Footwear Traction and Lower Extremity Noncontact Injury

John W. Wannop, Geng Luo, and Darren J. Stefanyshyn

Human Performance Lab, Faculty of Kinesiology, University of Calgary, Calgary, AB, Canada

Accepted for Publication: 30 April 2013
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John W. Wannop, Geng Luo, and Darren J. Stefanyszyn

Human Performance Lab, Faculty of Kinesiology, University of Calgary, Calgary, AB, Canada

Contact Information

John W. Wannop
Human Performance Lab
Faculty of Kinesiology
University of Calgary
2500 University Drive N.W.
Calgary, Alberta, Canada T2N 1N4
Phone: 1-403-220-7003
Fax: 1-403-284-3553
bwannop@kin.ucalgary.ca

Funding: This study was funded by the Natural Sciences and Engineering Research Council of Canada (NSERC). None of the funding organizations had any role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; and preparation, review, or approval of the manuscript.

Conflict of Interest: All authors declare no conflict on interest in the work reported in the manuscript
ABSTRACT

Purpose: Football is the most popular high school sport, however, it has the highest rate of injury. Speculation has been prevalent that foot-fixation due to high footwear traction contributes to injury risk. Therefore, the purpose of the study was to determine if a relationship exists between athletes specific footwear traction (measured with their own shoes on the field of play) and lower extremity non-contact injury in high school football.

Methods: Over three years, 555 high school football athletes had their footwear traction measured on the actual field of play at the start of the season and any injury the athletes suffered during a game was recorded. Lower extremity non-contact injury rates, grouped based on the athlete’s specific footwear traction (both translational and rotational) were compared.

Results: For translational traction, injury rate reached a peak of 21.7 injuries/1000 game exposures within the mid-range of translational traction, before decreasing to 4.7 injuries/1000 game exposures in the high range of traction. For rotational traction, there was a steady increase in injury rate as footwear traction increased, starting at 3.3 injuries/1000 game exposures at low traction, and reaching 19.2 injuries/1000 game exposures at high traction.

Conclusion: A relationship exists between footwear traction and non-contact lower extremity injury, with increases in rotational traction leading to a greater injury rate and increases in translational traction leading to a decrease in injury. It is recommended that athletes consider selecting footwear with the lowest rotational traction values for which no detriment in performance results.

Key Terms: Football, Foot Fixation, High School, Adolescent Injury
Introduction

Gridiron football is one of the most popular sports for adolescents, being played in more than 14,000 high schools in the United States, with an estimated one million students participating each year (27). Out of all high school sports, football has the largest overall injury rate (4,9,14,30) with over 61% of athletes being injured over the course of the season (19).

Lower extremity injuries are prevalent in football, with injuries to the ankle and knee joint being by far the most widespread and costly (10,28,30,39). Symptoms of ankle injuries (which account for up to 76% of all lower extremity football injuries) (12) can last for years, with mechanical instability, intermittent swelling, and accumulation of cartilage damage leading to degenerative changes (36) and osteoarthritis (40). Additionally, the highest incidence of anterior cruciate ligament (ACL) knee injuries were recorded in adolescents playing pivoting sports (2,25,26) with injured athletes having an increased risk of osteoarthritis within 15-20 years of injury (24).

Even though football is a high contact sport, 25-36% of injuries are reported to be non-contact (7,16,39). It has been long believed that one of the major causes of non-contact injury, especially in gridiron football, is foot fixation and the shoe-surface interaction (18,29,38).

Footwear traction is commonly broken into two components, translational traction, which is important for the athletes to run quickly, start and stop and rotational traction which is required for pivoting and rapid changes in direction. Most athletes’ think of traction in terms of performance. If athletes do not have enough traction they will slip, therefore, the common thought is that the greater the athlete’s footwear traction, the better the athlete is able to perform.

