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# 13 Boot–turf interaction during a 180° cutting movement on artificial turf when wet and dry

*Dirk De Clercq, Gijs Debuyck, Alison Sheets-Singer, Joeri Gerlo, Stijn Rambour, Veerle Segers and Ine Van Caekenberghe*

## 1. Introduction

The ability to perform fast cutting maneuvers is essential for success in soccer. These cutting maneuvers are characterized by substantial changes in speed and/or direction, thus requiring large horizontal forces and impulses to be exerted by the feet on the surface. Sufficient traction created by the interaction of the field and shoe is necessary to ensure that a player can successfully perform the movement with minimal slipping (Lake, 2000). Traction, along with stability and comfort, has also been among the most consistently requested attributes for soccer shoes by male players (Hennig & Sterzing, 2010).

Traction generated between the shoe and surface can be quantified both mechanically and biomechanically (Sterzing *et al.*, 2008, Potthast *et al.*, 2010, Luo & Stefanyshyn, 2011, McGhie & Ettema, 2013). The mechanically available traction is typically quantified using a machine to measure the resistance of the shoe (or portion of the shoe) to movement relative to the testing surface. Utilized traction is typically measured during biomechanical tests in which athletes perform maximal effort/speed movements which require the generation of large horizontal forces for successful completion. Numerous movements including accelerations, decelerations, cutting, and turning movements, with varying degrees of game-realism have been performed to biomechanically test utilized traction. Some experiments perform the movements in isolation, and others link them together to create "Functional Traction Courses" (Hennig & Sterzing, 2010).

Increasing the mechanically available traction between the shoe and surface has been shown to improve change of direction performances (Müller *et al.*, 2010) until a threshold minimum mechanical traction value has been exceeded. Once the minimum traction has been achieved, additional traction was not shown to continue to improve performance, and the biomechanically utilized traction was lower than the mechanically available traction that the footwear and surface could provide (Luo & Stefanyshyn, 2011).

Many factors can influence the mechanical traction of the soccer shoe–turf surface interface including the playing surface, footwear outsole attributes, and the environment, and individual player biomechanics can influence the utilized traction (Severn *et al.*, 2008). Artificial turf (AT) surfaces are widely used in soccer (e.g. through the FIFA Quality Concept for Football Turf (2009)). There are 25 AT manufacturers that provide turf to FIFA, and 2,508 turf installations around the world that achieved at least a quality rating (comparable to FIFA * rating) when this chapter was written (FIFA Quality Programme 2016). These third-generation AT surfaces are differentiated from previous generations by the inclusion of a loose infill between the synthetic fibers. An example infill is a sand base layer with a rubber particle layer on top, although other AT surfaces may vary the materials, ratio of materials, and/or layering of infill materials. These third-generation turf surfaces also utilize different fiber materials, shapes, lengths, and densities, all of which may affect the mechanical traction between the soccer shoe and turf surface.

Although AT surface moisture level and outsole stud configuration of the soccer shoe have been shown to affect mechanical traction, few studies have performed biomechanical experiments to investigate the effects on performance. Soccer players commonly report experiencing less grip in wet AT conditions, such as those occurring after a rain or after an AT field is watered, and previously reported mechanical traction values for wet and dry surfaces support this feedback (Heidt *et al.*, 1996). This could be due to a shoe–turf boundary lubrication effect created by the wet rubber infill particles. Players also commonly choose shoes with an outsole containing many, relatively short studs for playing on dry AT. But on wet AT, players may choose longer and/or fewer studded outsole designs in order to have greater penetration of the infill and interaction with the fibers. However, in a pilot study with five soccer players, Sterzing and colleagues (2009) found that on wet AT a soft ground stud configuration (i.e. with 6 long studs and suited for playing on soft natural grass) did not provide superior traction related functionality compared to hard and firm ground stud configurations with more, moderate length studs. Therefore, it is relevant to investigate moisture induced differences in traction related performance by performing a study with subjects wearing shoes with outsole configurations that players commonly choose for playing on AT. It has also been shown that experienced soccer players can perceive shoe–surface induced differences in traction (e.g. Sterzing, 2009), but we are unaware of experiments evaluating whether players can perceive traction differences between dry and wet artificial turf conditions.

