Comparison of Rotational Traction of Athletic Footwear on Varying Playing Surfaces

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Introduction

As an athlete accelerates, stops, and changes direction, numerous forces are transmitted to the lower extremities. The interaction between an athlete's shoe and the playing surface likely influences lower extremity injury risk. Specifically, non-contact injuries to lower extremities may result from an athlete's foot becoming "entrapped" in the playing surface during pivoting movements (Torg et al., 1974; Lambson et al., 1996; Orchard et al., 2001).

Numerous researchers have attempted to measure lower extremity injury risk by measuring the rotational traction forces that occur between shoes and playing surfaces (Bonstingl et al., 1975; Andreasson et al., 1986; Heidt et al., 1996; Torg et al., 1996; McNitt et al., 2004a; Livesay et al., 2006; Villwock et al., 2009a; b). A variety of mechanical testing methods have been used in attempts to mimic athlete movement and the associated rotational traction forces.

The American Society for Testing and Materials (ASTM) provides a standard test method for traction measurement (ASTM, 2009); however, not all traction testers meet this standard. For example, the test method requires the test foot to be in a forefoot stance (no heel contact with the surface) with the weight (normal load) distributed onto the forefoot for most sports with the exception of golf. This position attempts to simulate an athlete running and performing athletic maneuvers as opposed to being in a "flat-footed" stance in which the entire foot is in contact with the playing surface and the weight is largely distributed toward the rear of the foot.

Rotational traction data collected using mechanical devices allows for comparisons among shoe types and playing surfaces; however, 'safe' and 'unsafe' traction standards have not been established, as this type of data has not been directly correlated with injury risk. Hirsh and Lewis (1965), using the lower extremities of cadavers, suggested that the maximum torque that a human ankle can support is approximately 75 Nm under a normal load of 1000 Newton. Although research has yet to establish 'safe' threshold levels, it is generally accepted that low levels of rotational traction are desired over high levels from a lower extremity injury risk standpoint (Lambson et al., 1996). However, if traction is too low, playability may be reduced as athletes may be more prone to slipping.

The focus of many studies measuring rotational traction is often to compare playing surfaces. However, studies that include multiple shoe types often report larger differences among shoes than among surfaces (Bonstingl et al., 1975; Heidt et al., 1996; Villwock et al., 2009b). Therefore, it is possible for an athlete to adjust shoe selection based on cleat pattern, which may result in decreased injury risk (Smeets et al., 2012).

The purpose of this study was to evaluate rotational traction of various cleat designs on three synthetic turf systems and Kentucky bluegrass (*Poa pratensis* L.). Each shoe-surface combination was tested using three athlete weights (normal loads).

Methods

Rotational traction was measured using Pennfoot (McNitt et al., 1997). Pennfoot consists of a frame which supports a steel leg with a cast aluminum foot pinned to the lower end (Fig. 1). All traction measurements were taken with the forefoot in contact with the surface and the heel of the foot raised off the ground with the normal load distributed onto the forefoot. For each measurement, the shoe was rotated 45 degrees.

Three trials were conducted for each athlete weight - playing surface - shoe combination. Rotational traction measurements were quantified as the peak force during rotation through 45 degrees. The experimental design was a 3x4x8 factorial arrangement. The peak rotational values from each trial were analyzed using a three-way analysis of variance (ANOVA) with the main effects of normal load (n = 3), playing surface (n = 4), and shoe (n = 8). Tukey's post hoc tests were performed when main effects and interactions were significant at the 0.05 level.

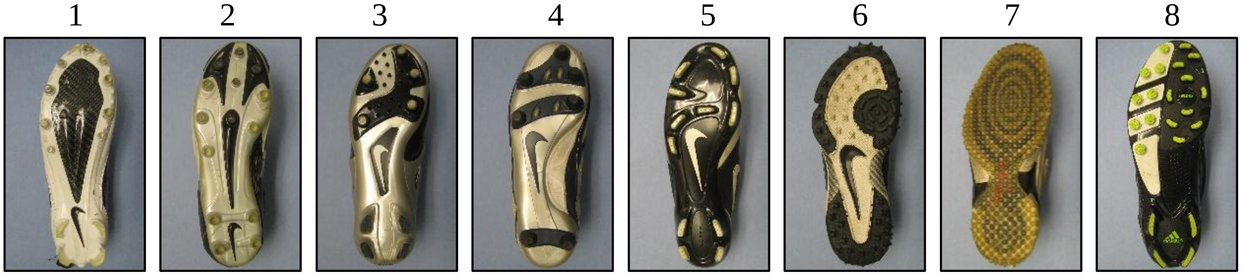
Figure 1. Pennfoot traction tester

Table 1. Athlete weights (normal loads), playing surfaces, and shoes tested. Each athlete weight - playing surface - shoe combination was tested.

