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IDENTIFICATION OF TOUCHDOWN AND TOE-OFF IN TURF-SPORT SPECIFIC MOVEMENTS USING KINEMATIC DATA

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The accurate determination of touchdown and toe-off during the stance phase in human locomotion is important for further motion analysis. The aim of this study was to evaluate the accuracy of using kinematic data to detect these events and therefore ground contact time of movements on artificial turf. Seven athletes performed five different turf-sport specific movements in which a single contact was made on a force plate (1000 Hz), while kinematic data of six markers were recorded (CODA, 400 Hz). A force threshold (20N) was set to determine the events of the touchdown and toe-off for the kinetic data. Comparison was made between the kinetic and kinematic derived event times. The errors between the kinetic and kinematic data ranged from 1.6 to 3.4% for the acceleration, hurdle hop and a turn with change of direction of 135°. It was concluded that kinematic data can accurately determine touchdown and toe-off events for certain movements on artificial turf.

KEY WORDS: kinematics, ground contact time, artificial turf

INTRODUCTION: INTRODUCTION: The accurate detection of touchdown (TD) and toe-off (TO) events during human locomotion are important factors for time normalisation to compare specific kinematic and kinetic parameters between participants (Zeni, Richards and Higginson, 2008). Investigators normally use force plates to detect these events, using the instance when the vertical force rises above or drops below a certain threshold to define the respective events. Other methods for the detection are pressure sensitive foot switches or accelerometers (Ross & Ashman, 1987; Jasiewicz et al., 2000). However, it can often be impractical to measure with either a force plate or pressure sensors in field or game settings. Consequently, a number of studies have determined the accuracy of defining TD and TO using just kinematic data for different human movements. Examples include clinical gait analysis with investigations performed on both flat ground and treadmills (Ghoussayni et al., 2004; Zeni et al., 2008; de Witt, 2010). Research has also validated the accurate detection of TD and TO using kinematic data for both running and sprinting (Hreljac & Stergiou, 2000; Bezodis et al., 2007). Therefore, if force plates are not available or difficult to install into the testing protocol, a kinematic alternative may be used. However, all the above studies have provided validation of solid surfaces, without any changes of compliance, and to the authors' knowledge no studies have measured on softer surfaces. There are many situations in natural or artificial turf studies where ground contact times of players are important, for example to normalise data for further kinematic comparisons between players (Meijer et al., 2006, Dowling et al., 2010; Wannop, Worobets & Stefanyshyn, 2010). The aim of this study was to evaluate the accuracy of using kinematic data to detect TD and TO events of movements performed on artificial turf.

METHODS: Seven team-sport-players (186.1 ± 6.7 cm, 84.7 ± 9.9 kg, 22.3 ± 3.5 yrs) participated in three to five turf-sport specific movements. All participants wore their own football boots during the study. A force plate (Kistler, 1000Hz) was located in a customised housing at ground level and covered with a Mondo track surface. A rectangular artificial turf sample housed in a purpose-built metal tray (900mm x 600mm x 50mm) was mounted on the force plate and the surrounding area was covered with firm mats to adjust the level of the ground to the artificial turf level. The force plate was synchronized with a CODA CX1 Motion Analysis System (Charnwood Dynamics Ltd., UK) sampling at 400 Hz. Kinetic and kinematic

data of different sport related movements were collected: accelerating from a three point start (protocol 1), cutting with a change of direction of 60° (protocol 2), landing after a hurdle-jump followed by an acceleration (protocol 3a and 3b, respectively), turning with a change of direction of 135° (protocol 4) and turning with a change of direction of 180° (protocol 5).
CODA active markers were positioned on the foot relative to the specific protocol. Markers were placed on the football boots corresponding to specific landmarks of the foot: superior to the distal end of the first toe [A], superior to the first inter-phalangeal joint of the second toe [B], fifth metatarsophalangeal joint [C], first metatarsophalangeal joint [D], on the lateral heel with a distance of 2 cm from the ground [E] and the tuber calcanei [F]. Markers and battery boxes were fixed to the boots using double-sided adhesive tape and additionally electrical tape was used to fix the cables and boxes securely. Each participant completed three running trials in which a single foot contact was made on the turf.

