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Rotational traction testing: How can we improve the current test device?

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Abstract

Rotational resistance is an important sports surface property in optimising both performance and safety for participants. Despite various attempts to create valid devices to measure the rotational traction, the Studded Boot Apparatus (SBA) originally developed in 1975 is still used in the synthetic turf standards of many governing bodies of sport. In addition to validity limitations, poor operator reliability of the SBA has been reported and it was postulated that the manual nature of the device contributed significantly to this result. Therefore, the aim of this paper is to present data on the automation of the SBA and to discuss the reliability and validity issues of the device. An automated version of the SBA was developed called the UB Turf Tester (UBTT) and data was collected by ten inexperienced operators using the original SBA and the UBTT. Testing was undertaken on a synthetic turf and each operator completed ten trials with each device. Despite a slightly greater peak traction value for the UBTT, there was no significant difference between the peak traction for the two devices, $F_{1,2} = 0.341$, $p = 0.57$. Greater reliability was found between operators for the UB Turf Tester. Given that the SBA is still commonly used to comply with standards, achieving the highest level of intra- and inter-operator reliability is both desirable and invaluable. However, the research on the validity of the device also needs to continue. Interestingly, limitations of the device were identified when it was first developed but very few adaptations have been implemented since then. Undoubtedly, the interaction between the human and the surface is a complex phenomenon but the weight force, the level of penetration, the pattern, shape and position of the cleats and the possibility of measuring rotational stiffness rather than peak traction all require further discussion and investigation.

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1. Main text

Rotational traction, denoting the resistance to the relative motion between a shoe outsole and a surface (Villwock et al. 2012) in a pivoting movement, has been identified as one of the most significant characteristics in optimising both performance and safety for participants of many sports (Milburn and Barry, 1998). Factors such as cleat design, cleat length and cleat position have all been shown to affect traction levels (Lambson et al., 1996) and it is also evident that the limits of the musculoskeletal system and elastic capabilities of anatomical structures are compromised when traction is too high (Cawley et al., 2003). Despite advancements in understanding the mechanistic link between injury and rotational traction, to date there are no epidemiological studies that have directly measured traction and related it to prospective injury data. This lack of empirical evidence may be linked to the issues of portability, validity and reliability associated with traction devices. In this context, validity refers to the ability of the device to measure traction as experienced by sporting participants and reliability denotes the accurate repeatability of the traction measure both within and between individual testers.

Since the development of the Studded Boot Apparatus (SBA) in 1975 (Canaway and Bell, 1986), quantifying rotational traction has been possible and over the past three decades many other traction testing devices have emerged. These include, the PENNFOOT (McNitt et al., 1997), The TrakTester (Grund et al., 2007), the Boise State TurfBuster (Cooper et al., 2009) and the Automated Turf Tester (Roche et al., 2008). Although most of these devices have endeavoured to improve the validity of traction testing, the SBA is still used to determine the rotational resistance in the synthetic turf standards of many governing bodies of sport (albeit some slight modifications) (International Rugby Board, 2003; Federation Internationale de Football Association (FIFA), 2009).

The validity issues associated with the SBA are complex and still require future investigation and improvement but the manual nature of its operation has led to issues of reliability among multiple users. It has been contended that the variability between different operators could occur from differences in the amount of force applied to the apparatus to produce rotation, the speed at which the force is applied or possible differences in technique between operators (Twomey et al., 2011). To address these manual-based limitations, Zeller (2008) designed and manufactured the Automated Traction Tester. Since then, the device has been further modified into the University of Ballarat Turf Tester (UBTT), with the addition of programmable maximum rotation angles, improved calibration hardware, and a global positioning system. It is proposed that the development of an automated device would improve the reliability of the data. Therefore, the aim of this paper is firstly to present data on the automation of the SBA and secondly to more broadly discuss reliability and validity issues of traction testing.

