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# The player surface interaction of rugby players with 3G artificial turf during rugby specific movements.

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## Abstract

A number of high profile rugby teams in the UK have installed ATS for both training and competition. However, little is known about how the player interacts with ATS during rugby specific tasks. To date the pitches are tested using mechanical testing devices with little understanding as to how these relate to the player interaction with the surface. The aim of this pilot study was to determine the viability of using 3D motion capture system to quantify the player surface interaction and surface performance characteristics during rugby specific movements. Two tasks were selected, kicking and simulated scrummaging, for players to perform on a sample ATS within a biomechanics laboratory. Using a 3D motion capture system synchronised with a force plate the movement of the players on the ATS was analysed. This analysis showed that using a 3D motion capture system with players on an ATS was a viable method to investigate and understand the interaction between the player and the surface. Baseline data for comparison between player loading and the mechanical testing devices was also obtained.

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**Keywords:** Rugby; 3G Turf; Scrummaging; Kicking; Artificial Turf

## 1. Introduction

The use of artificial turf surfaces (ATS) in rugby is becoming more common for games and practice. This has been supported by World Rugby, the international governing body for rugby, through the introduction of regulation 22, which outlines the performance characteristics that an ATS must achieve for certification. Third generation ATS

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are constructed from a number of layered components. Typically for rugby this consists of a shockpad, up to 30 mm in depth, with a carpet layer on top which is required to have a minimum fibre length of 60 mm. Within the carpet layer there are two layers of infill. The first layer of sand, often referred to as the stabilising infill, adds weight to the system keeping the carpet from moving. The sand infill has been shown to significantly lower the force reduction and vertical deformation of the surface system when present [1]. The second layer of rubber granules, referred to as the performance infill, is laid on top the stabilising infill and is considered to have the greatest impact on the performance characteristics of the surface. The type of rubber used, the size, shape and density of the granules have all been shown to affect the surface performance characteristics [1]–[3]. The combined depth of the two infills is normally two thirds of the pile height [4].

The performance of the surface is characterised using a number of mechanical test devices. These provide a reliable and repeatable measure of the surfaces performance. Regulation 22 requires that a number of sites across the pitch are tested for the vertical impact (19 sites) and rotational traction (6 sites) characteristics [5]. These are tested using two pieces of equipment, the Advanced Artificial Athlete (AAA) and the Rotational Traction Device (RTD). The AAA measures the shock absorption, energy restitution and vertical deformation of the surface by dropping a sprung 20 kg mass from 55 mm with an accelerometer attached. The RTD measures the peak torque of the surface by dropping a rigid disc with six equally spaced studs, weighing 46 kg, from 60 mm. This disc is then rotated at 12 rpm by the operator until a rotation of at least 45° has occurred. The vertical impact and rotational traction characteristics are used to simulate the interaction between the players boot and the surface. Although useful to give a quantitative measure of the surfaces performance it is not clear how they relate to the players interaction with the surface during participation.

Rugby is a contact sport in which players in certain positions regularly weight up to and over 120 kg. Integral elements of the game such as scrums, rucks, mauls, tackling and kicking are inherently affected by the way the player interacts with the surface. Players who take part in scrums commonly wear boots which have six studs on the fore foot of up to 22 mm in length. To date the research available regarding the player surface interaction on artificial turf surfaces has focussed on generic sporting movements such as running and cutting [6], which has often been specifically related to football. Rugby players are considerably larger [7], required to perform different movements and use different footwear in comparison to football. It is important therefore to understand how rugby players interact with the surface to inform future design of surfaces and footwear, review the safety criteria and inform player welfare decisions.

The aim of this pilot study was to determine the viability of using 3D motion capture system to quantify the player surface interaction and surface performance characteristics during rugby specific movements. Motion capture is commonly used within biomechanics and allows the movement of a participant to be tracked using spherical reflective markers placed on the body segments and landmarks of interest. By placing markers on the surface of the turf and on the boot of the participant it is intended that the nature of interaction between the boot and the surface will be quantified.

## 2. Method

A 3G ATS was constructed within a biomechanics laboratory (Loughborough University Sports Technology Institute). The surface was laid across the laboratory floor, covering a force plate (Kistler 9287BA, Switzerland) centered in the field of view of a motion capture system (Vicon, Nexus). This allowed an appropriate kicking run up to be taken and scrummaging movement to be performed over the force plate.

