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Full body motion analysis of trip recovery in younger and older adults

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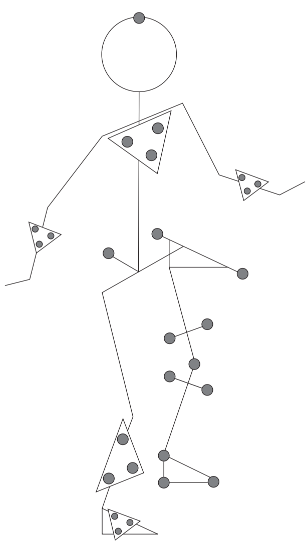
This research has set out to better understand why some people fall after they trip, while others are able to regain their balance.
This knowledge will provide important information for fall prevention practices and reduce the number of falls in older adults.
Falls in older adults are a major problem, as about one in every three adults aged over 65 fall at least once a year [1]. Most falls in older adults are caused by tripping over an obstacle, such as a kerb or uneven pavement when walking outdoors, or loose carpets or cables at home. These falls have large health, social and economical costs.



We compared tripping responses of a group of nine younger women (aged 20 to 35 years) with a group of eight older women (aged 65 to 75 years). We wanted to investigate the influence of the lower limbs as well as the arms on trip recovery success. Movements during trip recovery occur in planes, therefore three-dimensional full body kinematic data were collected at 200 Hz with the Coda cx1 system (Charnwood Dynamics Ltd.). A total of 27 markers were used in a combination of a custom triad set-up and the Codamotion segmental gait analysis marker set. The marker setup is shown in the figure below. In static trials, the relative positions of the joint centres to the triad markers were recorded. For dynamic trials, virtual markers were defined based on this information. This specific set-up was defined to be able to measure three-dimensional kinematics with the use of a single scanner. Additional measurements taken were ground reaction forces with a force plate (Kistler 9287BA), to be able to calculate the joint moments at the lower limbs, and muscle activity with EMG (Noraxon, Telemyo).
In the experimental protocol the women walked over a walkway and they were tripped in random trials. A tripping device was custom designed for this experiment. This device consisted of plates that could be rotated upwards and obstruct either the left or right foot to cause a trip. To ensure the participants could not fall if they were unable to recover from a trip, all participants were secured in a safety harness that was attached to an overhead rail.
The outcomes of this research showed that younger adults used their arms effectively during trip recovery to prevent them from falling. Older adults on the contrary used their arms in a more protective way and reached forward to arrest a possible fall [2]. This research also showed that older adults were not as effective as younger adults in using their recovery limb to prevent falling after a trip and in some occasions selected a different recovery strategy [3]. Possible underlying reasons for this are muscle strength, movement speed and placement of the recovery limb. These are at the moment being further investigated. Our research group uses a combination of experiments and computer simulations in this research and a computer model has been developed that simulates movements of trip

recovery [4]. The future goal is to develop an assessment tool that will assist in selection of the most appropriate fall prevention therapy for specific individuals. This tool will be designed using the experimental outcomes in combination with the computer simulation model.

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Identification of Instants of Touchdown and Take-Off in Sprint Running

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a) **b)**

Figure 1.
The lateral (a) and medial (b) locations of the CODA markers on the sprinting shoe prior to secure attachment of wires. Marker locations: superior to the distal end of the first toe [A]; lateral to the distal end of the third toe [B]; superior to the first interphalangeal joint of the second toe [C]; lateral to the distal end of the fifth toe [D] and lateral to the fifth metatarsophalangeal joint [E]; superior to the distal end of the first toe [F]; medial to the distal end of the first toe [G]; superior to the first inter-phalangeal joint of the second toe [H]; medial to the first inter-phalangeal joint of the first toe [J] and medial to the first metatarso-phalangeal joint [K].

The identification of the instants of touchdown and take-off are important in defining step characteristics in sprinting. Furthermore, previous studies of sprinting have identified the magnitude of key kinematic variables at touchdown and take-off as being important indicators of performance. Examples include high knee flexion velocity at touchdown (Mann & Herman, 1985) and reduced hip extension angle at take-off (Kunz & Kaufmann, 1981). The purpose of this study was to evaluate the accuracy in determining the instants of touchdown and take-off during a sprint run using a single CODA motion scanner unit, based on:
(i) The vertical displacement of toe markers from a standing trial;
(ii) The peak vertical acceleration as a threshold value for ground contact.

