to hold the three sporting surfaces and ten athletes executed numerous running, cutting and stopping trials for analysis.

Peak moments showed a consistent pattern across all joints for the grass surface. The measured peak moments for grass was observed to be between the weed and artificial surfaces. However, for running, the artificial surface produced the highest peak moments. With regard to joint moment variability, across all conditions and joints, the artificial surface showed the least amount of variability; the weed surface showed the most variability, and the grass surface was consistently between that of the artificial and weed surfaces.

Background

One of the most important aspects of a player's safety involves both the condition and properties of the playing surface; the very nature of the playing surface plays a role in determining the risk of injury. Over the past few decades there has been an increase in sporting participation, however, there is often insufficient number of traditional grass fields of suitable quality. Moreover, climatic conditions in certain parts of the world are unsuitable for the installation and maintenance of good quality year-round grass fields. To meet this demand for sporting surfaces, artificial sporting surfaces are often installed. Additionally, the traditional grass sporting surface may also be changed through the recently enactment of legislative policy to ban cosmetic pesticide use throughout Ontario and other Canadian provinces. Of particular

concern, this change could impact the development of vegetation species that lack the physiological and mechanical characteristics to survive in environments in which repeated wear is experienced, which is typical of athletic playing fields. These aforementioned changes to traditional sporting surfaces impact our understanding of the properties intrinsic to the sporting surface which will affect an athlete's mechanics while engaged in sport.

Over the past few decades, numerous studies have attributed a greater risk and incidence of articular (joint) and concussive trauma to playing on earlier generations of artificial turf when compared to natural grass[1-6]; as well, strong negative opinions of artificial turf have been expressed by elite athletes. However, the latest generation of artificial turf (employing synthetic infill materials, such as rubber crumb, and supported on an engineered foundation) is reported to closely reflect the performance characteristics of grass and when the two surfaces are compared, reports have shown no major differences in the incidence of match injuries sustained at both the professional and non-professional levels[6-8].

While the effects of different playing surfaces on acute injuries have been studied, the effect of playing surfaces on chronic injuries remains unknown. Research has shown that surface compliance may not be related to the frequency of acute injuries, but there is speculation it may be associated with chronic injuries such as medial tibial stress syndrome and boney stress fractures[9]. The potential mechanisms of surface properties affecting chronic injury risk could be based on increased peak moments or decreased impact attenuation properties of the surface. It has typically been assumed that excessive peak impact force values are associated with the occurrence of chronic injuries. However, it has been shown that athletes (subconsciously) adjust their lower extremity stiffness in order to maintain a consistent vertical stiffness and accommodate high impact forces when running over varied surfaces[10]. It has also been proposed that altered joint movement may contribute to development of chronic injuries. These changes in joint movement patterns could be based on surface variability and thereby measuring variability of joint kinetics may aid in elucidating the influence of the surface on injury development. Furthermore, the artificial and altered grass sporting surfaces may have differences in properties for stiffness, friction and elasticity, which could have significant influence on lower limb mechanics for athletes and warrants further investigation.

The purpose of this study was to investigate and compare measured peak moments (or rotational forces) and moment variability at the major joints of the lower limb during dynamic movements over three different sporting surfaces; artificial turf, a natural grass and grass/weed mixture.

Objectives	

The objective of this study was to investigate and compare the measured peak loads, moments (rotational forces) and moment variability at the major joints of the lower limb during movements over artificial turf, a natural grass and grass/weed mixture sporting surfaces.

Methods & Results	

Methods

Ten healthy young male participants volunteered to take part in this study. Approval to conduct this study was provided by the local human research ethics review board. Each participant wore their own athletic shoes and was outfitted with passive reflective markers that were strategically placed on the bony landmarks to produce a 7-segment (pelvis, left and right thigh, shank, and foot) lower body model. Marker positions were recorded using a seven-camera motion capture system.