### 2.1. Artificial turf system

The carpet was one piece of LigaTurf RS+ CoolPlus 260 16/4 (Polytan, Germany). The sample measured 3 m by 5 m and was laid over sample shockpads of 25 mm thickness. The carpet consisted of 60mm monofilament fibres with an approximate tuft density of 8400 per m<sup>2</sup>. Under the carpet layer in the run up area and on top of the force plate, 1 m<sup>2</sup> samples of 25 mm thick shock pad were laid. These samples were created at the same time as a shockpad being laid in situ on an outdoor ATS. Remaining areas of the laboratory floor had a layer of prefabricated BURLABURGA shockpad between the floor and the ATS. The shockpad laid over the force plate was cut to the

size of the force plate (600 x 900 mm) with an approximate 2 mm gap around to isolate the force plate as much as possible.

Infill was added to the carpet in accordance with the manufactures guidelines and was matched to that of an outdoor ATS recently constructed. 15 kg·m<sup>-2</sup> of Garside 2EW sand (Garside Sands, UK) was spread evenly over each square metre of the carpet sample using a lawn seed spreader. The carpet fibres and sand were then raked to ensure the carpet fibers were not buried. Once infill was laid in each square metre, the whole carpet was raked to ensure that the sand was evenly spread, with the average depth of the sand infill being 11 mm. Recycled rubber granules (Genan, Denmark) produced from used vehicle tires were then spread into the carpet over the sand layer. The manufacturers specification for the elastomeric composition of the material states that as guideline approximately 30% is natural rubber (NR), 40% Styrene-butadiene rubber (SBR), 20% Butadiene rubber (BR) and 10% Butyl- and halogenated butyl rubber (IIR / XIIR). The size of the granules was between 0.5 and 1.5 mm. The granules were spread into the carpet in two batches of 7.5 kg·m<sup>-2</sup>, raked between each application to ensure the carpet fibers were erect and the rubber was evenly spread. Once all the rubber infill had been laid the whole carpet was raked. Each metre square was then rolled 200 times using a FIFA approved studded roller weighing 40 kg to compact the infill layers. The average combined infill depth once rolled was 41 mm.

## 2.2. Movements

Two movements were selected for investigation: a penalty kick and a simulated scrummaging movement. The penalty kick required the participants to set the ball using a kicking tee so that their plant foot landed on the force plate. The participants were then instructed to kick using their normal routine and set up, performing 8 kicks at 50% effort level and 8 kicks at maximum effort.

The simulated scrummaging movement was performed using a weighted metal sled which had two pads approximately 30 cm apart attached so they were off the ground. The participants were able to place their head between the pads and push using their shoulders as they would in a scrum or rucking position during a game. The participants were then instructed to take a set position as they would in a scrum or when preparing to ruck and hit into the shoulders pads, performing 8 pushes at 50% effort level and 8 at maximum effort.

## 2.3. Subjects

Four amateur players (height; 180.9 ± 6.9 cm, weight: 88.3 ± 11.4 kg) took part in the study. Two conducted both the kicking and simulated rucking trials. One participant conducted kicking only and one participant conducted the simulated rucking only. This was determined by the participants playing position. All participants had played or trained on ATS previously.

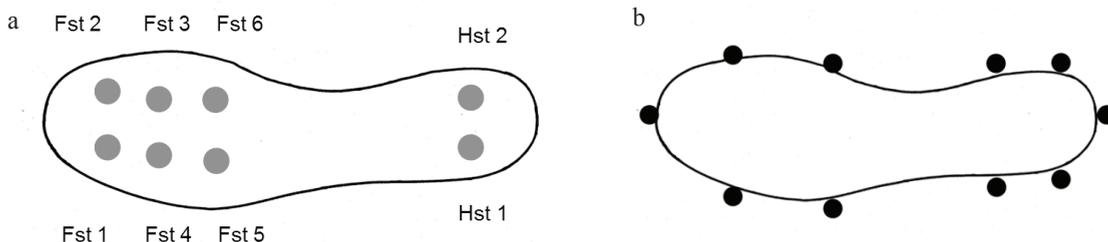


Figure 1. (a) Stud locations; (b) Location of marker placement around the soleplate.