While this is true to a certain extent, at a specific critical point, increases in the amount of footwear traction will not lead to further increases in performance (20). Increasing traction values above this threshold does not influence performance due to the fact that the athletes cannot utilize any more of the available traction. Therefore simply maximizing the amount of
available footwear traction will not continually increase an athlete’s performance, and may in fact induce some negative effects on the athlete. These negative effects are specifically foot fixation related, non-contact injuries. It has been shown previously that rotational traction may be linked with ACL injury in high school football (18). While this study was the first to examine the link between footwear traction and injury prospectively, it still possessed major limitations mainly that the actual surface and shoes were not used for traction measurements and only representative sample surfaces and footwear were used. Substantial differences in traction measurements can result when comparing laboratory testing to on-field traction testing (33). Additionally all football shoe models did not follow the trend of greater traction leading to a greater incidence of injury.

It is still widely thought that rotational traction is an important component of traction in terms of injury. However, the majority of work has examined rotational traction exclusively, completely ignoring translational traction without much justification (19,37,38,41,42). As a result it is generally believed that translational traction can be increased without increasing the risk of injury. However, this is not based on scientific evidence but rather the lack of any studies that actually investigated translational traction. Additionally, in the past decade new generations of artificial turfs as well as engineered grasses and soils have been developed, which will affect the footwear traction of athletes but no studies have been conducted along the lines of Lambson (18) on these new surfaces. Research into the actual relationship between an athlete’s footwear traction and injury over the entire range of traction actually used in sport is not available. Therefore, the purpose of this study was to determine if a relationship exists between athletes specific footwear traction (measured with their own shoes on the field of play) and lower extremity non-contact injury in high school football.
Methods

Data were collected over the course of three years at the local Athletic Park. The athletic park is a multiuse facility where all city high school grid-iron football games are played. Over the course of the three year study, the park converted its fields from all-natural grass to all artificial turf surfaces. During year one, the fields consisted of all grass surfaces, during year two they consisted of 50% grass fields, 50% artificial turf fields and during year three they consisted of all artificial turf fields.

The artificial turf surface consisted of the 6.35cm Duraspine product installed by Fieldturf. The surface was composed of 4.55 kilograms per square foot of in-fill consisting of 3.19 kilograms of silica sand plus 1.36 kilograms of cryogenic rubber. The infill was installed with an initial base layer of silica sand, followed by 8-10 applications of a silica sand/rubber mixture, finished with a final top layer of larger sized cryogenic rubber particles. The grass surface consisted of Kentucky Bluegrass (poa pratensis), which had a blade length of 5cm, with the underlying soil consisting of 40% clay, 30% sand and 30% silt. The fields underwent routine recommended maintenance which included a weekly surface brushing in addition to deep brushing four times per year and aeration twice per year.

There were a total of 18 high schools that were invited to be involved in the study, with 12 schools agreeing to participate. A total of 555 high school football athletes (115 in year one, 188 in year two and 252 in year three) participated in the study over the course of the three years. In order to participate, athletes were required to have their parents read and sign a consent form approved by the University ethics committee as well as fill out a baseline pre-season questionnaire, which collected data such as age, weight, height and playing experience. During each year, footwear of all athletes that participated were tested using a custom portable robotic traction testing machine at the start of the football season. The system consisted of a foot last
mounted under a moveable platform with a load cell used to measure the force resisting motion of the platform. The foot last was mounted at an angle of 20° of plantar-flexion such that only the forefoot of the shoe would be in contact with the floor. A shoe was placed on the foot last, a vertical load of 580N was applied on top of the load cell to plant the shoe on the surface, which was found during a previous study to be the most physiologically relevant load that could be utilized that was both repeatable and caused minimal damage to the field (45). Although the athletes that participated in this study encompassed a wide range of masses, the constant normal load of 580N was assumed to be appropriate for all footwear traction measurements due to the linear relationship that has been shown to exist between measured footwear traction and normal load (43). This previous study not only demonstrated that a linear relationship exists between footwear traction and normal load, it also indicated that the relative ranking of the footwear stays constant as normal load is increased (i.e. shoe A had the lowest traction at all normal loads, while shoe B had the highest traction at all normal loads). Although the previous study examined the relationship between normal load and measured footwear traction over the range of 335N-776N (which corresponds to a mass of ~34.1kg - 79.1kg), additional studies have shown this relationship to exist over a range of 67N-1335N (~6.8kg-136.1kg) (19, 47). Since a linear relationship exists between measured footwear traction and normal load, the normal load of 580N was appropriate and provided an accurate measure of all athletes’ footwear traction. The shoe was then dragged across the field at a speed of 200mm/s by an automated electrical motor in the anterior direction. While this speed does not correspond to the resultant speed of a high school football player running down the field, this speed was selected as it was found to have high repeatability during previous studies and was the maximum speed that could be tested with no residual movement of the testing machine (44). During this movement, horizontal forces
were collected by the load cell at a frequency of 2000Hz. These forces were then used to calculate the peak translational traction coefficient between the shoe and surface.

