CUSTOM-BUILT WIRELESS PRESSURE SENSING INSOLES FOR DETERMINING CONTACT-TIMES IN 60M MAXIMAL SPRINT RUNNING

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The purpose of this study was to evaluate a custom-built wireless pressure sensing insole system for recording ground contact times in sprinting. Despite interest in the foot contact time/ running velocity relationship, no study has examined the contact times in a maximal 60 m sprint. Insole data were collected on three athletes during maximal indoor sprint runs. Simultaneous kinematic data for start and maximum velocity phases were recorded with a CODA system to validate insole contact times and determine velocity. Insole derived contact times were accurate to ±4 ms. Preliminary data indicate a usable contact time/velocity relationship. It is anticipated that these data will provide support for the use of wireless technology in sprint performance monitoring, and facilitate novel insights into the contact time/sprint running velocity relationship.

KEY WORDS: athletics, remote sensing, performance.

INTRODUCTION:

The recording of foot contact times during sprint running presents an opportunity to gain insight into sprint-specific performance parameters. Previous research has shown that contact times decrease with increasing velocity as an athlete changes from a walk or jog to a fast run or sprint (Luhtanen & Komi, 1978; Nilsson & Thorstensson, 1987). Separate studies have investigated the velocity-time curve of a sprint run (e.g. Henry & Trafton, 1951; Arsac & Locatelli, 2002) and the relationship between ground contact time and sprint running velocity has been investigated in the past for specific sections of the 200m sprint (Mann & Herman, 1985) and treadmill sprinting (Weyand *et al.*, 2000). However, to the knowledge of the authors, no previous attempts have been made to link ground contact times and velocity throughout a maximal sprint run. To achieve this, a reliable, lightweight wireless pressure sensing insole system was developed to ensure minimal interference with the athlete and task. It is anticipated that these data will enhance our understanding of the relationship of foot contact times and sprint velocity and form a vital component in providing performance related feedback. The first aim of this study, therefore, is to validate the insole system and the second is to investigate the relationship between contact times and velocity.

METHOD:

Participants: Three competitive male sprint athletes volunteered for participation in the study (age = 21.7 yr, height = 182.8 ± 2.5 cm, body mass = 76.8 ± 6.9 kg). These athletes facilitated appropriate maximum sprint velocities (~10 m/s). All procedures were approved by the University's Research Ethics Committee and written informed consent was obtained from the participants before data collection.

Data Collection: Motion data were captured unilaterally from each athlete's left side, using four cx1 CODA scanners (Charnwood Dynamics Ltd, UK), sampling at 800 Hz, with six active markers located according to Bezodis *et al*. (2007). Custom built pressure sensing insoles were used for the sampling foot contacts at ~2.5 kHz. Each insole was equipped with Force Sensing Resistor (FSR) – a polymer thick film, which exhibits decreasing resistance with increasing applied force. Two FSR sensor pads (6 cm square) were fitted per insole (*middle* sensor = metatarsophalangeal for touch-down detection & *toe* sensor = great toe area for toe-off (Figure 1a). The FSRs were connected with fine wires to a lightweight (28 gm) custom-built WiFi wireless data logger[1] (IMote2 with CSK WiFi board, Figure 1b) in an athlete-worn pouch at rear of the pelvis.

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[1] Cambridge Sensor Kit (CSK): http://imote2-linux.wiki.sourceforge.net/UCAM-WSB100

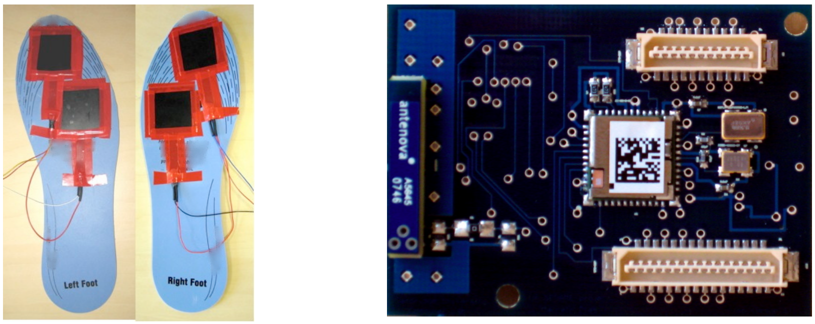

Figure 1a: FSR insoles; 1b: Cambridge Sensor Kit (CSK)

Participants were given time to perform their normal warm-up. The insoles and motion analysis markers were then attached. Following familiarisation, athletes performed six maximal 60 m sprint runs along a 120 m straight track. Motion capture data were recorded for the start (0 to 20 m) and the maximum speed phase (30 to 50 m) for three trials respectively, while the wireless insoles recorded throughout the duration of all sprints. Between runs the athletes were given self-selected recovery periods to allow for consistent performance and minimise the likelihood of fatigue effects.

Data Analysis: Contact durations were computed from the CODA data using marker acceleration maxima, (Bezodis *et al.*, 2007). Contact durations for the wireless insoles were computed using touchdown to toe-off events detected with an automated algorithm implemented in Matlab. Low-pass filtered data were differentiated and local maximum and minimum of first derivatives computed respectively. Individual step velocities were determined using the mean velocity of a greater trochanter marker throughout the duration of a step (touch-down of one foot to touch-down of the opposite foot).