Athlete Weights (Normal Loads)	Playing Surfaces	Shoes
787 N (177 lbs.)	AstroTurf GameDay Grass 3D*	Nike Zoom Vapor Carbon Fly TD[1]
1054 N (237 lbs.)	FieldTurf Revolution**	Nike Air Zoom Blade Pro TD[2]
1321 N (297 lbs.)	Sportexe Omnigrass 51***	Nike Air Zoom Apocalypse IV[3]
	Kentucky bluegrass****	Nike Air Zoom Blade D[4]
		Nike Vapor Jet TD[5]
		Nike Air Destroyer 5/8[6]
		Nike Air Zoom Turf[7]
		Adidas Scorch Thrill FieldTurf[8]

* monofilament fibers with nylon rootzone, 3/8 inch gauge, ambient styrene-butadiene rubber (SBR) infill, installed five years before testing
** monofilament fibers, 3/4 inch gauge, cryogenic SBR and sand infill, installed six months prior to testing
*** slit-film fibers, 3/8 inch gauge, ambient SBR infill, installed nine years prior to testing
**** *Poa pratensis* L., mowing height of 3.8 cm grown on a sand-based rootzone

1 2 3 4 5 6 7 8



Results

Athlete Weight: As expected, rotational traction differences due to athlete weight (normal load) show that the highest athlete weight produced the highest traction (55.9 Nm) and the lowest athlete weight resulted in the lowest traction values (47.5 Nm).

Playing Surfaces: When comparing playing surfaces, FieldTurf Revolution and Sportexe Omnigrass 51 produced the same level of traction as Kentucky bluegrass (Fig. 2). The rotational traction level on AstroTurf GameDay Grass 3D was slightly less than the other three surfaces; however, the differences were small and likely of little practical significance. The difference in rotational traction between the surfaces producing the highest and lowest traction levels was 3.8 Nm.

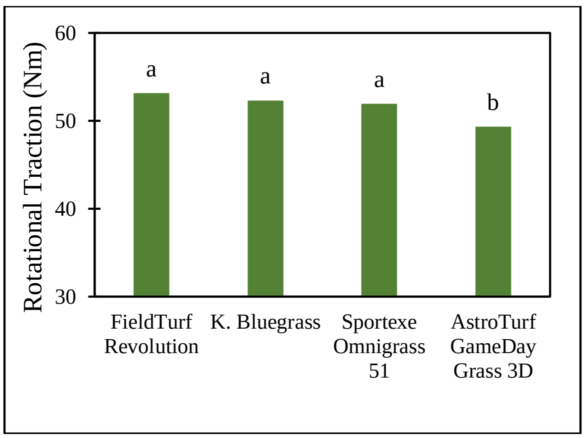


Figure 2. Rotational traction values for each playing surface. Surfaces with the same letter are not statistically different from one another

Shoes: Differences in rotational traction among shoes were larger than the differences among any other variable evaluated (Fig. 3). The difference between the shoe that produced the highest mean rotational traction value and the shoe that produced the lowest was approximately 15.0 Nm.

Playing Surface-Shoe Combinations: The six playing surface-shoe combinations that produced the highest rotational traction values were not statistically different from one another (Fig. 4). Based on the statistical analysis, the highest traction level was observed on all four surfaces in the study. For example, the traction level was the same for FieldTurf Revolution, Sportexe Omnigrass 51, AstroTurf GameDay Grass 3D, and Kentucky bluegrass-depending on shoe-type (either Nike Air Zoom Apocalypse IV or Nike Air Zoom Blade D).

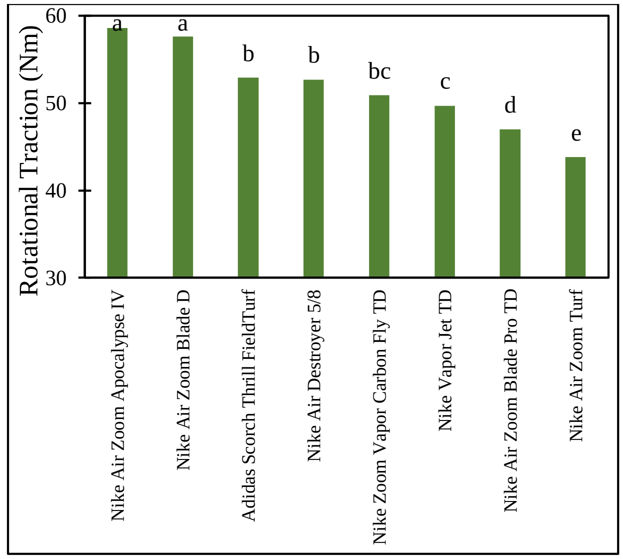


Figure 3. Rotational traction values for each shoe. Shoes with the same letter are not statistically different from one another.