2. Methods

2.1. Equipment

Two traction devices were used; the original Studded Boot Apparatus (SBA) (Fig 1a) and the UB Turf Tester (UBTT) (Fig 1b). The SBA used was compliant with the specifications outlined in BS EN 15301-1 except for the stabilising frame. The lack of a stabilising frame was addressed by using a digital height measurement tool and the same two individuals lifting and dropping the device for all tests. Where the drop was not observed to be absolutely vertical it was discarded and repeated. The test methods were in accordance with BS EN 15301-1 and the peak rotational traction in Newton metres (Nm) was recorded as the amount of rotational traction required to rotate the cleats in the surface using a digital torque wrench.

The UBTT consisted of the same physical parameters as the SBA (46 kg normal loading, 60 mm drop height and the same cleated base plate). The device used an electric motor to automate the drop and rotation process and the cleated base plate was rotated by a sprocket and chain drive. Rotation was performed at a rate of 31 degrees per second. Rotational traction was quantified by an electronic load cell measuring chain tension from the resistance between the surface and the base plate and converted to an equivalent torque value. These values were recorded at 0.5 degree increments of rotation, however, for the purpose of this study only the peak rotational traction was used in the analyses.
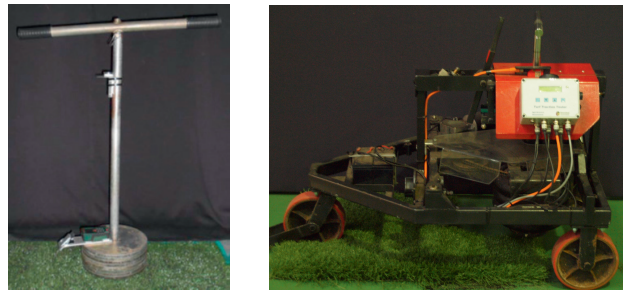
Fig. 1. (a) The SBA; (b) The UBTT.

2.2. Test Procedure

Ten inexperienced operators were recruited and a total of ten test sessions were conducted with a single session dedicated to each operator. At each session, the operator was provided with clear instructions (including hand and body positioning, speed of rotation and recording) and a demonstration and then performed five familiarisation trials with each piece of equipment. Following this, each operator completed ten trials with each of the two traction devices. The order of the trials was randomised for each operator to reduce potential bias in the results. All testing was undertaken on a new, unconditioned synthetic turf product and prior to each test, the synthetic turf was prepared with the quantities of sand and rubber infill according to the manufacturers specifications. The synthetic turf consisted of a 50mm polypropylene fibre with a ¾ inch tuft gauge and an infill comprising 6kg/m^2 siliceous sand and 24kg/m^2 of recycled crumbed styrene-butadiene rubber (SBR).To ensure consistency, the infill depth was measured before each trial and each trial was completed on a new area of the turf. Immediately before each testing session air temperature, relative humidity and surface temperature were measured to ensure consistent environmental conditions for each testing session.

2.3. Data Analysis

Descriptive statistics were calculated to establish measures of central tendency. A repeated measures analysis of variance (ANOVA) was undertaken to determine if any differences existed between the two devices and within the ten trials for each device. To adjust for multiple comparisons, a Least Significant Difference (LSD) correction was applied and an alpha level of 0.05 was considered significant.

Due to multiple layering in the data inter-operator reliability was determined using a one-way analysis of variance (ANOVA). The LSD was determined and used to compare the means. The mean peak rotational traction values that did not differ by more than the LSD value are assigned the same superscript letter. Therefore, mean peak rotational traction values with different superscript letters are significantly different from each other (Sokal and Rohlf, 1995).

3. Results

The overall mean peak traction for the SBA was 52.1 Nm (95% CI: 48.6 – 55.6) and for the UBTT was 53.1 Nm (95% CI: 51.2 – 55.0). Despite the slightly greater peak traction value for the UBTT, overall there was no significant difference between the peak traction for the two devices $F_{1,2} = 0.341$, p = 0.57 or between the trials $F_{1,9} = 1.27$ p = 0.27. Table 1 presents the differences between the ten operators for the two devices. For the SBA

only operator 2 and 3 were significantly different from all other operators and for the UBTT only operator 5 was significantly different from all others.

