DIFFERENCES IN GROUND REACTION FORCES WHEN PERFORMING THE SIDE-STEP CUTTING ACTION ON DIFFERENT INFILL DEPTHS

Ian Harris Sujae[1], Khalid Jabbar[1] Alex Ong[1] and Joseph Hamill[1, 2]

School of Sports Health and Leisure, Republic Polytechnic, Singapore[1]
University of Massachusetts Amherst, USA[2]

This study aimed to quantify differences in ground reaction forces (GRFs) when performing a side-step cutting action on artificial grass turf with two different infill depths. GRF_{XPeak} (7.27 ± 2.7 N/kg vs. 9.00 ± 2.7 N/kg, p=0.00) and GRF_{YPeak} (5.41 N/kg ± 1.4 vs. 6.15 N/kg ± 1.6, p=0.00) were significantly larger, but not GRF_{ZPeak} (28.26 N/kg ± 8.6 vs. 29.64 N/kg ± 9.3, p=0.58) when participants (n=17) performed side-steps on turf with greater infill depths. Larger GRF_{ZPeak} during heel-strike may be due to larger knee extension angle (39.7 deg ± 8.2 vs. 34.7 deg ± 8.5, p=0.03) while significantly larger GRF_{XPeak} and GRF_{YPeak} at the weight acceptance phase and push-off phase may be due to a larger knee extension angle in conjunction with the hardness of sand/rubber infills given the increased thickness as well as frictional components of the artificial grass turfs.

KEY WORDS: GRFs, Joint kinematics, side-step, infill depths and artificial grass turf.

INTRODUCTION: The playability of the new generation artificial grass turf has tremendously improved over the years. Turf characteristics such as moisture, hardness, grass cover, root density, naps in the turf, type, distribution, compaction and depth infills (Orchard, 2002; James and McLeod, 2008; Simon, 2010) have been reported to contribute to this resurgence of the use of artificial turf. Unlike early generation turfs, which have only sand infills, the new generation artificial grass turf have both sand and rubber granules as infills. Given the properties of rubber, the new generation artificial grass turf may provide a cushioning effect as studies on synthetic turf surfaces have reported that increases in infill depth were associated with reductions in surface hardness (Brosnan and McNitt, 2008a; 2008b; Brosnan, McNitt and Serensits, 2009; McNitt, 2005). Although these studies investigated baseball field surface conditions and not artificial grass turfs, infill depth is a major factor in determining surface hardness (Simon 2010). It may be that the level of hardness of artificial grass turf may also depend on infill depth where the thicker the infill depths, the greater the effect; thereby, possibly reducing knee joint loading. Considering that the ground reaction force (GRF) is the impact energy caused by an athlete’s foot striking the playing surface (Nigg et al., 1984), the ability of the surface to absorb foot strike impacts may be used to measure surface hardness. As such, the objective of this study was to determine differences in GRFs when performing a side-step cutting manoeuvre on a new generation artificial grass turf with different depths of sand and rubber granule infills. It was hypothesized that the GRFs would be greater in the turf with a lesser depth of infill.

METHODS: Ethical clearances were sought from the Republic Polytechnic ethics committee. Seventeen trained male inter-college soccer players (18 ± 0.7 yrs; 69.4 ± 5.9 kg; 1.70 ± 0.0 m), with no previous history of lower-limb musculoskeletal injuries, participated in this study. All subjects provided informed consent for participation. Data were collected in-doors within the Sports Biomechanics Laboratory. An artificial grass turf runway (14m x 1.2m), filled with sand and rubber granules infills (ratio 50:50), was secured on top of a walking board laid across the lab using double-sided Velcro tape. The boards were fastened together and onto the floor using in-build board clips and anti-slip mats. A force-plate (Kistler Instrument Corporation, Amherst, NY, USA) was positioned near the end of the runway. The distance between the start point and the centre of the force-plate was 7 m. The plate was flush with the boards lying beneath the turf. White paint was sprayed on top of the artificial grass to highlight the position of the force-plate. The sampling frequency for the force-plate was set at 1000 Hz. Ten high-speed optical cameras (Motion Analysis Corporation Eagle 4 System, Santa Rosa, CA, USA), individually mounted on overhead railings to capture side-step actions, provided a 360 degree area of foci on the force platform representing the three-dimensional (3D) volume space. The sampling frequency for the motion capture system was set at 250 Hz. The 3D volume space was calibrated at the beginning of every data collection day, ensuring that all cameras were synchronized with the force-plate which was reset to zero once the turf is placed on-top of it.