Using experienced soccer players, the aim of this study was to quantify the influence of moisture (dry and wet AT) and three commonly chosen shoe stud configurations (Turf Field (TF), Artificial Grass (AG) and Firm Ground (FG)) on maximal effort cutting performance, utilized traction during the cut, and players' perception.

## 2. Methods

Twelve experienced soccer players with active player status in a Belgian first division club (age 16 ± 1 years; stature 176.3 ± 8.8 cm; body mass 67.3 ± 8.1 kg; shoe size US 9.5 ± 1.5) participated in this study, which was approved by the

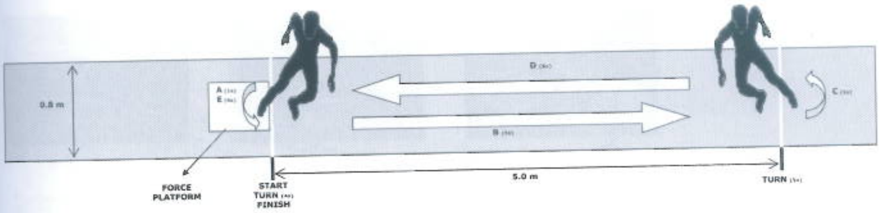
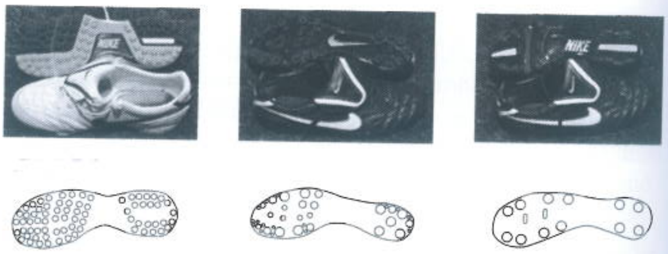



*Figure 13.1* Experimental set-up of the shuttle run test (SHR). Players start (A) from a standing position behind the start line, (B) run 5m to the turning line, (C) place one foot behind this line and turn 180°, (D) run back to the starting line (E) place one foot behind this line and 180° and repeat (B) to (E) four more times. During this last repetition at (E) the players continue to run over the line. Athletes are asked to execute the drill as fast as possible on different two turf wetness conditions, and in three different shoes conditions (6 combinations)

ethical committee of Ghent University Hospital. In this experiment, players performed two maximal effort 10 × 5 m shuttle runs in each condition (SHR) (see Figure 13.1) to measure footwear/turf traction related changes in cutting performance. This test was chosen because successfully completing the nine high speed, 180° turns requires large shear forces to be created between the cleats and turf (Shorten *et al.*, 2003), and because it is a reliable measure for fast acceleration, deceleration and turning agility since it is frequently used in soccer (Council of Europe, 1988).

During this experiment, dependent variables measured were player performance, utilized traction, and player perception. Performance was measured using time to complete the SHR drill, traction was quantified from the forces generated during the 180° turns on the force platform, and perception was measured using a visual analog scale questionnaire. Two different turf wetness conditions (dry or wet AT) x 3 different outsole designs (shoe outsole, Figure 13.2) were tested using a block randomized design. All 6 combinations of turf wetness and footwear conditions were performed in the same day, and the beginning surface wetness condition was randomized and balanced between subjects (i.e. half of the subjects started with the dry condition and vice versa).