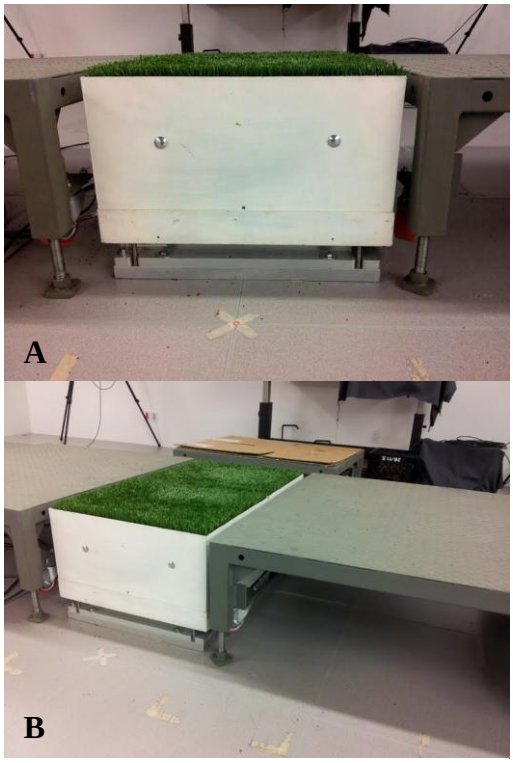
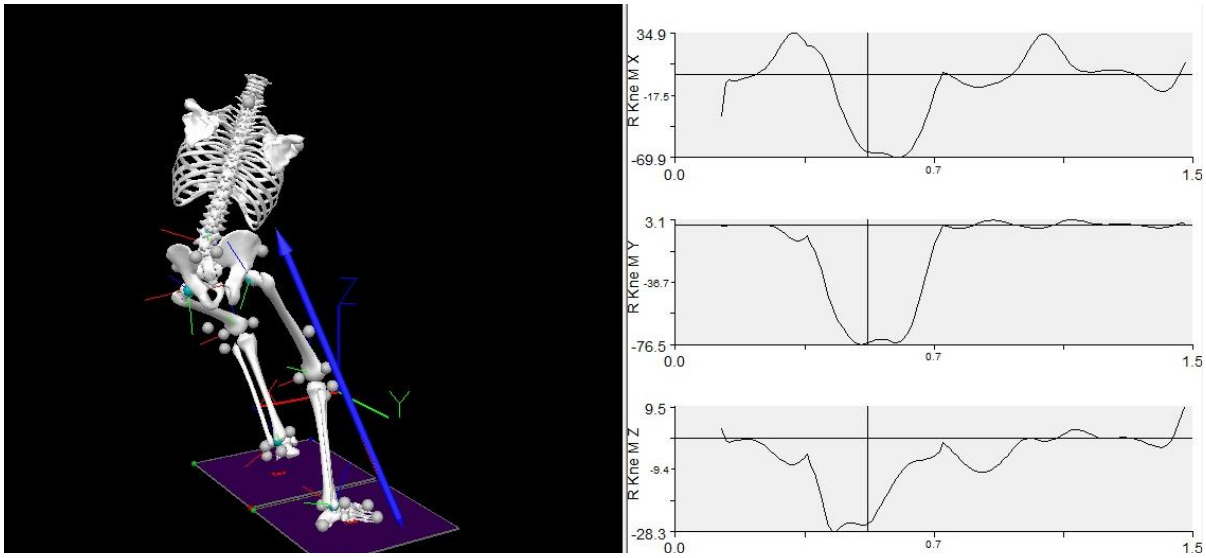


Figure 1. Experimental set-up depicting (A) box plots with artificial turf fixed atop of the force plates and (B) the custom built running stage.

Participants were asked to perform a series of cutting (*Cut*), running (*Run*), and stopping (*Stop*) trials over three different types of surfaces: artificial turf, natural grass, and grass/weed mixture. There were 5 trials conducted per condition; 15 trials conducted per surface type, for a total of 45 trials completed by each participant. Three pairs of custom designed boxes (47 x 51.5 x 21 cm; Fig. 1A) contained soil on which the grass (*Grass*), grass/weed mixture (*Weed*) surfaces were grown, and one pair contained new generation artificial turf (*Artificial*) surface. The Grass surface was Kentucky bluegrass (*Poa pratensis*) over-seeded with perennial ryegrass (*Lolium perenne*). The Weed surface was the same Grass that had been seeded, but also contained broadleaf (*Plantago major*) and narrow leaf plantain (*Plantago lanceolata*). The box plots were prepared at the Guelph Turfgrass Institute at University of Guelph.

Participants moved across a custom-built stage (Fig. 1B), that was designed to match the height of the surface. Each of the box plot pairs were mounted on top of the two force plates. The force plate measure the forces applied to the turf surface during movements, and in concert with a high resolution, 3D optoelectronic motion capture system in the laboratory, allowed for calculation of estimated lower limb joint forces and moments (Fig. 2).