For rotational traction, the translational movement was locked and the rotation of the shoe was enabled, with the rotational axis of the tester being placed in line with the forefoot. The load cell measured the moment generated around this axis of rotation. The shaft was rotated at a speed of 90°/s. The traction tester has both a high validity and repeatability (45) and additional information on the traction tester can be seen in previous published papers (43,44,45).

For traction testing, all footwear were collected from the athletes after a practice at the start of the season. The shoes were transported and tested at the athletic park during the next day and returned to the team before the start of their next practice. Due to the conversion of the fields during the study, during year one all games were played on natural grass, during year two games were played on both natural grass and artificial turf surfaces and during year three all games were played on artificial turf surfaces. Traction testing was conducted to match the surface with which the games were played. During year one, the shoes were tested on natural grass only, year two on both natural grass and artificial turf and during year three only on artificial turf. Three trials per shoe-surface condition were collected with the force transducer sampling at a frequency of 2000Hz.

Over the course of each year, data on all game injuries of the athletes were recorded by certified athletic therapists on site at the athletic field, with each season lasting three months. While the definition of injury lacks universal agreement (32), in this study a reportable injury was defined as any game-related football trauma that resulted in an athlete missing all or part of a game, any time away from competition as well as any injury reported or treated by the athletic trainer similar to previous studies (22,23). When an injury occurred, the athletic therapist immediately recorded the history (what caused the injury, whether it occurred as a result of contact or non-
contact), any additional observations, as well as the results of any functional, special tests performed. In addition, the outcome of the injury was recorded as well as the length of time the athlete was inactive (not participating in any games or practices) by practice participation forms filled out by trainers present at all team practices and games. This was a double blind design, in that the athletic therapists were not involved in the traction testing portion of the study, and the traction testers were not present during the assessment of athletic injuries.

For analysis, individual athlete injury data that were deemed to be due to a non-contact event were combined with the individual athlete footwear traction data. For traction data, the static peak translational traction coefficient and peak rotational moment were used to define the translational and rotational components of traction for each athlete.

Statistics

The effect of each surface on non-contact, lower extremity injury was first compared using a chi-squared test at a significance level of 0.05. The injury rate was calculated as the number of injuries per 1000 game exposures, to allow for comparison between previous studies (30,39) and 95% confidence intervals were estimated using a Poisson regression. Since no significant difference in lower extremity non-contact injury rate was found between surfaces, data from all surfaces were combined and divided into three groups depending on each athlete’s recorded footwear traction, with each group populated by an equal number of athletes. The number of injuries in the three groups was compared using a chi-square test with 95% confidence intervals of injury rates being estimated using a Poisson regression.

Additionally, the coefficient of determination (R²) between translational and rotational traction was calculated using a linear least squares fit (Pearson correlation) with the significance of the regression being set at a 95% level of confidence.
Results

The 555 athletes tested had an average age of 16.3±0.7yrs, mass of 79.5±14.1kg, height of 1.79±6.9m and playing experience of 2.5±2.4yrs. The mean temperature during the on field traction testing between all testing days was 10.6±5.4°C.

The breakdown and location of all 58 lower extremity non-contact injuries can be seen in Table 1. Ligament sprains represented the greatest percentage of the lower extremity non-contact injuries containing over 67% of all injuries, followed by muscle strain/spasm at 19% and ligament tears at 5.2%. The majority of injuries occurred at the knee and ankle accounting for over 79% of all reported injuries (27.6% in the knee and 51.7% in the ankle).