Methods

Six athletes (5 male, 1 female; age 22.8 ± 1.6 years, body mass 75.5 ± 9.4 kg; height 1.78 ± 0.06 m) participated in the study. As illustrated in Figure 1a, active CODA markers (800 Hz) were positioned on the lateral aspect of each subject's left sprinting shoe, at five sites. Two static, standing trials (flat feet and tip-toed), where position data were collected using a CODA motion analysis system (6.69G-CX1/MPX30) were acquired for each subject (capture time: 10 s). Subjects then completed ten running trials, in which a single foot contact was made with a force plate (1000 Hz, 9287BA, Kistler Instruments Ltd., Switzerland). A second series of two standing and ten sprint trials was performed in which markers were attached to the medial aspect of the shoe (Figure 1b).
Vertical ground reaction force, marker position and marker acceleration data (low pass filtered at 20 Hz) for all static and sprint running trials were exported at 800 Hz for further analysis. Criteria

Table 1: Mean RMS Differences in Touchdown (TD) and Take-off (TO) Times between Force Plate Criterion and Marker Derived Criterion from Three Experimental Conditions across Six Subjects.

Marker		Marker RMS Differences with respect to Force Plate Criterion [s]					
		Flat-footed Coordinate		Tip-toed Coordinate		Vertical Acceleration	
		TD	TO	TD	TO	TD	TO
Lateral	**A**	0.007	0.015	0.026	0.012	0.006	0.009
	B	0.005	0.008	0.047	0.008	0.005	0.017
	C	0.015	0.006	0.033	0.004	0.007	0.007
	D	0.003	0.012	0.023	0.024	0.005	0.022
	E	0.004	0.048	0.004	0.040	0.005	0.009
Medial	**F**	0.005	0.015	0.031	0.011	0.007	0.009
	G	0.047	0.009	0.025	0.006	0.007	0.008
	H	0.013	0.005	0.035	0.009	0.007	0.007
	I	0.007	0.009	0.019	0.015	0.007	0.006
	J	0.017	0.030	0.013	0.026	0.007	0.008

for touchdown and take-off were determined from force data. Marker derived touchdown and take-off times were determined using the standing trials as a criterion and, separately, using peak vertical acceleration. Mean RMS differences across all subjects between force plate and marker derived criteria were calculated.

Results

Mean RMS differences across six subjects for each condition are displayed in Table 1.

The lowest individual RMS differences between the criterion measure and marker derived event time occurred when using coordinates from the static trials.

Discussion

The instants of touchdown and take-off during sprint running contacts could be determined to between 0.003 and 0.005 s of the force data-derived criterion measure when using coordinate data of lateral and medial foot markers. The presented RMS differences were equivalent to a resolution of measurement of at least 200 Hz. This provided a similar level of accuracy to that reported by Hunter et al. (2004), who identified the instant of touchdown to within one field at 240 Hz in 93% of trials when using the method of Hreljac and Marshall (2000). The findings of this study suggest that two markers located on each of the lateral and medial aspects of the foot could be used to identify the instants of sprint running touchdown and take-off. Lateral and medial marker sets of the foot were necessary to accommodate laboratory-based data collections in which a unilateral CODA scanner was used to track bilateral sagittal plane motions. The peak vertical acceleration threshold could be used when the collection of a standing trial is not possible; for example, the vertical displacement threshold for sprint contacts on a banked curve may be difficult to derive.

Conclusion

Identification of contact events are important for the determination of step characteristics and event-specific kinematics during sprint running performances. Using vertical displacements of foot markers, touchdown and take-off events in sprinting could be identified to between 0.003 and 0.005 s of a force data derived criterion measure.