Figure 2. The left panel is the representation of the 3D kinematic model of a participant performing a cut to the left. The right panel shows plots of the right knee joint moment time series in sagittal, frontal, transverse planes.



Outcome measures included: three-dimensional peak right ankle, knee, and hip internal joint moments (estimated using an inverse-dynamics model) and moment waveform coefficient of variation (CV; calculated for each participant based on the time-normalized moment profiles).

Results and Discussion

Peak Moments

Gross peak moments showed no consistent pattern across joints and surfaces in the *Cut* condition (Table 1A). In the *Run* condition peak moments, though statistically not significant, appeared to be lowest for the *Weed* surface, and highest for the *Artificial* surface, with *Grass* in between (Table 1B).

Table 1A. Summary of the peak joint moment and moment waveform CV for the Cut condition.

		Extension Moment		Adduction Moment		Internal Rotation Moment	
		M (Nm/kg/m)	CV (%)	M (Nm/kg/m)	CV (%)	M (Nm/kg/m)	CV (%)
Joint	Surface	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Ankle	Artificial	1.18 ± 0.04	16.60 ± 1.25	0.64 ± 0.04	16.25 ± 1.19	0.52 ± 0.04	18.45 ± 1.95
	Grass	1.15 ± 0.04	19.01 ± 1.28	0.70 ± 0.04	15.71 ± 1.64	0.54 ± 0.05	17.38 ± 1.48
	Weed	1.22 ± 0.05	17.72 ± 1.90	0.71 ± 0.04	16.11 ± 1.75	0.55 ± 0.05	19.46 ± 1.65
	p =	0.22	0.54	0.12	0.97	0.41	0.37
Knee	Artificial	1.24 ± 0.10	21.27 ± 2.20	0.91 ± 0.10	16.59 ± 0.99	-0.42 ± 0.04	29.99 ± 5.60
	Grass	1.21 ± 0.07	25.28 ± 2.24	0.93 ± 0.12	15.04 ± 1.21	-0.43 ± 0.05	27.90 ± 2.85
	Weed	1.17 ± 0.08	23.35 ± 3.04	0.94 ± 0.11	16.00 ± 0.78	-0.45 ± 0.05	29.72 ± 4.40
	p =	0.55	0.55	0.79	0.56	0.52	0.94
Hip	Artificial	0.91 ± 0.14	37.34 ± 6.07	1.09 ± 0.07	20.24 ± 2.41	0.26 ± 0.03	47.16 ± 4.71
	Grass	0.92 ± 0.10	38.72 ± 5.93	1.08 ± 0.11	19.65 ± 1.92	0.28 ± 0.03	44.97 ± 1.84
	Weed	0.91 ± 0.10	34.24 ± 3.67	1.10 ± 0.10	20.72 ± 2.26	0.27 ± 0.04	48.28 ± 5.56
	p =	0.97	0.84	0.92	0.95	0.54	0.87

In the *Stop* condition peak moments appeared to be lowest for the *Artificial* surface, highest for the *Weed* surface, with *Grass* in between (Table 1C). The results created an interesting comparison between conditions; the *Grass* surface was consistently between the other two surfaces for peak moments, but *Weed* and *Artificial* surfaces demonstrated no pattern across condition. The observation of the higher peak moment during *Run* for the *Artificial* surface gives support of the recent reports that observed greater acute ankle injuries, which is generally sustained during running and cutting maneuvers, on artificial playing surfaces.

Table 1B. Summary of the peak joint moment and moment waveform CV for the Run condition.