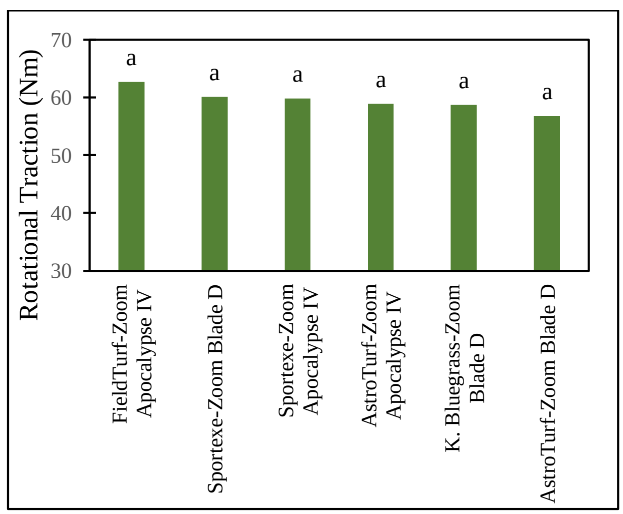


Figure 4. Rotational traction values for the six surface-shoe combinations that produced the highest rotational traction values. Combinations with the same letter are not statistically different from one another.

Discussion

Under the conditions of this study, shoe type had a much greater effect on rotational traction compared to the playing surfaces and athlete weights evaluated. The range of traction values due to shoe type was nearly four times as large as the range measured across surface types. Other researchers have also reported that rotational traction values, and theoretically injury risk, are influenced to a greater extent by shoe type than by commonly used surfaces and point to the characteristics of how shoes produce different traction levels on different surfaces. (Bonstingl et al., 1975; Heidt et al., 1996; Villwock et al., 2009b; Sorochan, 2013).

In this study, rotational traction values on synthetic turf surfaces were either the same or only slightly different from Kentucky bluegrass. Researchers from Michigan State University (Villwock et al., 2009a) reported larger differences between synthetic and natural turf than those observed in this study. One reason for this difference may be the manner in which traction was tested. Villwock et al. (2009a; b) measured traction by rotating each shoe 90 degrees in a flat-footed stance with the weight located near the rear of the foot (Fig. 5). In this current study, traction was measured by rotating the shoe in a forefoot stance with the weight distributed onto the forefoot as required by ASTM (2009) for most sports (Fig. 6).

While a testing method simulating a theoretical "worst-case" scenario such as used by the group of Michigan State University researchers (Villwock et al., 2009 a;b) is sometimes useful, if unrealistic, the results may not be applicable to scenarios experienced by athletes. Using the 75 Nm upper limit presumed by Hirsch and Lewis (1965) and referenced by Villwock et al. (2009a; b), nearly all traction values reported by Villwock et al. (2009a; b), including those on Kentucky bluegrass, exceeded this proposed safety limit. An attempt to repeat the current study using methods similar to Villwock et al. (2009a; b) including rotating the shoe 90 degrees in a flat-footed stance, resulted in severe shoe buckling and twisting, thus creating a scenario that is unlikely to occur as an athlete interacts with the surface.

Figure 5. The traction tester used by researchers at Michigan State University (Villwock et al., 2009 a;b) tests rotational traction in a flat-footed stance and the weight distributed at the rear portion of the foot.

Figure 6. Pennfoot tests rotational traction in a forefoot stance with the weight distributed onto the forefoot as required by ASTM

In addition to varying traction measurement techniques, synthetic and natural turf traction differences between this current study and the studies conducted by Villwock et al. (2009a; b) illustrate the inherent difficulties of comparing synthetic to natural turf. The characteristics of natural turf vary from field to field and are constantly changing. For example, mowing height, turf species, soil type, and soil moisture have been reported to significantly influence traction (McNitt, 1994; McNitt et al., 2004b). Rotational traction can even vary significantly within the same field (Kirby and Spells, 2006). Air temperature has also been shown to influence traction (Torg et al., 1996). Additionally, the amount of wear and subsequent loss of turf cover affects traction to a large degree (Roche et al., 2008). The characteristics of synthetic turf change over time and within a playing surface as well, further increasing the difficulty of comparing synthetic and natural turf characteristics (Wannop et al., 2012).

Although research data illustrates the importance of shoe selection on injury risk, athletes may put an emphasis on factors other than safety when selecting a shoe. For example, a 2006 National Football League Players Association (NFLPA) survey revealed that 39% of players base shoe selection on comfort, 22% on weight of the shoe, 21% on appearance, and 18% on safety rating (NFLPlayers.com, 2008). This survey demonstrates the importance of athletic trainers, parents, and coaches in selecting appropriate footwear for athletes in order to reduce injury risk as athletes may value other factors above safety.

Mechanical studies provide valuable information for comparing playing surface and shoe-type combinations. However, because traction data acquired from mechanical devices has not been directly correlated to injury risk, and because variations exist among traction testing devices and surface conditions at the time of testing, caution should be used when making conclusions about the relative safety of varying surfaces, especially when these differences are small.

The most appropriate way to assess injury risk is likely through epidemiological studies. The number of large scale epidemiological studies comparing injury rate among varying playing surfaces is limited as these studies require a large sample size. As more injury data is collected and analyzed, additional epidemiological studies will be published, allowing for a deeper understanding of injury risk factors and the appropriateness of varying mechanical methods of measuring traction.

Conclusion

The differences in rotational traction among shoe types in this study was nearly four times larger than differences measured among playing surfaces. This data suggests that shoe selection has a greater influence on rotational traction and potentially lower extremity injury risk than the surfaces evaluated in this study.

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