Table 1: Differences in mean rotational torque (Nm) between operators for the SBA and UBTT, values with the same superscript letter are not significantly different.

Operator	1	2	3	4	5	6	7	8	9	10	LSD
SBA Mean Rotational Traction (Nm)	46.0[a]	54.0[c]	61.0[e]	50.2[b]	56.1[d]	45.8[a]	56.5[d]	49.6[b]	50.1[b]	50.7[b]	1.4
UBTT Mean Rotational Traction(Nm)	53.8[c,d]	55.0[d]	52.5[b]	51.8[b]	57.2[e]	54.8[c,d]	55.1[d]	49.8[a]	53.1[b,c]	48.5[a]	1.8

Figure 2 presents a visual display of the inter- and intra-operator variability, with the longer boxes indicating greater variability within the operators' trials and the width between the box plots represents the variability between operators. While there is little overall difference between the length of the box plots for the two devices, the width between them (i.e., the inter operator variability) is less for the UBTT indicating greater reliability in peak traction results across the ten operators.
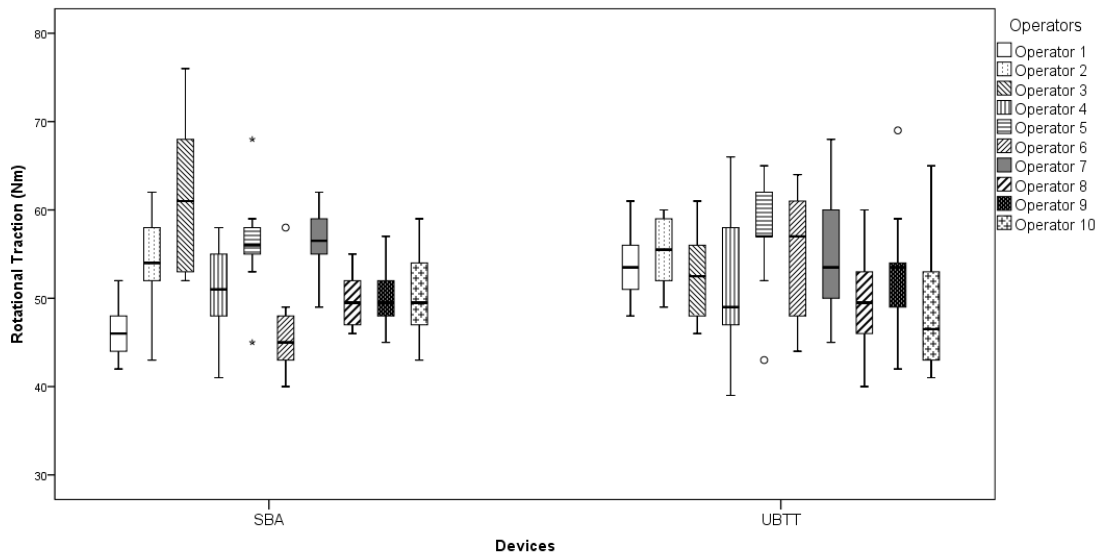

Fig 2: Graphical representation of the variability within and between operators for the SBA and UBTT. The outliers are denoted by circles and the far outliers by an asterisk.

4. Discussion

The UBTT was designed to improve the reliability of the SBA and not alter the actual measurement, therefore, the similar peak traction results between the two devices was expected. The results of this study confirmed that the automation of the SBA improves the reliability in measurement between operators. This result is important as considerable inter-operator variability can significantly affect the accuracy of data where multiple operators are required to collect data across different ground locations. As decisions regarding safety and /or optimum performance are based on such data, accuracy is paramount.