Tests were performed on wet (1.5 L $m^{-2}$) and DRY Desso Challenge Pro[2] artificial grass (6 cm fibre length) with SBR-infill (4 cm). The correct amount of water for the given surface area was sprayed on the entire length of the artificial turf at the beginning of the experiment and qualitatively maintained throughout the experiment i.e. entirely dry or entirely wet. Mechanical tests for impact, rotational resistance and linear friction fulfilled the FIFA recommended 2 star requirements (FIFA, 2009), but did not differentiate between dry and wet AT conditions. It is possible that the FIFA mechanical tests did not differentiate the wetness conditions because the testing procedure prescribes more water immersion for the wet testing condition.



| | Turf Field (TF) | Artificial Grass (AG) | Firm Ground (FG) |
|---|---|---|---|
| **Number of studs** | 74 | 24 + 18† | 14 |
| **Length of studs** | 0.3 – 0.5 cm | 0.3 – 1.2 cm | 1.1 – 1.6 cm |
| **Diameter of studs** | 0.6 – 0.8 cm | 0.3 – 1.2 cm | 0.8 – 1.1 cm |

*Figure 13.2* Three Nike Tiempo Mystic III models with different artificial turf outsole stud characteristics were tested.† In the AG model, these 18 studs are very small compared to the other 24

Players wore the Nike Tiempo Mystic III model with three different types of shoe stud characteristics ranked from small to average stud length: Turf Field (TF), Artificial Ground (AG) and Firm Ground (FG) sole. It is reasonable to assume that players/consumers might choose to wear any of these three outsole designs on AT, therefore, the supposition was made that they present a realistic range of available traction.

Performance was quantified by measuring the time to complete each of the maximal effort 10 × 5 m shuttle runs. The beginning of the shuttle run time was defined as the moment when the subject last contacted the force platform (Figure 13.1, portion A), and the end of the shuttle run time was defined as the first contact on the force platform at the finish (Figure 13.1, portion E). In the few cases when no contact was made on the force platform at the finish, the time when the center of mass of the hip segment crossed the finish line was measured, using motion capture data (Qualisys Pro Reflex, 200 Hz). This alternate measurement procedure yielded a minimal accuracy of 0.01 s. If subjects slipped and/or lost balance during the test, it was noted and the results were not included in the analysis of the performance and the subjects were asked to complete the trial again. Players performed two shuttle runs in each outsole design–moisture combination. The intra-class correlation coefficient (ICC) for these two trials was higher than 0.87, indicating a high intra-subject repeatability. As such, the average performance for these two trials was used in the comparisons.

Ground reaction forces generated by the outside foot (Shorten *et al*., 2003) during the 180° cuts were used to calculate the utilized traction and were measured at 1000 Hz with a 1.0 × 0.4 m AMTI (Watertown, MA, USA) force plate.

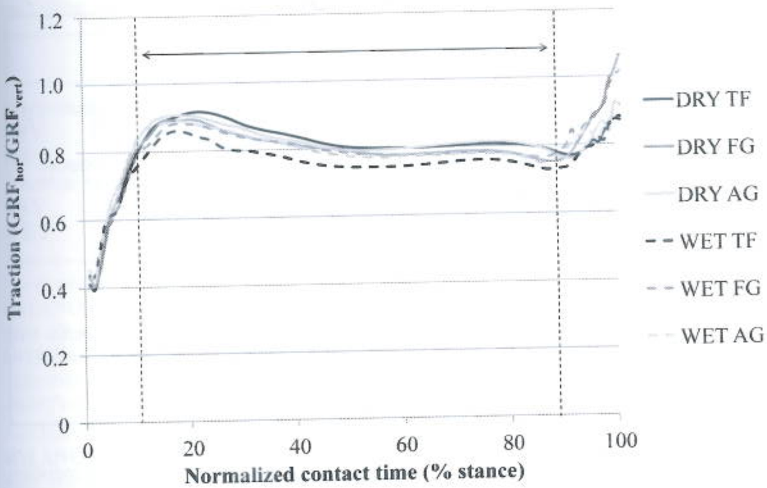



*Figure 13.3* The average utilized traction produced throughout the 180° cut by the outward pivot foot, was calculated as ratio of the horizontal to the vertical component of the ground reaction force. Six conditions were measured: three shoe types Turf Field (TF), Artificial Grass (AG), Firm Ground (FG), each combined with two wetness conditions wet and dry AT. The grey area indicates the interval during which mean traction was calculated