## 2.4. Data Capture

Each trial was recorded using a 3D motion capture system, Vicon Nexus, (Vicon Oxford, UK) captured at 250 frames per second synchronised with a Kistler force plate (Kistler Instruments Ltd, UK) at 1000 Hz to obtain ground

reaction forces. Each subject also had alternate trials recorded using high speed video. The Vicon system was set up so that the force plate and turf were in the centre in the field of view. Participants had 13 markers attached to their boot, shown in figure 1, of their non-kicking foot. Markers were also placed on the medial and lateral malleoli of the ankle and on the medial and lateral aspects of the knee aligned to the axis of rotation of the joints.

### 2.5. Data Processing

For each trial the positions of the markers were reconstructed and labelled using a template created in the Vicon motion capture software (Vicon Nexus 1.8.2). Markers which did not have complete trajectories for the whole trial were spline filled unless the marker remained obscured for the remainder of the trial. The file was then exported in to Matlab (R2010a) in .C3D format. A Matlab script was written to process the data of each trial. A local coordinate system was determined about the heel and forefoot segments of the boot allowing the position of the stud markers to be calculated in reference to the markers on the upper of the boot. The reference was taken from a static trial of the boot with markers placed on the studs. The stud marker locations in reference to the markers being tracked on the upper were then virtually created during the dynamic trials. Each trial was interpolated so that all data matched the frequency of the force plate. Ground contact in the kicking trials was determined as the point at which the vertical force on the force plate exceeded a threshold of -10 N, and for the simulated scrummaging when the vertical force increased or decreased by a threshold 10 N from the baseline start position. The trials were cropped from ground contact until the foot left the force plate or to a maximum of 250 frames for the kicking trials and 1000 frames for the scrummaging trials. The axial rotation of each segment was determined from the position of the local co-ordinate system created for that segment in reference to the global co-ordinate system of the laboratory created in Vicon. Translation of the markers through the turf was assumed to be linear and calculated from the change in position of the marker in the X and Y planes when the height of the marker (Z plane) was below that of the surface markers.

## 3. Results

Mean results from all processed trials are presented below in Tables 1 and 2. Three of the four participants completed the kicking trials and three of the four completed the sled pushing trials. Due to the occlusion of markers 20 sled pushing trials and 19 kicking trials were analysed. Therefore at this stage no comparison between the effort levels was conducted.

Table 1. Mean maximum values of force, boot position and boot rotation during ground contact for the left (stance foot in kicking) boot.

	Vertical Force (N)	Anterior/Posterior Force (N)	Medio / lateral Force (N)	Forefoot Stud Vertical Displacement (mm)	Forefoot Segment Rotation (°)	Heel Stud Vertical Displacement (mm)	Heel Segment Rotation (°)
<b>Kicking</b>							
Mean	-2394.99	-393.50	234.36	-38.62	31.64	-37.68	30.53
SD	195.04	67.25	28.39	6.81	18.60	6.66	17.12
<b>Simulated Scrummaging</b>							
Mean	-621.36	-212.12	23.06	-29.29	31.34	N / A	N / A
SD	185.17	128.15	18.55	10.68	24.69	N / A	N / A

The results in table 1 indicate that there are much greater forces and stud penetration involved in the kicking trials than the scrummaging trials. In both kicking and scrummaging the force is the greatest in the vertical direction. The maximum heel and forefoot stud displacements during the kicking trials appear to be of a similar magnitude -38.62

$\pm 6.81$  mm and  $-37.68 \pm 6.66$  mm respectively which are both greater than that of the forefoot during the scrummaging trial  $-29.29 \pm 10.68$  mm.

In contrast to the higher forces and vertical displacement shown in table 1, table 2 appears to show that there is greater translation of the forefoot studs during the scrummaging movement. However, the large standard deviations associated with the translations of the stud locations during the scrummaging suggest caution is required when interpreting these results. Closer inspection of the individual scrummaging trials data highlighted that two trials were calculated to have translations of a much greater magnitude ( $\sim 110$  mm) than the others, significantly affecting the results. The forefoot rotations in both the scrummaging and the kicking trials as well as the heel in the kicking trial are very similar, around  $31^\circ$ , however all three have large standard deviations.