Previous research has shown that the overall reliability between operators for the SBA is only moderate and worse between experienced compared to inexperienced operators (Twomey et al., 2011). The automation of the UBTT removes the distinction in experience and any inconsistencies are most likely due to variability in the surface, particularly on natural turf surfaces. Given the inexperienced nature of the operators in this study, the relatively good level of reliability between the ten trials for each operator for the SBA was a pleasing result and consistent with previous findings where inexperienced operators had greater intra-rater reliability than more experienced operators of the SBA (Twomey et al., 2011). The exceptions to this were operators three and four, if the outlier values for operator four are considered. Although not formally recorded, it was observed that changes in the speed of rotation could have contributed to the lack of reliability for these operators. The advantage of the UBTT is the consistent speed of rotation compared to the recommended but unmeasured and uncontrolled speed of the SBA (British Standards Institution, 2007). Although not relevant to the reliability results presented, it is notable that the rotational velocity differed between the devices, with a velocity of 72° per second for the SBA and 31° per second for the UBTT. The UBTT rotates from 0-6° in 194 milliseconds which corresponds well with the ACL injury timeframe of 50 – 250 milliseconds after ground contact. The addition of a device to display and record the speed of rotation of the SBA is recommended to further improve reliability.

It is evident from this paper that the automation of the SBA (i.e. the modifications evident in the UBTT) improves the reliability of the measurement but issues of validity of the SBA still remain. Interestingly, limitations of the device were identified when it was first developed (Canaway and Bell, 1986) but very few adaptations of the original device have been reported in the literature. Undoubtedly, the interaction between the human and the surface is a complex phenomenon but the weight force or load used, the level of cleat penetration, the pattern, shape and position of the cleats and the possibility of measuring rotational stiffness rather than peak traction all require further discussion and investigation.

In terms of injury risk, the anterior cruciate ligament (ACL) of the knee is the most common injury associated with rotational traction (Lambson et al., 1996). ACL injury occurs very soon after footstrike, most likely in the range of 50 – 250 milliseconds after ground contact (Grund et al., 2010). Given this knowledge, the notion of recording rotational stiffness (the rate of increase of torsion) in addition to peak traction value requires consideration. Currently, the SBA only provides a measure of peak traction but in terms of ACL injury risk, it is possible that peak traction is attained after the first 250 milliseconds. Although not presented in this paper, the UBTT produces traction values at every 0.5 degrees and therefore, has the ability to calculate rotational stiffness. Further testing is needed to determine when peak traction is achieved on different surfaces and whether rotational stiffness information would better inform future injury prevention strategies.

In addition to reducing injury risk, optimizing player performance is also important. Cleat placement and number of cleats have been shown to significantly influence the rotational resistance experienced by players (Lambson et al., 1996) and the circular pattern on the baseplate of the SBA has been identified as not accurately reflecting the traction produced by regular football boot sole designs (Twomey et al., 2013). While it is acknowledged that many different cleat patterns exist, there is sufficient evidence at this stage to warrant changes to the sole plate of the SBA to improve the validity of the device. Finally, many devices have sought to determine the most appropriate or variable weight/load for accurately measuring traction. Differences in traction were found above and below a normal load of 666N(68 kg) and the authors suggested that loads similar to players should be used in future devices (Kuhlman et al., 2010). Undoubtedly, the interaction between the human and the surface is complex but confirmation whether there is a linear or non-linear relationship between load and traction still needs to be properly established.

Despite the fact that the link between traction and injury has been suggested and seems feasible, there are no epidemiological studies that have directly measured traction and then related it to prospective injury data. The difficulties experienced in creating a portable, and valid measuring device for traction may be a reason for the lack of evidence in this area. Therefore, in a continued effort to address many of the limitations of the SBA portability needs to be strongly considered. Although potentially more valid, the widespread adoption of many of the devices developed since the original SBA have been limited by their lack of portability.

5. Conclusions

As the SBA is the predominant device used to assess the level of traction acceptable in terms of performance and safety of playing surfaces, there is a need to continue to understand the human interaction and work towards a more valid portable device.

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