The AT was firmly fastened on top of the plate and isolated from the surrounding AT surface. After low pass digital filtering at 50 Hz, the utilized traction was quantified using the time dependent traction ratio (Shorten *et al.*, 2003), dividing the horizontal by the vertical component of the ground reaction force as follows.

$$\text{Required traction } \tau(t) = \frac{\text{GRF total}(t)}{\text{GRF vert}(t)}$$

The traction ratio shows large variability at initial contact and at the end of the foot contact phase due to the small vertical ground reaction forces. Therefore, the average traction value was calculated starting at 10% of foot contact time and ending when the vertical component of the ground reaction force dropped under half body weight (Figure 13.3). Two SHRs were executed per condition, and five foot contacts out of the potential eight collected during the two trials were studied to test the repeatability of movement with intra-class correlation coefficients (ICC). ICC's of the average traction ratio for these five foot contacts was 0.935, meaning there was a high intra-subject repeatability between trials, which allowed averaging per subject per condition.

A specific questionnaire (visual analog scale, Figure 13.4) was used to assess the subjective perception of the players. The subjective parameters investigated were foot/ankle stability, shoe–surface grip, overall shoe comfort, rotational load and the general appreciation of the shoe. Players scored each parameter by

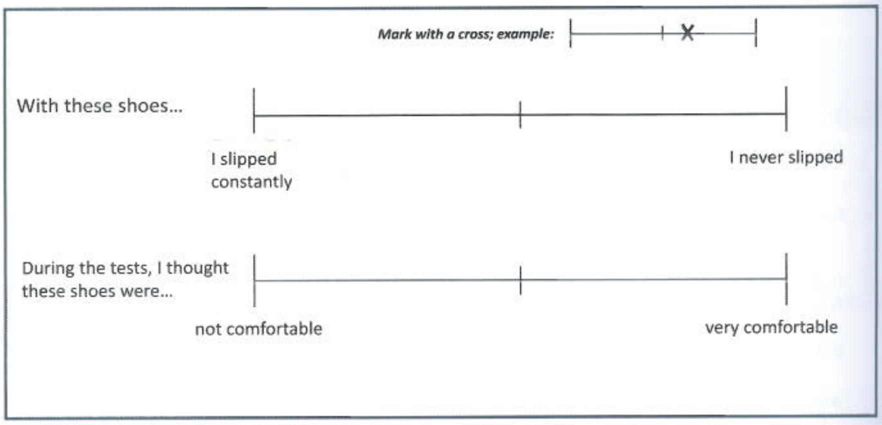



*Figure 13.4* An example of a visual-analog scale that players used to provide perception feedback on different attributes of each shoe–turf combination

placing a cross on a 10 cm long line, on which the left extremity represented the worst score, and the right extremity the best score. The middle of the line was indicated by a short vertical hatch mark and represented neutrality.

Effects of the shoe and surface were statistically tested within subjects using a 3 × 2 Repeated Measures ANOVA with Bonferroni correction on the potential main shoe effect. Significance was obtained when $p < 0.05$ (SPSS 15, Chicago IL). Whenever a significant shoe × surface interaction effect was present, two additional statistical tests were conducted. Post-hoc pairwise comparisons were conducted for each shoe in the dry and wet condition (paired samples t-test), and an ANOVA with Bonferroni correction was conducted comparing the three shoes within the dry and wet conditions separately.