The number of lower extremity, non-contact injuries, exposures and injury rate on each surface can be seen in Table 2. There were a total number of 58 injuries recorded, with 36 injuries on the artificial turf and 22 injuries on the natural grass surface. No significant difference in the number of injuries were seen between the two surfaces (p=0.066). The total injury rate of both surfaces was 13.7 (95% CI=10.2-17.2) injuries per 1000 game exposures. When broken down by surface, the injury rate on artificial turf was 14.8 (95% CI=10.0-19.6) injuries per 1000 game exposures compared to 12.2 (95% CI=7.1-17.3) injuries per 1000 game exposures on natural grass.

Results of the non-contact lower extremity injuries divided into the three traction groups can be seen in Table 3. Due to error in data collection and file corruption of some traction data, the total number of athletes analyzed for translational traction was 531 and the total number of athletes analyzed for rotational traction was 551.

Significant differences in injury were present for both translational and rotational traction groupings (p<0.001). For translational traction, injury rate reached a peak of 21.7 injuries per 1000 game exposures within the traction range of 0.686-0.719, before decreasing to 4.7 injuries per 1000 game exposures in the traction range 0.720-0.970. For rotational traction, there was a
steady increase in injury rate as footwear traction increased, starting at 4.2 injuries per 1000 game exposures at 15.0-30.9Nm, and reaching 19.2 injuries per 1000 game exposures at 39.0-54.9Nm.

The severity of injury for each group can be seen in Table 4. Mild injuries were defined as injuries less than 7 days in duration, moderate were between 7 to 20 days in duration, while severe injuries were greater than 20 days in duration or season ending injuries. In terms of the translational traction groups, the low traction grouping (0.480-0.685) had the greatest percentage of severe injuries, with the mid traction group (0.686-0.719) having the largest number of mild injuries and the high traction group (0.720-0.970) having the greatest number of moderate injuries. Examining the results when grouped by rotational traction, the low traction grouping (15.0-30.9 Nm) had the largest percentage of moderate injuries, while the mid traction group (31.0-38.9 Nm) had the largest amount of mild injuries and the high traction group (39.0-54.9 Nm) had the highest amount of severe injuries.

Figure 1 shows the correlation of translational and rotational traction using data from all tested shoes in the current investigation. No significant correlation could be found between rotational and translational traction.

**Discussion**

The majority of research on footwear traction and injury has examined rotational traction exclusively, completely ignoring translational traction without much justification. Furthermore, research into the actual relationship between an athlete’s footwear traction and injury over the entire range of traction actually used in sport was not available. The results of the current study indicate there is a relationship between footwear traction and non-contact lower extremity injury risk, with increases in rotational traction leading to a greater injury rate and increases in translational traction leading to a decrease in injury.
Injury

When comparing overall non-contact injury rate, regardless of surface or traction group, a rate of 13.7 injuries per 1000 game exposures was observed. Comparisons to previous studies are difficult due to the fact that not all studies reported the mechanism of the injury. Some previous studies on American Football reported injury rates of 25.8 injuries per 1000 game exposures (30), 11.8 injuries per 1000 game exposures (34) and 12.8 injuries per 1000 game exposures (39). These previous studies did not differentiate between the type of injury (contact or non-contact), and the current study had much higher injury rates than the aforementioned studies. However, it is important to note that the majority of previous studies defined an injury only if the athlete was unable to participate for a full practice or game after requiring medical attention, while the current study collected data on all injuries that required treatment by the athletic therapist, owing to the recent thought that omitting these injuries leads to underreporting and that these minor injuries may lead to major injuries (6,22,23). In this context, the higher injury rate of the current study was expected and seems to be within the realm of the previous reports. When the injury data was compared based on player positions (Table 1), defensive backs, wide receivers, linebackers and running backs constituted the majority of the injuries that occurred (82.7%). Players in these positions perform a large amount of plant and cut movements that involve many rapid changes in direction, which lends support to the notion that those types of movements place the athlete at risk of a traction related, lower extremity non-contact injury.