Figure 1: Active CODA markers placed posterior and anterior on the football boot

The vertical ground reaction force, marker velocity and marker acceleration data for all trials were filtered using a Butterworth low pass filter at 20 Hz and exported for analysis. The data were imported to Matlab (The MathWorks Inc., USA, version R2008b) and analysed with a custom written program. For the kinetic data a vertical ground reaction force threshold of 20 N was defined as the point of TD and TO on the force plate. Analysis used kinematic data to define event detection for TD and TO, including marker velocity and acceleration (maxima, minima and zero-point) in vertical and horizontal directions. After defining the TD and TO events, the mean of the absolute differences was used to calculate the average difference between the kinetic and kinematic data for all participants. In addition, a relative percentage error relating to total contact time was calculated by comparing kinematic and kinetic ground contact times.

RESULTS AND DISCUSSION: Previous studies investigating the accuracy of detecting TD and TO events in human locomotion have used surfaces with little or no compliance. To the authors' knowledge this study was the first to investigate a surface with higher compliance and turf-sport specific movements. In addition to validating the use of kinematic analyses of ground contact events, this study can inform further investigations looking at other turf-sport specific movements and surfaces with an even higher compliance. The aim of this study was to evaluate the accuracy of using kinematic data to detect TD and TO events of movements performed on artificial turf.
Tables 1-4 display the mean differences (s) between kinematic and kinetic detection of TD and TO for the five different protocols. The results of linear acceleration (Table 1, Protocol 1), hurdle-jump landing and first step acceleration (Table 2, Protocols 3a and 3b respectively)

and the 135° turn (Table 3) show relative errors of 2,3%, 3,4%, 1,6% and 1,7% respectively. The 180° turn (Table 4) and the 60° cut with change of direction (Table 1, Protocol 2) exhibited errors of 6.0% and 9.5%. Due to space restriction only mean absolute differences and relative percentage errors were listed in the results section, without further explanation of the exact parameters used.

Protocols 1, 3a, 3b and 4 exhibited more accurate detection than protocols 2 and 5 when compared to the kinetic data. The largest error was found with the movements including change of direction away from the sagittal plane (Protocols 2 and 5). These errors may be explained by the movements themselves being unsuitable for kinematic detection. Another possibility could be due to the complex nature of the movements that cause a higher inter-player variability in the execution of these skills. However, the results of protocol 4, which may also be viewed as a complex movement, can be considered as accurate detection of both events with an error of 1.7 %. It is therefore concluded that it is the movement itself rather than the player variability that caused the higher error in protocol 2 and 5. For each protocol, the most accurate values were enabled by different marker positions and parameters. Consequently it is suggested, that for other investigations under different conditions, it is necessary to identify the most suitable marker positions and parameters by conducting a pilot study. Overall the results of this study indicate that it is possible to use kinematic data to accurately detect TD and TO of selected movements on artificial turf.

Table 1 – Mean ± SD absolute average differences for instances of TD (s) and TO (s) between force plate benchmarks and maximal marker vertical acceleration for protocols 1 and 2.

	Protocol 1*		Protocol 2*	
Marker	TD	TO	TD	TO
A	N/A	N/A	0.038 ± 0.013	0.021 ± 0.014
B	**0.004** ± 0.0017	**0.007** ± 0.0025	0.033 ± 0.013	**0.017** ± 0.011
C	0.006 ± 0.0037	0.015 ± 0.0046	**0.031** ± 0.011	0.024 ± 0.012
E	0.033 ± 0.0369	0.040 ± 0.0040	0.052 ± 0.039	0.062 ± 0.008

*best values are bold and average contact times were 0.226 s (Protocol 1) and 0.252 s (Protocol 2)

Table 2 – Mean ± SD absolute average differences for instances of TD (s) and TO (s) between force plate benchmarks and maximal vertical marker acceleration for protocol 3a and 3b.