## 3. Results

### *3.1 Performance*

There was a significant shoe x surface interaction effect on the time to complete the SHR ($p < 0.005$, Table 13.1), and a significant main effect of surface ($p < 0.005$). Pairwise comparisons indicated that only for the TF shoe, SHR time is significantly larger (0.73 s) for the wet compared to the dry condition ($p < 0.05$). Only in the wet condition, SHR time is significantly longer for the TF compared to the other two shoes (ANOVA $p < 0.05$ and pairwise $p < 0.05$). The longer SHR time with the TF shoe in the wet condition concurs with the trend for an interaction effect ($p = 0.1$) in the foot contact time; post-hoc pairwise comparisons indicated a trend ($p = 0.08$) for a longer contact time when wearing the TF shoe in the WET ($0.40 \pm 0.04$ s) compared to the dry condition ($0.36 \pm 0.06$ s).

*Table 13.1* Performance of the 10 × 5 m shuttle run and traction ratio (mean ± SD) in each shoe – surface wetness condition tested [N = 11].

| | *Turf Field (TF)* | *Artificial Grass (AG)* | *Firm Ground (FG)* |
|---|---|---|---|
| ***Performance time (s)*** | | | |
| **DRY** | $14.66 \pm 0.46^{*}$ | $14.86 \pm 0.57$ | $14.85 \pm 0.58$ |
| **WET** | $15.39 \pm 0.59^{*, FG, AG}$ | $14.99 \pm 0.46^{TF}$ | $14.98 \pm 0.53^{TF}$ |
| ***Traction ratio*** | | | |
| **DRY** | $0.81 \pm 0.05^{*}$ | $0.81 \pm 0.05^{t}$ | $0.79 \pm 0.05$ |
| **WET** | $0.76 \pm 0.05^{*, FG, AG}$ | $0.79 \pm 0.04^{t, TF}$ | $0.79 \pm 0.04^{TF}$ |

*For Performance time*
**RM ANOVA:**
main effect shoe ($p > 0.1$), main effect surface ($p < 0.005$), shoe-surface interaction effect ($p < 0.005$).
**INTERACTION EFFECT:**
- pairwise comparison DRY-WET for each shoe: * = $p < 0.05$.
- ANOVA comparing shoes: DRY condition ($p > 0.1$) - WET condition ( $p < 0.05$; $^{TF, AG, FG} = p < 0.05$).

*For Traction ratio*
**RM ANOVA:**
main effect shoe ($p > 0.1$), main effect surface ($p < 0.05$), shoe-surface interaction effect ($p = 0.06$).
**INTERACTION EFFECT:**
- pairwise comparison DRY-WET for each shoe: * = $p < 0.05$, t = $p < 0.1$.
- ANOVA comparing shoes: DRY condition ($p > 0.1$) - WET condition ($p < 0.05$; $^{TF, AG, FG} = p < 0.05$).

### *3.2 Utilized traction*

A trend towards a shoe x surface interaction effect was observed ($p = 0.06$, Table 13.1), as well as a significant main effect of the surface ($p < 0.05$). Pairwise comparisons indicated that only for the TF shoe, utilized traction is significantly lower for the wet compared to the dry condition ($p < 0.05$). only in the wet condition, utilized traction is significantly lower for the TF compared to the other two shoes (ANOVA $p < 0.05$ and pairwise $p < 0.05$). Additionally, during the entire experiment 7 of the 8 slips of the outward pivot foot that resulted in a complete loss of body balance occurred in the wet x TF shoe condition.

### *3.3 Player perception*

A significant shoe x surface interaction effect was measured for the player's perception of shoe–surface grip ($p < 0.005$), foot-ankle stability ($p < 0.05$) and general shoe appreciation ($p < 0.05$) (Figure 13.5 A, B, and C, respectively). Pairwise comparisons indicated that only for the TF shoe grip, stability and appreciation are lower for the wet compared to the dry condition ($p < 0.05$). ANOVA including pairwise comparisons indicated that only in the wet condition, a significantly worse and a trend towards a significantly worse perception was observed compared to the FG and the AG shoe (ANOVA $p < 0.05$, pairwise respectively $p < 0.05$ and $p = 0.08 \pm 0.01$).

