Development of a Test Methodology for Representing the Shoe-Turf Interaction of Complex Player-Like Motions

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I. INTRODUCTION

In recent years, much attention has been focused on how different playing surfaces affect lower extremity injury risk for athletes [1]. Several turf testing methods have been utilised to evaluate cleat-turf interactions, where simplified cleat motions and forces are applied to evaluate how such interactions vary by surface type [2-6]. Such test methods employ simplified motions (like shear translation under constant load), with a goal of easily understandable results or to facilitate test device portability and permit on-field testing in situ. Test methods that permit more complex, player-like cleat-turf interactions may provide for richer and more diverse assessments of cleat-turf interaction, which may be necessary to better understand and address injury risks. Thus, this study aimed to develop and demonstrate a test methodology for exploring cleat-turf interaction through complex player-like motions using a 6 DOF force/torque and position-controlled robotic test system.

II. METHODS

The force/torque and position-controlled robotic test system consisted of a 300 kg-payload 6DOF serial industrial robot (KR300 R2500 Ultra, Kuka, Augsburg, Germany) instrumented with a 6DOF load cell that was controlled by a suite of purpose-built hardware/software tools (simVITRO, Cleveland Clinic). Turf samples were constructed, as per manufacturer recommendations, in 0.84 x 1.45 m aluminum boxes that were fixed to the floor near the test system (Fig. 1). Three different turf surfaces were evaluated in this study: a control surface; a low-faceweight (lower fiber density stitching) surface; and the control surface with a 23 mm shockpad included under the turf construct. A 3-D printed aluminum surrogate of a late-model American football cleat (VaporJet, Nike Inc., Beaverton, Oregon, USA) was mounted to the robotic end effector to simulate the player's foot/cleat (Fig. 1, Right). 6DOF player motion kinematics, collected from on-field athletic drills [7], were used to create kinematic input trajectories for the robotic-controlled cleat surrogate. Player kinematics were smoothed and time-scaled (slowed by a factor of 5-20) to ensure the robot could complete the complex player motion as fast as possible (Fig. 1). Kinematics were applied to a coordinate system with an origin roughly at the center of the player's talus, and the cleat was positioned with the same start height above the top surface of the turf for each test. (Fig. 1). Each of the three turf types was tested n=3 times for each of the two player motions.

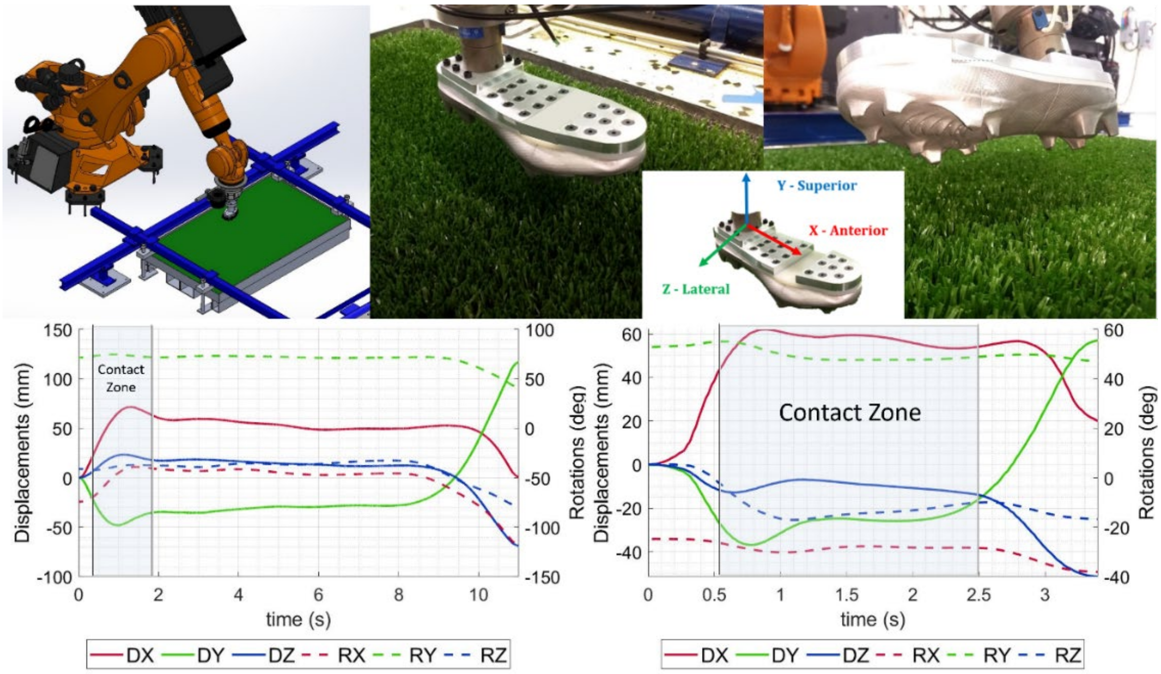

Fig. 1. Top Left: experimental test setup. Top Center, Right: metal cleat surrogate attached to robot end effector with coordinate system defined. Bottom: 6DOF cleat kinematics for the "Agility" (left) and "Sudden Stop" (right) motions. Displacements (solid lines) are expressed using the coordinate system shown, and rotations (dashed lines) are Euler angles with Z, Y, X rotation order.