Surfaces

While not the primary measure of the study, the methodology employed allowed the effect of each surface (natural grass vs. artificial turf) to be compared in terms of injury rate. There was no significant difference in the number of injuries or the injury rate between the artificial turf and natural grass surfaces, however, there was a non-significant trend towards more injuries on
artificial turf. In the literature there have been conflicting outcomes regarding the effect the surface can have on injury. Research on first and second generation artificial surfaces had much more definitive results, with virtually every study showing an increased risk of injury on these early artificial surfaces compared to natural grass (1,3,17,31). When comparing recent studies on third generation artificial turf surfaces and natural grass the results have been inconclusive. A number of studies have concluded that artificial turf can increase injury risk (5,11,13,23), while other studies claim there is no difference in injury risk between surfaces (8,22,35). While none of these studies focussed on non-contact lower extremity injury, the results of the current study provide support to the notion that there are no differences in injury rates between current third generation artificial turf surfaces and natural grass on non-contact, lower extremity injuries in high school football.

Traction

When examining rotational traction, the trend that increasing traction led to increases in injury supported previous research (18). Low rotational traction footwear was associated with a smaller rate of injury than the mid and high rotational traction footwear. As rotational traction increased, the rate of lower extremity non-contact injury increased significantly. The mid traction footwear increased injury rate 319% and the high traction footwear increased injury 357%, as compared to the low traction footwear. This result draws attention to the fact that for the lowest risk of sustaining a lower extremity non-contact injury, the athlete should have rotational traction as low as possible. While this trend of low rotational traction reducing injury risk has been shown previously (18), this is the first study to display this result for all non-contact lower extremity injuries, not just ACL injury.

In comparison to rotational traction, increases in translational traction did not result in a significant increase in the injury rate, but in fact resulted in a decrease in the number of injuries.
and injury rate. The low and mid traction groups had no difference in injury rates, while the high translational traction group reduced the injury rate 362% compared to the mid traction group. This is interesting especially considering this result is in direct contrast to the rotational traction results. Perhaps athletes are aware of this increase in translational traction, and consciously or subconsciously alter their movement patterns in order to protect themselves from injury. This is the first study to show an influence of translational traction on injury and this result as well as the mechanism involved in this decrease in injury warrants further investigation.

When the severity of the injury was compared for the two groups, some additional information was obtained. It appears that at high translational traction, a large percentage of moderate injuries occurred, while at mid traction ranges (which had the highest injury rate) the largest percentage of mild injuries occurred. Even though the high translational traction group had the lowest injury rate, the majority of these injuries were moderate to severe in nature, making the conclusion for translational traction difficult. This result raises the question as to whether an athlete would want a shoe associated with a high risk of injury, with the high likelihood of the injury being mild, or would the athlete want a shoe with a lower risk of injury, but with the likelihood that if they get an injury it would be moderate to severe in nature.

In terms of rotational traction, the injury severity gave a much clearer picture with the high traction group getting the largest percentage of severe injuries. The high injury rate of this group in addition to the fact that out of the three groups it had the largest percentage of severe injuries provides strong evidence that athletes should avoid wearing footwear in this range of rotational traction if possible.

It has long been believed that a relationship exists between the two components of traction with an increase in one component causing an increase in the other component (46). Intuitively this makes sense, as rotational traction is simply elements of the shoe translating in a circular path.
However, no correlation was seen between translational traction and rotational traction, likely due to the inclusion of many secondary traction elements, which are directional in nature, and allow a decoupling of translational and rotational traction. This introduces the potential to alter the translational and rotational traction independent of one another and would allow the development of footwear that encompasses high components of one type of traction while keeping the other component low. If the specific component of traction (translational or rotational), that places the athlete at a greater risk of injury is identified, then this component could be altered to produce safer footwear. It has been previously shown that increases in traction lead to increases in joint moments of the knee and ankle joint (46), which is believed to be an indication of the loading the joint experiences (15). However, in the previous study increases in traction were facilitated by increases in both the translational and rotational traction of the footwear tested (46). No information could be gathered regarding how translational traction and rotational traction separately influence joint loading.