A significant main shoe effect ($p < 0.05$), combined with the pairwise comparison between all shoes, indicated that the overall shoe comfort was lower in the TF shoe compared to the other two types ($p < 0.05$).

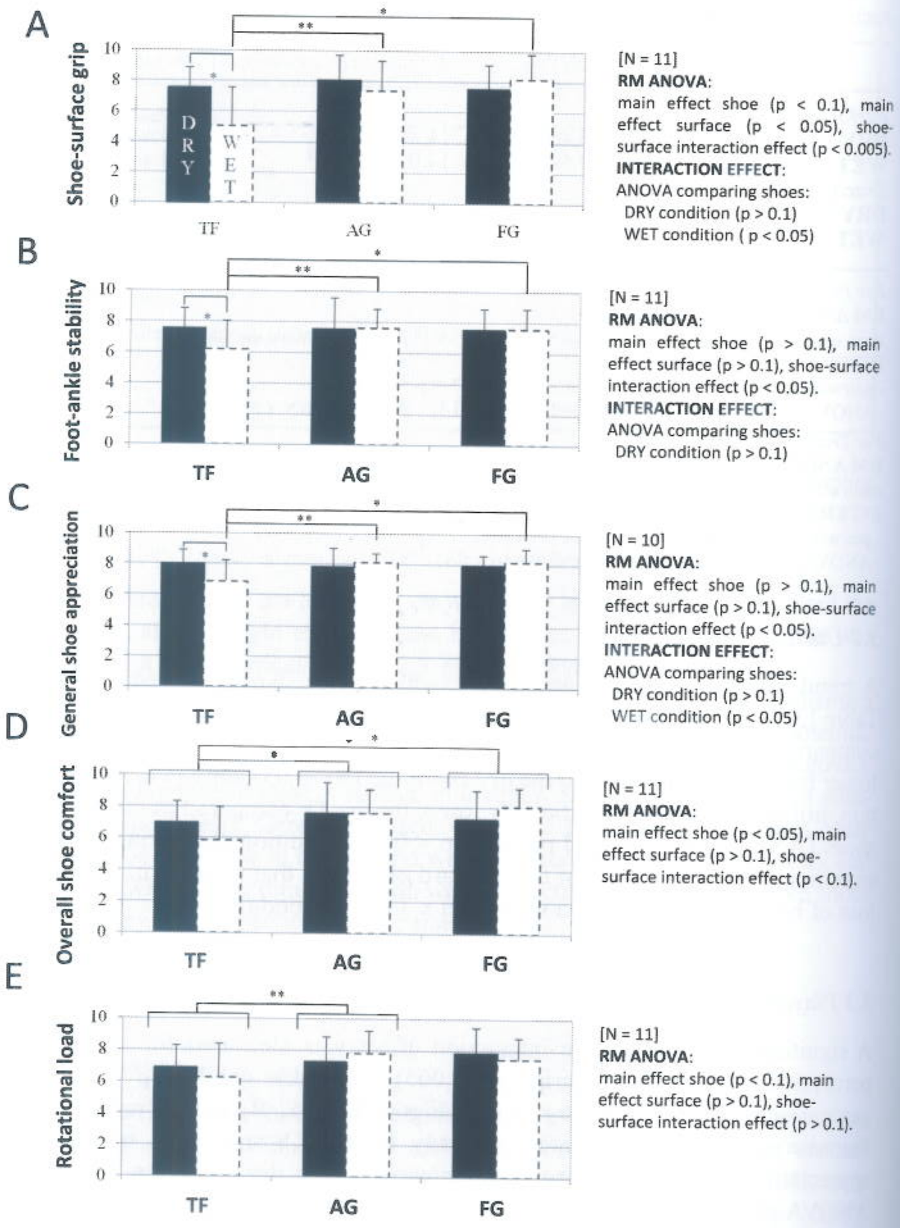



*Figure 13.5* Players' perception of the three soccer shoe designs in the wet and dry condition. Error bars indicate 1 standard deviation. * $p < 0.05$, ** $p < 0.1$ (pairwise comparisons)

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## 4. Discussion

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A trend towards a significant main shoe effect (p = 0.09), combined with a pairwise comparison between all shoes, indicated that the perception of rotational load tended to be lower for the TF shoe compared to the AG shoe (p = 0.09).