Passive retro-reflective markers were placed on selected anatomical landmarks, namely the iliac crest, greater trochanter of femur, lateral and medial epicondyle of femur, lateral and medial malleolus as well as 1^{st} and 5^{th} metatarsal using 3M double-sided tape to determine the trunk, pelvis, thigh, shank and foot segments. Sufficient practice trials were allocated to subjects prior to actual data collection. All subjects wore the same FIFA approved artificial turf shoes and were instructed to run as fast as they could from the starting point, plant their dominant foot onto the force-plate and change direction at a 45° angle. Time to run this distance was recorded using a stop watch. All subjects performed 10 side-step trials for an infill depth of 2 cm (condition A) first followed by an infill depth of 4 cm (condition B). Only the best 3 trials with consistent average speeds were selected for final analysis. Kinematic data were smoothed using the Butterworth low-pass digital filter at a cut-off frequency of 7 Hz and interpolated with a maximum gap fill of thirty frames using a 3rd order polynomial established within Visual 3D software. Variables measured were knee joint flexion-extension angle ($Knee_{\Theta}$) and peak GRF data (GRF_{XPeak}, GRF_{YPeak} and GRF_{ZPeak}) normalized to body mass. Data were analyzed from the instant of foot contact until toe-off (Besier et al., 2001a). Statistical analyses were conducted using paired *t*-test (SPSS software version 16.0) with alpha value set at $p < 0.05$.

RESULTS: Time history patterns of mean knee angle and GRFs are illustrated in Figure 1. When compared to condition A, GRF_{XPeak} (7.27 N/kg ± 2.7 vs. 9.00 N/kg ± 2.7, p=0.00) and GRF_{YPeak} (5.41 N/kg ± 1.4 vs. 6.15 N/kg ± 1.6, p=0.00) were significantly larger for condition B. No significant differences were reported for GRF_{ZPeak} (28.26 N/kg ± 8.6 vs. 29.64 N/kg ± 9.3, p=0.58) between conditions. Knee flexion-extension angle ($Knee_{\Theta}$) at GRF_{ZPeak} was significantly greater for condition B than condition A (39.7 deg ± 8.2 vs. 34.7 deg ± 8.5, p=0.03).

DISCUSSION: The objective of this study was to determine differences in GRFs when performing the side-step cutting action on new generation artificial grass turf with different depths of sand and rubber granule infills. It was hypothesized that there would be greater force in the turf condition with a lesser infill depth (condition A). Based on our results, however, we must reject this hypothesis. Performing the side-step action on turfs with greater infill depth (condition B) actually elicited significantly larger GRF_{XPeak} and GRF_{YPeak}, but not for GRF_{ZPeak}.

Regardless of the infill depth, GRF_{ZPeak} occurred within the first 20% of normalized time from the point of initial contact (Figure 1). Similar studies (Koga et al., 2010) have also reported that peak vertical GRF occurred within the first 40ms from the point of initial contact. One possible reason for this may be attributed to maximal knee extension during first 20% of normalized time from the point of initial contact. This was expected as studies have reported that GRF_{ZPeak} occured at the instant of maximum knee extension (James and McLeod, 2004). Although not significant, GRF_{ZPeak} were larger for condition B than A. This suggests that the thicker sand and rubber infill depth (condition B) may indeed be harder as it has been reported that the hardness of synthetic natural fields is related to infill depth whereas hardness of natural fields varies according to soil-moisture (Simon, 2010). As such, instead of absorbing foot strike impacts, athletes may experience greater lower limb loading when performing the cutting action on thicker infill depths. This potentially increase stress on the ligaments which in turn may increase the risk of knee ligament injuries.

Unlike GRF_{ZPeak}, GRF_{XPeak} and GRF_{YPeak} occurred during the weight acceptance (WA) phase (Figure 1). The occurrence of both peak forces at WA phase may have contributed to the execution of the side-step action. Indeed, studies have reported that the push-off force in the medial/lateral (GRF_{XPeak}) and anterior/posterior (GRF_{YPeak}) directions are both contributors to changing directions (Patla, Prentice and Robinson, 1991). This pattern is likely dominated by the large posteriorly directed force acting on the tibia during stance which stems from the posterior external GRF during deceleration (McLean, Su and van den Bogert 2003). Between conditions, our results show that GRF_{XPeak} and GRF_{YPeak} were significantly larger for condition B then A. This infers that there may be a greater push-off force in the medial/lateral and anterior/posterior directions due to the different lower extremity posture (technique) as exemplified by the larger knee flexion angle and the greater surface hardness in condition B. Since studies have reported greater GRF during WA phase may be due to the inability of the calf musculature to cushion the landing (Boden et al., 2009), it is also plausible that given the harder surface, this inability may be augmented when athletes performed the side-step actions in condition B. It is also plausible that the increase in infill depths could have increased the static as well as kinetic fictional components of the two surfaces (sole of athletes shoes and the turfs), which, in turn, could have caused the significant increase in the GRF_{XPeak} and GRF_{YPeak} forces. Performing the side-step action on turfs with thicker infills, therefore, probably elicits larger lower-limb loadings to quickly change the direction of run. Future studies will investigate knee and ankle kinematics and kinetics to fully understand what the lower limb is experiencing when performing the side-step action on two different types of artificial grass turf with different depths of sand and rubber granule infills.