		Extension Moment		Adduction Moment		Internal Rotation Moment	
		M (Nm/kg/m)	CV (%)	M (Nm/kg/m)	CV (%)	M (Nm/kg/m)	CV (%)
Joint	Surface	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Ankle	Artificial	1.29 ± 0.04	11.66 ± 0.99	0.29 ± 0.02	22.89 ± 2.75	0.13 ± 0.02	42.20 ± 7.52
	Grass	1.35 ± 0.03	13.36 ± 1.66	0.32 ± 0.04	27.99 ± 4.64	0.13 ± 0.02	49.32 ± 15.73
	Weed	1.37 ± 0.03	15.72 ± 2.14	0.32 ± 0.04	29.57 ± 3.80	0.14 ± 0.02	57.41 ± 11.58
	p =	0.07	0.24	0.25	0.42	0.79	0.63
Knee	Artificial	1.36 ± 0.08	17.77 ± 2.06	-0.08 ± 0.02	91.39 ± 10.41	0.14 ± 0.02	36.50 ± 7.00
	Grass	1.33 ± 0.07	21.98 ± 2.92	-0.09 ± 0.02	64.77 ± 10.22	0.14 ± 0.02	34.47 ± 4.49
	Weed	1.28 ± 0.05	23.12 ± 4.35	-0.07 ± 0.02	97.62 ± 23.31	0.11 ± 0.01	47.70 ± 9.01
	p =	0.32	0.48	0.21	0.31	0.010* **a**	0.38
Hip	Artificial	1.06 ± 0.08	21.70 ± 1.92	-0.45 ± 0.05	28.85 ± 4.04	-0.21 ± 0.02	37.00 ± 3.25
	Grass	0.99 ± 0.10	23.68 ± 3.45	-0.43 ± 0.06	31.78 ± 5.58	-0.19 ± 0.02	40.50 ± 5.34
	Weed	1.11 ± 0.10	26.06 ± 4.05	-0.39 ± 0.04	28.76 ± 2.39	-0.18 ± 0.01	47.03 ± 3.77
	p =	0.043* **b**	0.63	0.07	0.85	0.09	0.25

* - significance at alpha level <0.05: **a**) Artificial = Grass > Weed; **b**) Grass < Weed.

Table 1C. Summary of the peak joint moment and moment waveform CV for the Stop condition.

		Extension Moment		Adduction Moment		Internal Rotation Moment	
		M (Nm/kg/m)	CV (%)	M (Nm/kg/m)	CV (%)	M (Nm/kg/m)	CV (%)
Joint	Surface	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Ankle	Artificial	1.06 ± 0.06	18.77 ± 2.26	0.19 ± 0.06	50.97 ± 8.39	0.16 ± 0.03	36.90 ± 6.59
	Grass	1.11 ± 0.05	20.49 ± 3.22	0.23 ± 0.05	47.43 ± 6.73	0.17 ± 0.03	31.38 ± 3.15
	Weed	1.24 ± 0.06	21.74 ± 3.16	0.21 ± 0.04	57.90 ± 7.10	0.18 ± 0.03	33.48 ± 4.29
	p =	0.0004* **a**	0.78	0.014* **b**	0.58	0.040* **c**	0.72
Knee	Artificial	0.71 ± 0.04	34.27 ± 5.45	0.32 ± 0.07	30.05 ± 2.29	-0.16 ± 0.03	45.95 ± 6.76
	Grass	0.74 ± 0.03	32.60 ± 3.78	0.35 ± 0.07	28.63 ± 3.30	-0.17 ± 0.03	42.57 ± 6.24
	Weed	0.66 ± 0.03	36.71 ± 3.66	0.35 ± 0.06	24.51 ± 2.23	-0.17 ± 0.03	38.59 ± 5.82
	p =	0.013* **d**	0.80	0.16	0.36	0.23	0.72
Hip	Artificial	1.11 ± 0.08	26.67 ± 2.40	0.50 ± 0.07	30.26 ± 6.06	-0.10 ± 0.02	100.95 ± 12.32
	Grass	1.12 ± 0.11	28.38 ± 4.45	0.57 ± 0.08	31.03 ± 5.02	-0.11 ± 0.03	77.79 ± 10.44
	Weed	1.16 ± 0.11	25.82 ± 1.99	0.54 ± 0.06	28.20 ± 4.23	-0.12 ± 0.03	93.43 ± 14.20
	p =	0.59	0.84	0.09	0.92	0.20	0.42

* - significance at alpha <0.05: **a**) Artificial = Grass < Weed; **b**) Artificial < Grass; **c**) Artificial < Weed; **d**) Grass > Weed

Variability

Moment waveform CV showed no consistent pattern across joints and surfaces in the *Cut* condition (Table 1A). CV in the *Run* condition, though not statistically significant, showed a clear pattern with the lowest variability for the *Artificial* surface, highest variability in the *Weed* surface, and *Grass* was in between (Table 1B). There was no consistent pattern observed across joints and surface in the *Stop* condition (Table 1C). Overall across all conditions, joints, and surfaces the moment waveform CV suggests that *Artificial* showed the least variability, *Weed* the most, and *Grass* was consistently in the middle (Table 1 and 2). Further data analysis, though quite preliminary, suggests that waveform CV became progressively smaller for *Artificial* and *Grass* in *Cut* and *Stop* condition, but not for *Weed*, where moment waveform CV increased with repeated use across participants (Fig. 3 and 4).