## 4. Discussion

Experienced soccer players executed 180° turns, during a 10 × 5 m maximal effort shuttle run, to test for differences in performance and biomechanics with changes in traction due to interaction between the soccer shoe outsole and artificial turf (AT) surface wetness. This was done for three realistic shoe outsole conditions, and a wet and dry AT surface condition. The intra-subject variability was low for the performance and traction variables, demonstrating that results obtained with this test are reliable.

The wet artificial turf condition in combination with the multi-short-studded Turf Field (TF) shoe, equipped with 74 short studs, led to a 5% worse SHR performance and players had an approximately 6% lower utilized traction. The performance reduction is comparable with (and even slightly exceeds) results of studies testing performance differences on Functional Traction Courses when players wear soccer shoes with realistic differences in stud designs (e.g. Sterzing *et al.*, 2009). The detrimental effect of moisture on utilized traction when wearing multi-studded outsole designs on third-generation AT surfaces also concurs with mechanical testing results, which demonstrated a substantial reduction in available traction of this outsole configuration on wet AT (Wannop *et al.*, 2012). Furthermore, seven of the eight real slips (out of 528 recorded trials) occurred in the TF shoe x wet AT condition. These real slips were characterized by a marked loss of balance and large performance deficit, and were not included in the statistical comparisons. These results indicate that the TF shoe outsole does not offer enough traction on wet AT to enable maximal player performance. Conversely, on wet AT compared to the dry condition, performance and utilized traction did not significantly change for the Artificial Grass (AG) and the Firm Ground (FG) outsoles, suggesting that these medium aggressive outsole designs (defined by the combination of length and number of studs) provide enough traction for maximal performance on wet AT.

In the dry condition, players performed the SHR equally well in all three shoes with similar utilized traction. This result is similar that of McGhie and Ettema (2013) who found similar utilized traction coefficients during a 90 degree cut using three cleat configurations on three different third-generation AT surfaces. These results are interesting because each model tested in this experiment had a different number of studs, with different lengths. It is possible that the mechanisms of stud and turf interaction were slightly different between the shoes, yet all provided the minimum amount of mechanical traction necessary in the dry condition.

The combination of the findings about shoe performance on wet and dry artificial turf is relevant for soccer practice. On dry or wet AT, performance and utilized traction were similar during the SHR in the AG and FG shoes, suggesting that both shoes provided a minimum amount of mechanically available traction independent of the surface wetness. While no differences were found on dry AT in this experiment, Sterzing and colleagues (2010) found that soccer shoes with multiple relatively short stud elements provided better functional traction on dry AT.

The agreement between measured differences in performance, utilized traction, and player perception measurements reveal that experienced players could perceive performance-related traction differences. The perceived grip is indeed lower for the wet x TF condition compared to all other conditions. Interestingly, there is also a difference in perception for foot–ankle stability with the wet x TF condition. The perceived comfort of the TF shoe was lower than the other shoes independent of surface wetness condition. Finally, the general appreciation score of the TF shoe on the wet surface was worse, indicating that general appreciation indeed depended on a combination of perceived traction, stability and comfort (Hennig *et al.*, 2010).