	Protocol 3a*		Protocol 3b*	
Marker	TD	TO	TD	TO
B	**0.009** ± 0.008	0.022 ± 0.040	**0.004** ± 0.002	0.012 ± 0.020
C	0.014 ± 0.007	**0.014** ± 0.012	N/A	N/A
D	0.018 ± 0.024	0.055 ± 0.070	0.005 ± 0.002	**0.003** ± 0.001
E	0.027 ± 0.014	0.058 ± 0.021	N/A	N/A

*best values are bold and average contact time were 0.323 s (Protocol 3a) and 0.212 s (Protocol 3b)

Table 3 – Mean ± SD absolute average differences for instances of TD (s) and TO (s) between force plate benchmarks and minimal vertical marker velocity for TD and minimal horizontal marker acceleration for TO in a 135° turn.

	Protocol 4*	
Marker	TD	TO
A	0.009 ± 0.0100	0.012 ± 0.0115
B	0.008 ± 0.0094	**0.010** ± 0.0073
C	**0.006** ± 0.0062	0.011 ± 0.0086

*best values are bold and average contact times was 0.455 s

Table 4 – Mean ± SD absolute average differences for instances of TD and TO (s) between force plate benchmarks and maximal horizontal acceleration for TD and maximal vertical velocity for TO in a 180° turn.

	Protocol 5*					
Marker		TD			TO	
B	0.060	±	0.023	0.058	±	0.0288
C	0.056	±	0.013	**0.027**	±	0.0247
E	0.039	±	0.013	0.027	±	0.0386
F	**0.028**	±	0.016	0.030	±	0.0370

*best values are bold and average contact times was 0.452 s

CONCLUSION: Kinematic data can be used to accurately measure TD and TO events of in different turf-sport specific movements on artificial turf. The level of accuracy achievable depends on the movement being investigated. The accurate identifications of TD, TO and therefore ground contact time are necessary for further kinematic analysis. For example, it enables the comparison of joint angles and angular velocities between participants during the stance phase.

REFERENCES:

Bezodis, I., Thomson, A., Gittoes, M. & David Kerwin, 2007. Identification of Instants of Touchdown and Take-Off in Sprint Running Using an Automatic Motion Analysis System. In Proceedings of the 25th Symposium of the International Society of Biomechanics in Sport. Metropolitan University Cardiff, Wales.

De Witt, J.K. (2010). Determination of toe-off event time during treadmill locomotion using kinematic data. *Journal of Biomechanics,* 43, 3067-3069

Dowling, A.V., Corazza, S., Chaudhari, M.W. & Andriacchi, T.P. (2010). Shoe-Surface Friction Influences Movement Strategies During a Sidestep Cutting Task. *The American Journal of Sports Medicine,* 38 (3), 478-485

Ghoussayni, S.,Stevens, S., Durham, S. & Ewins D. (2004). Assessment and validation of a simple automated method for the detection of gait events and intervals. *Gait and Posture,* 20, 266-272

Hreljac, A. & Stergiou, N. (2000). Phase determination during normal running using kinematic data. *Medical & Biological Engineering & Computing,* 38, 503-506

Jasiewicz, J.M., Allum J.H.J., Middleton, J.W., Barriskill, A., Condie, P., Purcell, B. & Li, R. (2006). Gait event detection using linear accelerometers or angular velocity transducers in able-bodied and spinal-cord injured individuals. *Gait & Posture,* 24, 502-509

Meijer, K., Dethmers, J., Savelberg, H., Willems, P. & Wijers, B., 2006. The Influence of Third Generation Artificial Soccer Turf Characteristics on Ground Reaction Forces During Running. In Proceedings of the 24th Symposium of the International Society of Biomechanics in Sport. University Maastricht, Netherlands.

Ross, J. D. & Ashman, R. B. (1987) A thin foot switch, *Journal of Biomechanics*, 20, 733-734

Wannop, J.W., Worobets, J.T. & Stefanyshyn, D.J. (2010). Footwear Traction and Lower Extremity Joint Loading. *The American Journal of Sports Medicine,* 38 (6), 1221-1228

Zeni, J.A., Richards, J.G. & Higginson, J.S. (2008). Two simple methods for determining gait events during treadmill and overground walking using kinematic data. *Gait & Posture,* 27, 710-714