It is important to note that several limitations were present in the current study that may have influenced the results. When performing mechanical traction measurements it is important to remember that the results are sensitive to the boundary conditions during testing. While some variables were easy to control (normal load, movement speed), others were out of the control of the investigator (surface temperature, ground hardness, surface moisture). While every effort was made to keep these conditions similar between testing sessions, fluctuations in the surface temperature, ground hardness and surface moisture were present and could have influenced the traction measurements. The traction measurements were also only representative for the mechanical testing methods employed. The footwear traction was tested in the forward direction (translational traction) and the internal rotation direction (rotational traction) with the forefoot only. This may have not been representative of what was occurring when the athlete was injured.
and therefore, the traction values may have been different. Additionally, traction testing was only
drawn at the beginning of the season and wearing down of the surface did occur as the
season progressed, which would have affected the traction values of the footwear (44). Perhaps
implementing multiple footwear testing sessions at the beginning, middle and end of the season
or performing addition traction tests in other directions may remove this limitation, but for the
current study that was not feasible.

While every effort was made to get accurate injury data, some sources of bias may have been
present. The injury data were based off of the athletes’ recall of the mechanism of the injury,
which leaves some possibility of potential recall bias. Since completion of the study, video
recorders have been implemented at the fields which may allow for the elimination of this recall
bias in future studies. Additionally, an injury was defined as any game-related football trauma
that resulted in an athlete missing all or part of a game, any time away from competition as well
as any injury reported or treated by the athletic trainer similar to previous studies (22,23), which
may have increased the number of injuries presented in the current study. Lastly, non-contact
lower extremity injuries are very complex and are likely affected by multiple variables. It must
be recognized that footwear traction is not the only variable that can have an influence on the
injury rate.

Conclusion
A relationship exists between footwear traction and non-contact lower extremity injury, with
increases in rotational traction leading to a greater injury rate and increases in translational
traction leading to a decrease in injury. It is recommended that athletes consider selecting
footwear with the lowest rotational traction values for which no detriment in performance results.
Future work is ongoing examining the mechanism of how traction can influence non-contact
lower extremity injury.
Acknowledgments

This study was funded by the Natural Sciences and Engineering Research Council of Canada (NSERC). None of the funding organizations had any role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; and preparation, review, or approval of the manuscript. The results of the present study do not constitute endorsement by ACSM.

The authors would like to thank University of Calgary Sport Therapy Service, especially Kerri Downer, for assistance in collection of the injury data. We would also like to thank all the Calgary high school football coaches, the Calgary Public and Catholic Boards of Education for their cooperation and participation in the study, in addition to Warren Whiteway, Rob Eng for their assistance with on field testing and adidas International for use of the portable traction tester used in the study.

Conflict of Interest

The authors declare no conflict of interest.
References


Figure Legends

Figure 1. Correlation of translational and rotational traction
Figure 1

Correlation of Translational and Rotational Traction

\[ y = 7.99x + 30.52 \]

\[ R^2 = 0.0018 \]

\[ p = 0.320 \]
Table 1. Breakdown and location of all non-contact lower extremity injuries.