It should be stressed that all results apply to these tested conditions, including low to medium aggressive outsole designs and a third-generation AT surface with rubber infill. It remains to be seen whether the threshold values for utilized traction on movements performed in a laboratory setting are the same as when performed in more game-realistic situations, or on different turf surfaces. It is possible that athletes would need slightly more traction in game-realistic settings, as there may be more reactive movements, movement variability, and/or less consistency in the field surface. If more traction was needed, it is possible that differences in performance between more conditions may have been found. Additionally, it is unknown whether the results from this experiment are directly applicable to other shoe and turf systems. The different components used to create the artificial turf surface (e.g. fiber density, length, shape, and/or material, infill depth and/or material, turf age and/or maintenance history, etc.) can affect mechanical traction testing results and player perception data (Potthast *et al.*, 2010).

Incorporating fast cutting maneuvers in a maximal effort shuttle run task, which soccer players are familiar with, resulted in consistent and reliable movement patterns. Consistency in the movement technique and effort level enabled a relationship to be found between differences in utilized traction and maximal performance. Nevertheless, it can be questioned whether the 180° turn performed in this experiment is frequently executed in match situations. Alternative movements that have increased traction requirements, and thus would be appropriate for evaluating the relationship between performance and traction, are cutting maneuvers with smaller directional changes (e.g. Müller *et al.*, 2010), or Functional Traction Courses that incorporate numerous different directional changes performed continuously (Sterzing *et al.*, 2009).

A methodological strength of the current study was that the whole AT surface track was transformed to the dry or wet conditions, and not only the AT surface on top of the force platform. A limitation was that movement phases other than the 180° cut, such as the accelerating and decelerating steps in the total SHR task, can also influence the global performance outcome, and utilized traction during the steps before or after the outward pivot foot contact were not measured. It is possible that players adapt in these support phases to the different turf x shoe conditions.

## 5. Conclusions

A within-subjects experiment was conducted to test the effect of dry and wet artificial turf conditions on performance, utilized traction, and perception for three realistic soccer shoe stud designs. The findings apply for third-generation artificial turf and the wet condition can be compared to field conditions after a light rain fall. Soccer players wearing a multi-short-studded Turf Field shoe, utilized less traction on the outward pivot foot when performing fast 180° turns on wet artificial turf compared with dry. This finding corresponded to an approximately 5% slower 10 × 5 m shuttle run performance, which incorporated nine 180° turns. Performance was not affected by wet artificial turf when players wore shoes with other common Artificial Grass or Firm Ground stud designs, both of which had fewer, longer stud lengths. Experienced players perceived these differences in performance and traction. On dry artificial turf, no differences between the three tested stud designs were measured for performance or utilized traction. From a maximal performance perspective, the results from this experiment suggest that a Turf Field shoe stud design may negatively impact performance when playing on wet AT, but did allow players enough traction on dry AT. During this experiment, shoes with stud characteristics similar to the Artificial Grass and Firm Ground shoe fulfilled the traction needs on both wet and dry artificial turf. Therefore, shoes with even more pronounced stud designs may not be necessary on dry or wet artificial turf.

## Acknowledgements

This majority of the content of this article is taken from "Cutting performance wearing different studded soccer shoes on dry and wet artificial turf" (authors Dirk De Clercq, Gijs Debuyck, Joeri Gerlo, Stijn Rambour, Veerle Segers and Ine Van Caekenberghe) published online on 1 April 2014 in the *Footwear Science Journal* (Taylor & Francis Ltd, http://www.tandfonline.com), Volume 6, issue no. 2: pp. 81–87.

Study granted by NIKE Inc. USA.

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*Routledge Research in Football*

# FOOTBALL BIOMECHANICS

Edited by
Hiroyuki Nunome, Ewald Hennig and Neal Smith

ROUTLEDGE

First published 2018
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

and by Routledge
711 Third Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an Informa business



British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
A catalog record for this book has been requested

ISBN: 978-1-138-19512-7 (hbk)
ISBN: 978-1-315-63855-3 (ebk)

Typeset in Times New Roman
by Cenveo Publisher Services

MIX
Paper from responsible sources
FSC® C013604

Printed and bound by CPI Group (UK) Ltd, Croydon, CR0 4YY

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