RESULTS:

Contact times computed from FSRs were compared to those from CODA. The absolute RMS error was 4 ms for a total of 96 steps (53 in starts and 43 in maximal velocity). The distribution of the error (FSR ct – CODA ct) follows a standard normal distribution with mean around zero, (Figure 2). Contact time and step velocity data for a representative participant are displayed in Figure 2. Regression analysis statistics of contact time against step velocity for individual and group data is presented in Table 1.

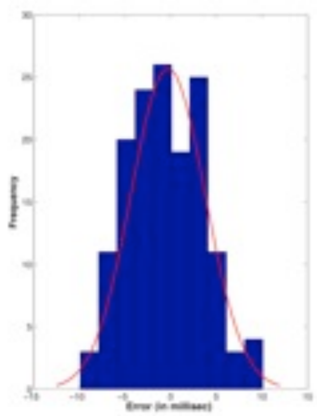

Figure 2: Distribution of error

	Combined Contact Data	Dominant Foot Only	Non-dominant Foot Only

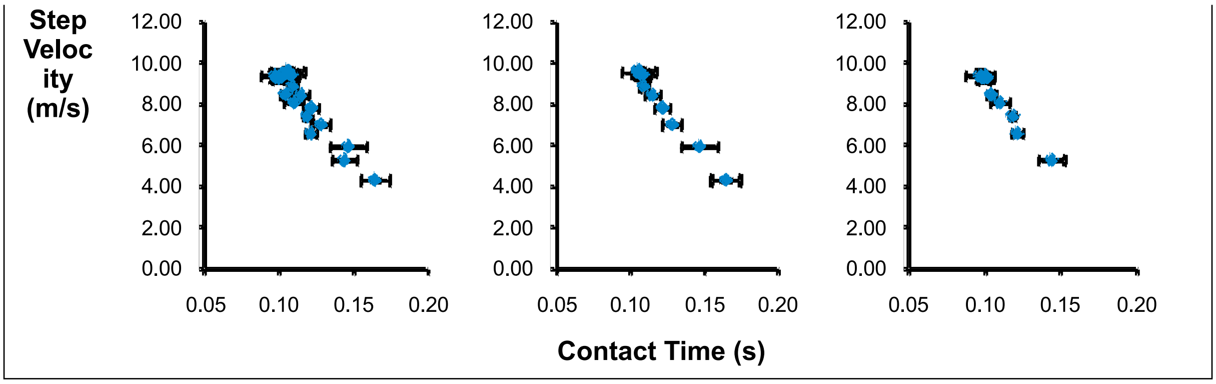

Figure 3: Contact time and velocity data for a representative athlete performing 60 m maximum speed sprints.

Table 1: Coefficient of determination values for regression analysis of individual and group contact time against velocity data

Combined Contact Data				
	Regression analysis (R^2)			
Participant	**Exponential**	**Linear**	**Power**	**Exponential Equation**
1	0.920	0.898	0.907	$y = 32.218e^{-12.09x}$
2	0.977	0.971	0.968	$y = 26.491e^{-10.16x}$
3	0.930	0.900	0.927	$y = 28.402e^{-10.51x}$
All	0.927	0.908	0.919	$y = 27.69e^{-10.53x}$
Dominant Limb Contact Data				
1	0.991	0.984	0.985	$y = 37.758e^{-13.02x}$
2	0.982	0.978	0.974	$y = 28.432e^{-10.73x}$
3	0.909	0.887	0.898	$y = 25.943e^{-9.88x}$
All	0.950	0.936	0.945	$y = 29.675e^{-11x}$
Non-dominant Limb Contact Data				
1	0.979	0.964	0.979	$y = 33.358e^{-12.95x}$
2	0.979	0.962	0.976	$y = 23.907e^{-9.307x}$
3	0.978	0.941	0.989	$y = 32.806e^{-11.56x}$
All	0.902	0.877	0.895	$y = 25.705e^{-10.02x}$

DISCUSSION:

The aim of this study was to validate a lightweight, wireless insole pressure sensing system for measuring foot contact times in sprinting and investigate the relationship between ground contact times and velocity.

Contact times for the start and maximum sprint phases can be determined with a high level of accuracy using the custom built insole system. For the mean data of three runs, there appears to be a usable relationship of contact time and velocity (Figure 3). Regression analysis showed that an exponential relationship resulted in the best data fit (Table 1). Continuous bilateral monitoring of foot contact times provides novel insight into the fundamentals of sprint running. In addition to the relationship with sprint velocity the tracking of contact times over the entire length of a sprint run may eventually allow for the evaluation of additional performance parameters such as transitional phases of the sprint run. This relationship was strongest for the data from individual athletes compared to group results. Furthermore, the dominant limb displayed a slightly closer relationship than the non-dominant limb.

These findings suggest that athlete-specific contact and velocity data recorded for multiple sprint runs may allow for the creation of individual contact time/velocity relationships and the prediction of velocity based on the regression equation (Table 1) and contact times only. The prediction of velocity from contact time would provide an essential tool for the sprint coach to track athlete development and enhance coach-athlete communication. Moreover, these findings show that the inclusion of lightweight, wireless technology in the sporting setting allows for continuous and un-intrusive recording of performance measures

CONCLUSION:

Moreover, the use of contact time data and its inclusion as a performance measure in athlete feedback may provide vital information to enhance task comprehension and performance. Using the simple measurement of individual ground contact times may therefore allow for enhanced performance related feedback and act as an essential tool in sprint coaching through athlete monitoring in competition and training.

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