Effect of Loading Condition on Traction Coefficient between Shoes and Artificial Turf Surfaces

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INTRODUCTION

Characterization of the shoe-sports surface interface has become an increasingly popular topic among researchers as seen by the proliferation of journal articles published within the past five years [1-6]. It has been hypothesized that an increase in traction increases musculoskeletal loads and concomitantly injuries [7]. Therefore, traction has been quantified on both artificial and natural surfaces, in rotational and translational motions, and across varying loading conditions.

Though research has been ongoing since the 1970's, the majority of the early testing methodologies used are not relevant [7] and most are not up to date with technologies currently available for both data acquisition and data analysis. One of the key weaknesses of many existing studies is the use of vertical compressive forces that are lower than those created by an athlete in realistic situations[8]. Vertical loads ranging from as low as 67 N and up to 1055 N have been used, often without much justification[1, 3, 4, 8-10].

The purpose of this paper is to quantify the effect of varying vertical load on the shoe-turf traction characteristics on an actual artificial turf installation.

METHODS

In determining the performance characteristics of turf surfaces, researchers have generally reported static and dynamic traction forces or coefficients based upon the model of Coulomb friction, even though many of the assumptions of Coulomb friction are violated in the case of turf-shoe interactions. The following definitions were used to determine the dynamic, static and peak traction variables.

1. Static Traction Coefficient- Ratio of the horizontal force resisting motion and the normal force at the instant before motion occurs.
2. Dynamic Traction Coefficient- Ratio of the horizontal force resisting motion and the normal force while the object is moving at a constant velocity. The dynamic traction coefficient was computed as the average of the traction coefficient over a 2 cm distance while sliding at a constant velocity.
3. Peak Traction Coefficient– The peak value of the ratio of the horizontal force resisting motion and the normal force during the entire trial.

Variations in traction characteristics due to changes in the vertical load applied were quantified using four different sport shoes on FieldTurf (FieldTurf Inc., Montreal, Quebec). Four shoe types were selected to encompass the range of different styles currently available to football players. The specific shoes tested were: Adidas Scorch 7 Fly Low, Nike Air Zoom Super Bad, Reebok 4 NFL Speed III, and Nike Air Zoom Super Speed. All shoes tested were men's size 12 and were kept complete and in original sale condition for testing. Each shoe was fitted with a rigid steel foot and ankle shaft with the remaining void in the shoe filled with an acrylic resin fortified grout. The foot position was chosen to engage all the shoe cleats as would occur under the condition of a hard stop by an athlete.

All testing was done in the Boise State University (BSU) Caven-Williams indoor practice facility with the BSU TurfBuster. Each shoe was tested in 8 different loading conditions ranging from 222 N to 1780 N in 222 N increments. All shoes were tested at a horizontal velocity of 10 cm/second over a 20 cm displacement. Data were collected at a rate of 250 Hz and post-processed using Matlab software. After determining the individual magnitudes of static, dynamic, and peak traction coefficients, the results were averaged together over three trials. A one-way ANOVA was performed to determine any differences across the shoes with a Tukey post-hoc analysis. For comparison within each shoe and across the load conditions a repeated measures ANOVA procedure was performed with a pair-wise T-Test post-hoc using a Bonferroni sliding scale adjustment for multiple comparisons.

RESULTS

The primary results for the traction characteristics are displayed in Figure 1. For all four shoes tested there was a distinct change in the slope of the traction coefficient vs. load slope between 666 N and 888 N. For all three variables, static, dynamic, and peak traction coefficients there were no significant differences between the shoe styles below 666 N except for a difference between the SuperBad and SuperSpeed shoes at 222 N in dynamic and peak traction. At 888 N and above there were multiple differences between shoe styles with the majority of the differences involving the SuperBad and SuperSpeed shoes ($p < 0.05$).

Within each shoe comparisons were made between loads of 888 N and above. Between the loads of 888 N and 1332 N there were no statistical differences in any of the traction variables or shoes. The only differences found were between highest and lowest loads, i.e. between 1779 N and 888 N.

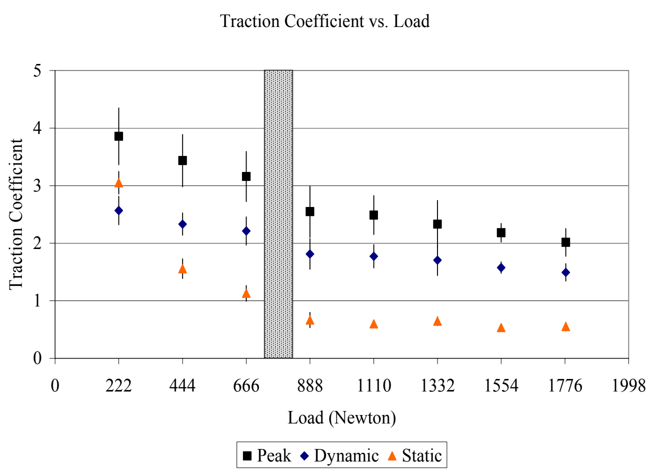

Figure 1: Average traction coefficient vs. vertical load condition for Static, Peak, and Dynamic traction variables

DISCUSSION

The statistical results of the comparisons across the four cleat styles show a distinct difference in shoe performance at loads below 666 N and above 888 N. In the lower load range the shoes perform almost identically implying a non-realistic load condition which is supported by McNitt [8]. Above 888 N however the differences in shoe design begins to emerge as seen by the many statistical differences among the shoes.

While there were performance differences seen across the shoes at all loads of 888 N and above there were only statistical differences within each shoe at a load of 1554 N and 1779 N. Implying that each shoe has no performance difference in traction characteristics in loads representing one bodyweight (up to 1332 N or 300 lbs). Above the one bodyweight range the shoes themselves begin to react differently to the turf surface. Further testing will be conducted to expand the current findings to multiple artificial and natural turf surfaces.

References

1.Livesay, G.A., et al., *Peak Torque and Rotational Stiffness Developed at the Shoe-Surface Interface.* Am J Sports Med. **34**(3): p. 415-422. 2006.

2.Naunheim, R., et al., *A Comparison of Artificial Turf.* J TRAUMA. **57**(6): p. 1311-1314. 2004.

3.Shorten, M., et al. *Shoe-Surface Traction of Conventional and In-Filled Synthetic Turf Football Surfaces*. in *XIX International Congress on Biomechanics*. 2003.

4.Cawley, P.W., et al., *Physiologic Axial Load, Frictional Resistance, and the Football Shoe-Surface Interface.* FOOT ANKLE INT. **24**(7): p. 551-556. 2003.

5.Childs, S.G., *The Pathogenesis and Biomechanics of Turf Toe.* ORTHOP NURS. **25**(4): p. 276-280. 2006.

6.Villwock, M.R., et al., *Football Playing Surface and Shoe Design Affect Rotational Traction.* Am J Sports Med: p. -. 2009.

7.Nigg, B., *The validity and relevance of tests used for the assessment of sports surfaces.* MED SCI SPORT EXER. **22**(1): p. 131-139. 1990.

8.McNitt, A.S., et al., *Development and Evaluation of a Method to Measure Traction on Turfgrass Surfaces.* J TEST EVAL: p. 99-107. 1997.

9.Villwock, M.R., et al. *Football Playing Surface Components May Affect Lower Extremity Injury Risk*. in *North American Congress on Biomechanics*. 2008. Ann Arbor, MI.

10.Villwock, M.R., et al. *Football Shoe Design May Affect Lower Extremity Injuty Risk*. in *North American Congress on Biomechanics*. 2008. Ann Arbor, MI.

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