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III. INITIAL FINDINGS

Robot-controlled kinematics were nearly identical across all 18 experiments, which provides a platform to compare turf responses. Compression and resultant shear force responses showed generally good repeatability, but the variation seen is likely related to localised variations in the turf construct (Fig. 2). Peak shear forces generated by the motions varied between 45% and 85% of the respective peak compression forces. The shockpad and control surfaces showed similar peak compression forces for both motions, while the low faceweight surface had lower compression and shear forces. Interestingly, the shock pad seemed to only have a minimal effect on the compression response, whereas it had a more substantial effect on the shear force response.

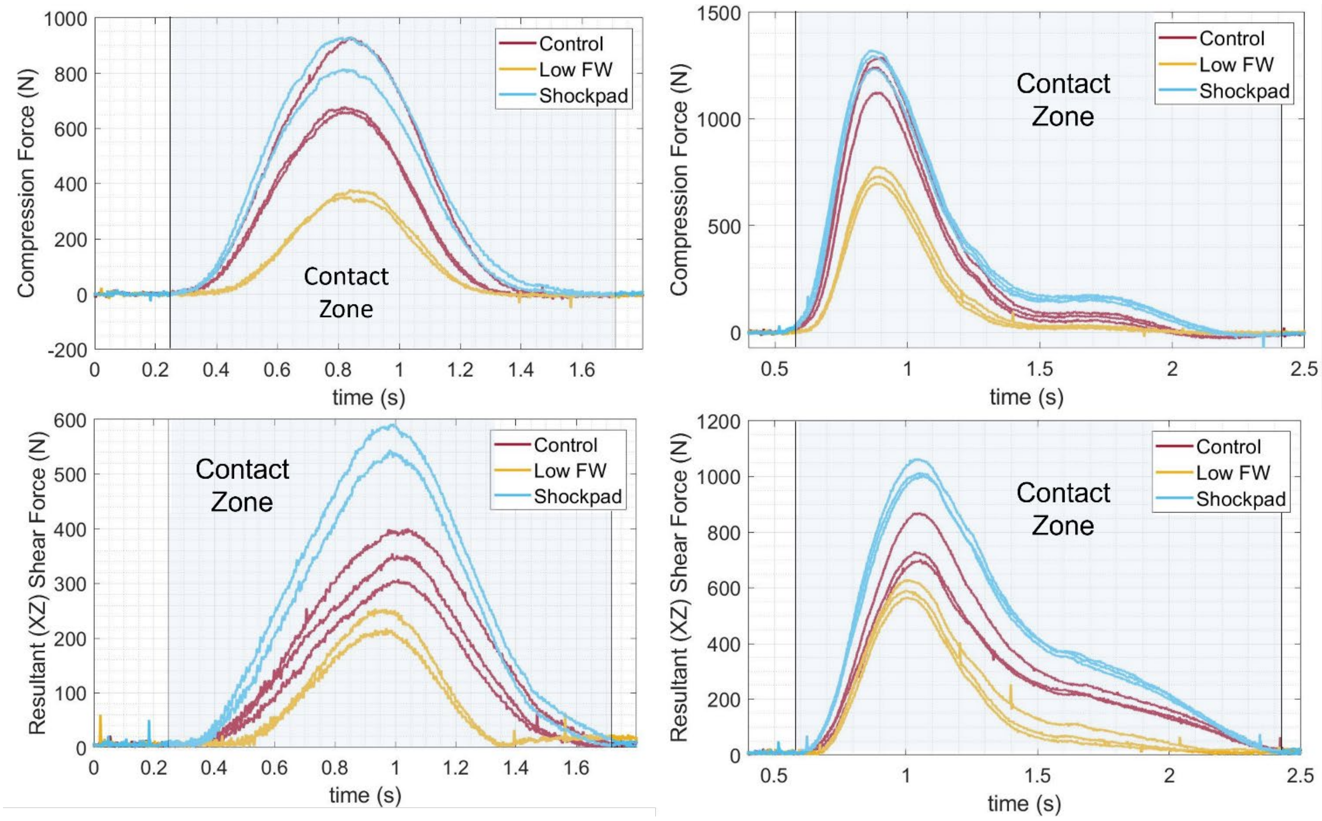

Fig. 2. Compression (top) and resultant shear (bottom) force response (measured from the end-effector load cell and transformed to a coordinate system at the turf surface) for the “Agility” (left) and “Sudden Stop” (right) kinematic inputs.

IV. DISCUSSION

While simplified motion testing has provided for the ability to compare cleat-turf interaction kinetics across a variety of surfaces, both in the laboratory and on the field [2-6], injury risk assessments of turf designs that utilise more complex motions may be required to better understand detailed mechanisms of injury and how turf-design relates to injury risk. This study introduced a test method that utilised a robotic test system to evaluate cleat-turf interaction using player-like manoeuvres of greater complexity and used it to explore differences in force response across multiple artificial turf types. Despite the size and speed of the robotic test system, robot velocity and acceleration limits required tests to be performed at rates slower than that of real players, so future work should aim to quantify the extent of loading rate sensitivity in cleat-turf interactions. Further, since the rigid cleat may overload the turf surface, the use of a deformable cleat, which may be required to match player-like compression and shear forces, and other modifications should be explored.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

[1] Mack, C. D., *et al*., *Amer J Sports Med*, 2019.

[2] Kent, R., *et al*., *Sports Biomech*, 2012.

[3] Kent, R., *et al*., *Sports Biomech*, 2015A.

[4] Kent, R., *et al*., *Sports Biomech*, 2015B.

[5] Heidt, R., *et al*., *Amer J Sports Med*, 1996.

[6] Bowers, K., *et al*., *Med Sci Sports*, 1975.

[7] Wannop, J., *et al*., *Life*, 202