This pattern did not hold true in the *Stop* condition, where moment waveform CV increased similarly for *Grass* and *Weed* surfaces with the surface use, yet there was no change in moment waveform CV for *Artificial* surface (Fig. 5). These findings suggest that the *Weed* surface, across all conditions, consistently produced the largest variability, which could have implications for incidence of chronic injuries. It also fits with the hypothesis that the weedy surfaces lack the physiological and mechanical characteristics to survive in environments in which repeated wear

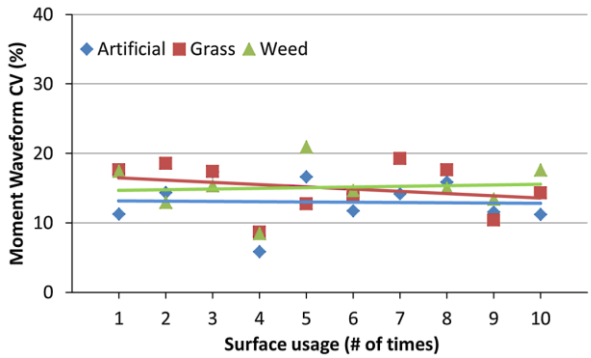


Figure 3. A representation of moment waveform CV as a function of the number of times the surface was used in Cut condition.

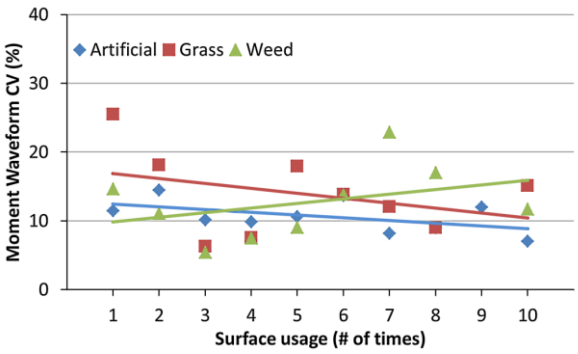


Figure 4. A representation of moment waveform CV as a function of the number of times the surface was used in Run condition.

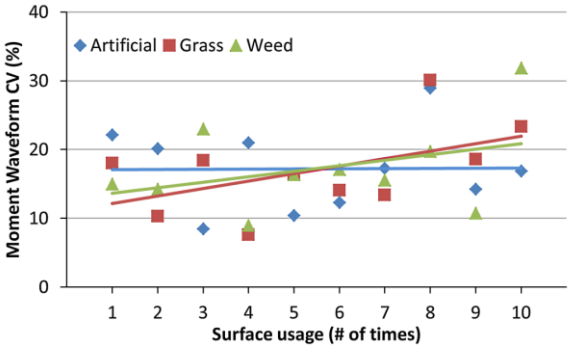


Figure 5. A representation of moment waveform CV as a function of the number of times the surface was used in Stop condition.

is experienced and therefore potentially affect the safety of sportsfields. The *Artificial* and *Grass* surfaces demonstrated consistent or reduced variability with repeated use, which we speculate is less problematic for the development of chronic/overuse injuries.

Conclusions	

The literature has shown that during sporting events the playing surface can influence the athlete's risk of injury, and safety. In this study we compared three different playing surfaces for peak loading, rotational forces and the variability for these measures across the three major joints of the lower limbs, while completing three different sporting maneuvers. We found that the traditional grass surface produced peak moments that were consistently between that produced by the weed and artificial playing surfaces. It was also observed that the weed surface produced the largest peak moments at the ankle, whereas the artificial surface consistently produced the largest peak moments at the knee, both occurring for all conditions. The artificial surface was shown to be the least variable with use and the grass surface became less variable across all but the cut condition. However, across all conditions, the weed surface was observed to have increased variability with use. The increased variability associated with the weed playing surface could have negative consequences on chronic/overuse injuries, which could be further exacerbated with the high moments observed (specifically at the ankle) on this surface.

Project Communication	List all industry and academic presentations and submitted publications

A session at the upcoming Ontario Turfgrass Symposium is expected in February 2013

Results have been incorporated in the Sports Turf Management and Maintenance Course that has been offered in Spring 2012 Fall 2012 and will be offered in the future.

Scientific presentation will be presented at the 2014 CSSA meetings

Trade journal article will be submitted to the STA for winter issue of the Sports Turf Manager
Scientific Publication is to be submitted by December 2012