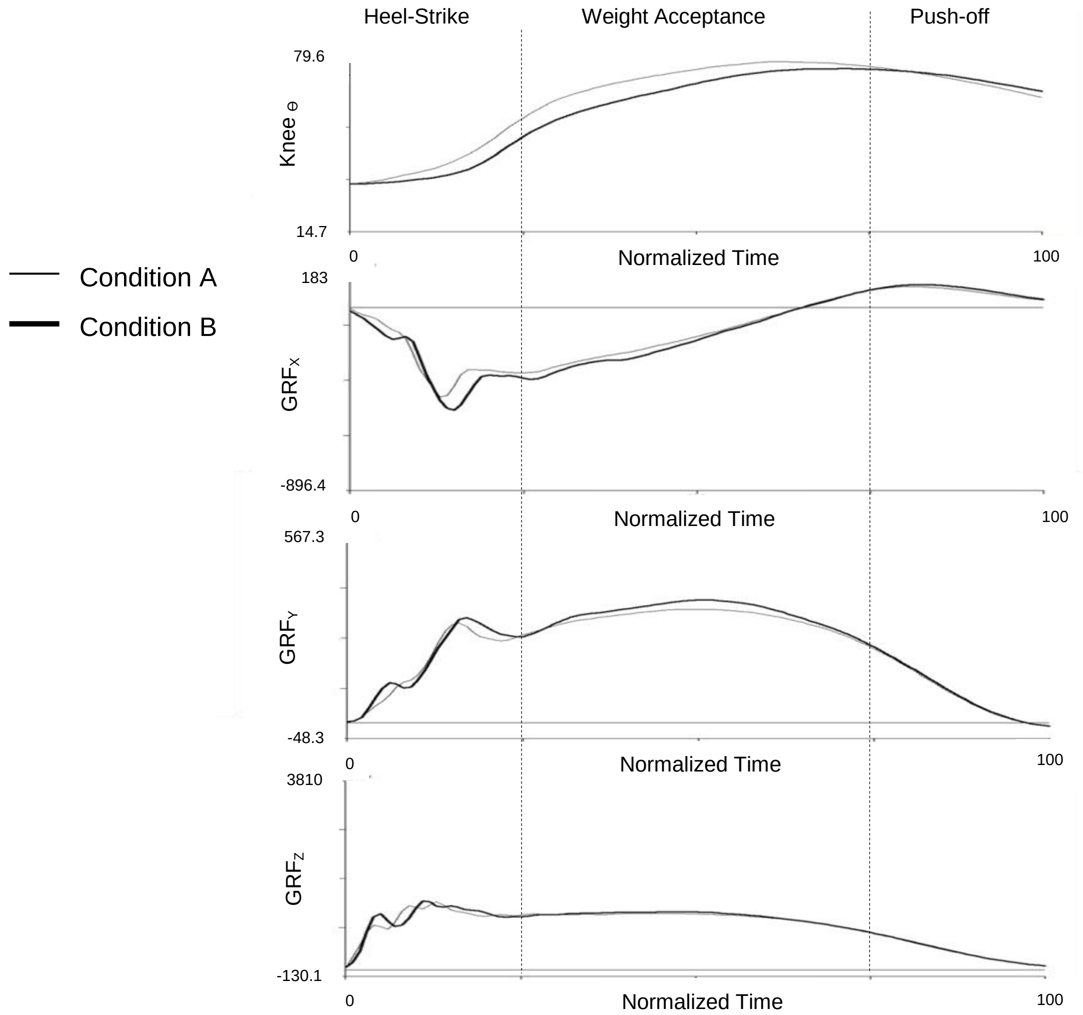

Figure 1: Time history patterns of mean GRF_X, GRF_Y, GRF_Z and Knee $_\theta$ normalized to 100%.

CONCLUSION: Significant differences were reported for normalized GRF_{XPeak} and GRF_{YPeak} but not for normalized GRF_{ZPeak} when performing the side-step manoeuvres on two different infill depths. Although not significant, GRF_{ZPeak} were larger for condition B and this occurred during after heel-strike phase possibly due to significantly larger knee extension. Significantly larger GRF_{XPeak} and GRF_{YPeak} for condition B occurred during weight acceptance phase and push-off phase. This may be attributed to i) differences in lower extremity posture (significantly larger knee extension); ii) the hardness of sand/rubber infills; and, iii) the frictional components of the walkway.

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Acknowledgement

The authors would like to thank Abel Quek Woon Teck, Muhammad Dzulyadain Bin Mohamed Bakri, Nor Hidayahwati Binte Abdul Fattah, Muhammad Syazwan Bin Mohamed Sadan and Nurkhairah Binte Mohammad who have contributed to this paper as part of their Final Year Project.