Table 2. Translation of the virtual stud markers through the turf.

Kicking - Stud Translation (mm)								
	Hst1	Hst2	Fst1	Fst2	Fst3	Fst4	Fst5	Fst6
Mean	18.21	21.13	18.01	9.51	7.41	15.39	12.85	6.76
SD	5.42	6.02	5.04	4.41	4.42	7.58	11.55	3.64
Simulated Scrummaging - Stud Translation (mm)								
	Hst1	Hst2	Fst1	Fst2	Fst3	Fst4	Fst5	Fst6
Mean			18.51	23.45	26.88	23.69		
SD			32.62	41.56	47.58	42.88		

#### 4. Discussion

The aim of this pilot study was to determine the viability of using 3D motion capture system to quantify the player surface interaction and surface performance characteristics during rugby specific movements. The global results presented indicate that using common techniques from biomechanical analysis of movement, a 3D motion capture system is able to quantify the player surface interaction during rugby movements on ATS. The calculated position of the markers, both those tracked and the virtual markers created, refers to the centroid of the marker itself. In the data presented this has not been accounted for with an offset. The markers used were 9 mm in diameter, therefore the results presented can be considered as an overestimation of the marker position. However, even taking this into consideration it can be seen that the stud markers are penetrating in to the surface by up to 20 mm. None of the boots worn by the players in this trial had 22 mm studs which are commonly used in rugby boots, it is therefore possible that the stud penetration when using 22 mm studs will be greater and close to breaking in to the sand infill layer.

Stud translation was determined as the horizontal displacement of the marker when it was under the surface level of the ATS. As previously mentioned the translations of the scrummaging trials are affected by two trials which appear to have very large translations causing large standard deviations. On inspection of the trial data and video captured, it would seem that these large translations were not actually present, therefore a more thorough investigation of the data inputted at each stage of the analysis process is required to account for this, and is thought likely to be human error. The calculated stud translations' from the kicking trials shows that there is some variation depending on the stud position e.g. heel stud 2 (Hst2) has a greater average translation than heel stud 1 (Hst1). This suggests that there is an element of horizontal sliding as the foot is planted, up to 20 mm, which may be dependent on the order, time period and angle with which the studs come in to contact with the turf as well as the movement of the studs through the turf. It has been suggested that a common mechanism for player injury is the foot locking when coming into contact with turf specifically as ATS are thought to have more friction and therefore grip than natural turf surfaces. The results show that there is a translational movement of the studs when the boot is in contact ATS, to further understand if this is a mechanism which may lead to higher injury rates on ATS a comparison to a natural turf is needed.

The magnitude of the vertical ground reaction forces measured, approximately 2400 N during the kicking trials and approximately 600N (left foot only) during the scrummaging trials, provides some data for comparison to the mechanical testing devices. The AAA typically measures between 1800 N and 2000 N for its maximum force reading calculated from the attached accelerometer. The ground reaction forces recorded during each trial will have been affected by the shockpad as well as by the infill layers; this would have dampened the magnitude of the forces. Although the forces of the mechanical test devices are similar to those found from the player trials, the considerable differences in the masses involved to generate those forces suggests that the AAA does not necessarily represent how a player loads the surface.

This pilot study has highlighted that the biggest limitation of using motion capture on ATS was the occlusion of key markers during the trial and the sensitivity of the data analysis process to this. The result of this was that a large number of the trials collected were not able to be fully processed. The number and positioning of the markers placed on the upper of the boot which are tracked during the dynamic trials need to be sufficient to account for this. In future use of the method presented above, two additional markers will be placed on the forefoot region. One participant had the markers secured to their boot using superglue while the markers for the remaining participants were placed on the boot using double sided tape, this had a noticeable impact on the quality of the data captured and prevented the markers from being dislodged, improving the quality of the data obtained.

The preliminary data from this pilot study suggests that the use of a 3D motion capture system is a viable way to quantify the player – shoe – surface interaction and has provided some baseline data for player loading of ATS. It has also helped to inform that future work in with some minor amendments to the method would be beneficial. Particularly, conducting a comparison between ATS and a natural turf surface, comparing the effect of the intensity of movement on ATS and extending the analysis of the data collected to include a biomechanical analysis of the player movements on ATS.

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