ANALYSIS OF A FOOTBALL KICK USING INERTIAL SENSORS
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SUMMARY
The purpose of this study was to conduct a preliminary investigation into the application of inertial sensors to the analysis of knee moments during kicking. Knee moments at ball impact and maximum shank back position were determined for dominant and non-dominant limbs. There was no significant difference between limbs at impact (Dominant: 79.5±7.3 Nm; Non-Dominant: 73.8±15.5 Nm, t(4)=.663, p>.05) or maximum shank back (Dominant: -43.1±11.2 Nm; Non-Dominant: -34.4±7.3 Nm, t(4)=−2.027 p>.05). The results suggest that despite footballers typically favouring a particular limb skilled amateur players are capable of producing similar net knee moments. Any differences in kicks between the two limbs are therefore more likely to be attributed to factors other than the muscular effort applied to changing the motion of the leg. Inertial sensors proved effective in analyzing a high velocity kick. It is suggested that further research on football kicking utilises this technology to carry out research in the natural sporting environment and replicate skills as performed during game play rather than be simulated within a laboratory environment.

INTRODUCTION
Although kicking is the most widely analysed skill in football, the majority of biomechanical studies have been constrained to the laboratory environment. However, to gain an accurate picture of the mechanics of sporting activities they should ideally be monitored within their natural environment. Microelectromechanical (MEMs) inertial sensors, including accelerometers and gyroscopes, provide the potential to do this. Such devices are small and low powered enabling them to be battery powered and discretely attached to the body. While these devices have been used extensively to research activities of daily living and monitoring gait, very few studies have applied this technology to activities involving high velocity motion such as a football kick.

Studies on the kinetics of the instep kick have typically relied on calculating knee moments from force platform and motion analysis data [1,2]. Limitations to these analysis methods include expense, being restricted to the laboratory setting, and analyzing the skill at point of contact with the force platform as well as the limited accuracy of differentiating the position data to obtain accelerations [3]. Researchers have started to explore using alternative methodologies such as accelerometers to examine football kicking [4]. More studies are needed to determine comparability between methods.

An important issue in football kicking is limb dominance. Due to the nature of the game, players who can kick effectively with both feet have an advantage. Studies have reported differences in kicking characteristics between dominant and non-dominant limbs [1,2,4]. However further research is required into the effect of limb dominance on the muscle moments produced during the kick.

The work presented in this paper represents a preliminary analysis of the effectiveness of inertial sensor technology to analyse a low instep kick and an investigation of the differences in net knee moments between dominant and non-dominant limbs.

METHODS
Five male skilled amateur footballers (age: 23.9±3.80 years, height: 1.80±0.02 m, mass: 83.1±12.71 kg) were required to perform five low maximum velocity instep kicks of a stationary ball with their dominant and non-dominant limbs. Data was collected using two wireless inertial sensors (InterSense, InertialCube3) attached to the shank and thigh. Each sensor incorporated a MEMs accelerometer and gyroscope from which angular displacement, velocity and linear acceleration values were obtained. Following a warm up participants were required to hit a 1m x 1m target with a FIFA approved size 5 football, by kicking it from the ball placement site 5m in front of the target. Participants were allowed a two-step run-up with a straight approach from directly behind the ball as this study used 2D analysis in the sagittal plane.

Trials were analysed from final toe-off of the kicking limb prior to impact, to the instant just prior to foot ball impact. The three trials with the maximum shank angular velocity for each condition were chosen for further analysis. Data processing was carried using Matlab R2010b. The angular displacement, angular velocity, and linear acceleration data from the sensors was resampled to 100Hz and filtered using a Butterworth low pass filter (6Hz). Angular acceleration was derived from the filtered angular displacement data. The net knee moments ($M_k$) were calculated using the following equation: $M_k = -R_{y1}lsinθ + R_{y2}lcosθ + Iα$. Figure 1 illustrates the variables incorporated into this equation.

Net knee moments were calculated at the instant immediately prior to impact, which was defined as the point of maximum horizontal acceleration and the maximum shank back position, defined as the point of maximum shank
angle prior to impact. Differences in net knee moments were statistically tested using dependent t-tests.

The moments reported in this study are slightly lower than those reported in studies using video analysis techniques to calculate knee moments [1,2]. These differences are likely to be due to the nature of the measurement systems and further comparisons between systems is recommended.

**RESULTS AND DISCUSSION**

The net knee moments at impact and maximum shank back are reported in Table 1. Dependent t-tests revealed no significant difference between dominant and non-dominant limbs at impact (t(4) = .663, p>.05) or maximum shank back (t(4) = -2.027 p>.05).

**Table 1:** Net knee moments (Nm) for dominant and non-dominant limb during a low instep kick.

<table>
<thead>
<tr>
<th>Net Knee Moment (Nm)</th>
<th>Kicking Limb</th>
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<tr>
<td></td>
<td>Dominant</td>
</tr>
<tr>
<td>Impact</td>
<td>79.5 ± 7.3</td>
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<tr>
<td>Max shank back</td>
<td>-43.1 ± 11.2</td>
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Although having a preference to kick with a particular limb is common amongst footballers these results show that they are capable of producing similar net knee muscle moments with both limbs. This applies to the muscular effort applied to the knee during the peak of the backswing and at the instant prior to impact. Previous studies have also revealed no significant differences in the knee moments they have reported for 2D [2] and 3D [4] analysis on skilled footballers. However differences in knee moments between limbs have been reported for highly skilled players [1]. It is possible that the differences in knee muscle moments between limbs is affected by skill level. The use of inertial sensors to continue to explore this area has the potential to further the understanding of limb dominance in football.

CONCLUSIONS

From this work it can be seen that it is possible to monitor net knee moments during a high velocity kick using inertial sensors. The results suggest that skilled amateur players are capable of producing similar net knee moments with both limbs. Any differences in kicks between the two limbs are therefore more likely to be attributed to factors other than the muscular effort applied to changing the motion of the leg. While this work has analysed kicking in the sagittal plane it can be extended for 3-dimensional analysis and used in the natural sporting environment. This will allow analysis of skills as performed during game play rather than simulated within a laboratory environment.

**REFERENCES**