<table>
<thead>
<tr>
<th>Primary Type of Injury</th>
<th>Number of Injuries</th>
<th>% of Total Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ligament Sprain</td>
<td>39</td>
<td>67.2</td>
</tr>
<tr>
<td>Muscle Strain/Spasm</td>
<td>11</td>
<td>19.0</td>
</tr>
<tr>
<td>Ligament Tear</td>
<td>3</td>
<td>5.2</td>
</tr>
<tr>
<td>Fracture</td>
<td>2</td>
<td>3.4</td>
</tr>
<tr>
<td>Muscle Tear</td>
<td>1</td>
<td>1.7</td>
</tr>
<tr>
<td>Tendon Sprain</td>
<td>1</td>
<td>1.7</td>
</tr>
<tr>
<td>Hyperextension</td>
<td>1</td>
<td>1.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location of Injury</th>
<th>Number of Injuries</th>
<th>% of Total Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle</td>
<td>30</td>
<td>51.7</td>
</tr>
<tr>
<td>Knee</td>
<td>16</td>
<td>27.6</td>
</tr>
<tr>
<td>Thigh</td>
<td>9</td>
<td>15.5</td>
</tr>
<tr>
<td>Foot</td>
<td>2</td>
<td>3.4</td>
</tr>
<tr>
<td>Shank</td>
<td>1</td>
<td>1.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Position of Injury</th>
<th>Number of Injuries</th>
<th>% of Total Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarterback</td>
<td>2</td>
<td>3.4</td>
</tr>
<tr>
<td>Running Back</td>
<td>9</td>
<td>15.5</td>
</tr>
<tr>
<td>Wide Reciever</td>
<td>13</td>
<td>22.4</td>
</tr>
<tr>
<td>Line Backer</td>
<td>12</td>
<td>20.7</td>
</tr>
<tr>
<td>Defensive Back</td>
<td>14</td>
<td>24.1</td>
</tr>
<tr>
<td>Offensive Linemen</td>
<td>3</td>
<td>5.2</td>
</tr>
<tr>
<td>Defensive Linemen</td>
<td>5</td>
<td>8.6</td>
</tr>
</tbody>
</table>
Table 2. Number of injuries, game exposures and injury rate on the artificial turf and natural grass surfaces.

<table>
<thead>
<tr>
<th>Surface</th>
<th>Number of Injuries</th>
<th>Number of Game Exposures</th>
<th>Injuries per 1000 Game Exposures (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial Turf</td>
<td>36</td>
<td>2436</td>
<td>14.8 (10.0-19.6)</td>
</tr>
<tr>
<td>Natural Grass</td>
<td>22</td>
<td>1804</td>
<td>12.2 (7.1-17.3)</td>
</tr>
<tr>
<td>Total</td>
<td>58</td>
<td>4240</td>
<td>13.7 (10.2-17.2)</td>
</tr>
</tbody>
</table>

CI = Confidence Interval
Table 3. Number of injuries, exposures and corresponding injury rate when athletes were divided into three equal groups based on their footwear traction.

<table>
<thead>
<tr>
<th>Traction</th>
<th>Non-contact, Lower Extremity Injuries</th>
<th>Number of Game Exposures</th>
<th>Injuries per 1000 Game Exposures (95% CI)</th>
<th>Number of Athletes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Translational Coefficient</td>
<td>0.480-0.685</td>
<td>19*</td>
<td>1415</td>
<td>13.4 (7.4-19.5)</td>
</tr>
<tr>
<td></td>
<td>0.686-0.719</td>
<td>31#</td>
<td>1428</td>
<td>21.7 (14.1-29.3)</td>
</tr>
<tr>
<td></td>
<td>0.720-0.970</td>
<td>7#</td>
<td>1497</td>
<td>4.7 (1.2-8.1)</td>
</tr>
<tr>
<td>Rotational [Nm]</td>
<td>15.0-30.9</td>
<td>6#</td>
<td>1417</td>
<td>4.2 (0.9-7.6)</td>
</tr>
<tr>
<td></td>
<td>31.0-38.9</td>
<td>24*</td>
<td>1364</td>
<td>17.6 (10.6-24.6)</td>
</tr>
<tr>
<td></td>
<td>39.0-54.9</td>
<td>28#</td>
<td>1459</td>
<td>19.2 (12.0-26.3)</td>
</tr>
</tbody>
</table>

CI = Confidence Interval

*, # represent significant differences (p<0.05) as determined by the chi-squared test.
Table 4. Severity of injury of the three groups [% of total injuries]

<table>
<thead>
<tr>
<th>Traction Grouping</th>
<th>Types of Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mild</td>
</tr>
<tr>
<td>Translational Coefficient</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>60.9</td>
</tr>
<tr>
<td>Mid</td>
<td>80.0</td>
</tr>
<tr>
<td>High</td>
<td>50.0</td>
</tr>
<tr>
<td>Rotational [Nm]</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>33.3</td>
</tr>
<tr>
<td>Mid</td>
<td>69.2</td>
</tr>
<tr>
<td>High</td>
<td>65.4</td>
</tr>
</tbody>
</table>