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Human walking and running forces:

novel experimental characterisation and application in civil engineering dynamics

VIBRATION ENGINEERING SECTION

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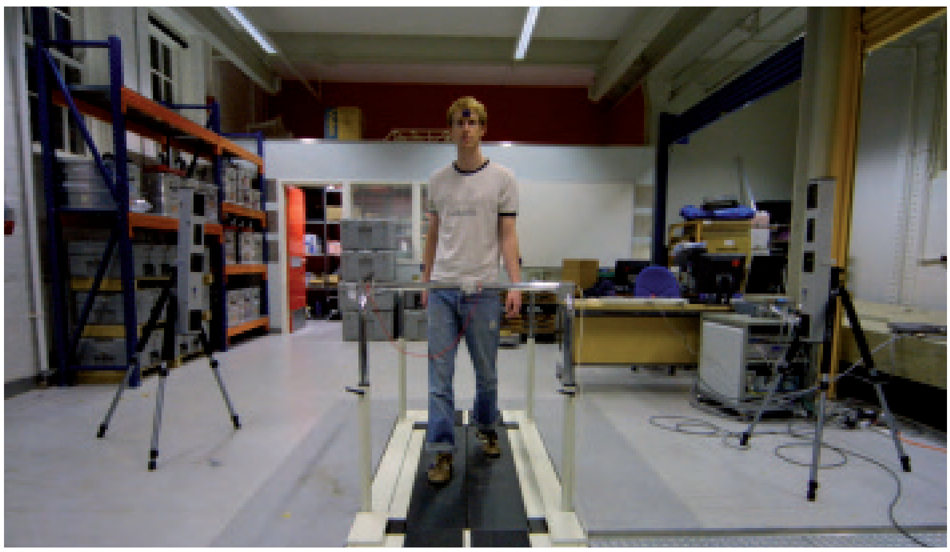

The Vibration Engineering Section in the Department of Civil & Structural Engineering, University of Sheffield, is utilising the Codamotion (Charnwood Dynamics, UK) and ADAL3D (Medical Development, France) instrumented treadmill to study how people walking and running affect slender civil engineering structures, such as footbridges, floors and staircases, prone to vibrations when occupied and dynamically excited by humans.

Of all dynamic forces induced by humans, such as jumping, bouncing/bobbing and swaying, the dynamic forces induced by human walking and running are the least understood and most complex to deal with when considering performance of civil engineering structures that are dynamically excited by these activities. This is because they change simultaneously in time and space, being random in nature and varying considerably not only between different people but also for a single individual who cannot repeat two identical steps. The variations in how people walk and run make the effect of such movements on engineering structures unpredictable and have to be quantified in order to provide adequate guidance to designers. There are varied opinions on the extent to which the constrained motion on a treadmill can represent normal walking. Hence data on variability and statistics of the loads induced by individuals and groups when walking and running will be gathered using the Codamotion tracking system. There are two key novelties in the proposed approach:

(1) utilisation of 'free field' measurement of three-component continuous walking/running forces by measuring movement of the human body or bodies without artificial restrictions such as handrails or the controlled speed of the treadmill belt. Procedures for identifying these forces will be calibrated by comparison with standard direct measurement of forces on a treadmill.

(2) the investigators aim to establish a database of measured time-varying traces of walking/running forces to develop stochastic models that can predict more realistically the vibration behaviour of real-life structures under pedestrian-induced excitation leading to more rational and efficient designs.

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The Effects of a Taping Technique on Foot Motion and Joint Displacement During Gait

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Low dye (LD) taping is a commonly used physiotherapy technique to treat symptoms in the lower limb related to excessive pronation. Various measures of pronation including vertical navicular height, navicular drop, plantar pressure patterns and 2D video analysis have been used to assess the effectiveness of LD taping in subjects with excessive pronation. However no studies have previously investigated the effects of LD taping at the subtalar joint using 3-D analysis. The aim of this study was to investigate the effects of LD taping on pronation, supination and total range of motion at the subtalar joint in healthy subjects with increased pronation using 3-D CODA motion analysis. A convenience sample of 20 healthy university staff and students participated in the study. A repeated measures crossover study design was used, where subjects were assessed under both taped and non-taped condition. Pronation, supination, mean joint position and total subtalar ROM were analysed and compared between the two conditions. Descriptive statistics were used to determine whether differences at the subtalar joint under both conditions were statistically significant. The results demonstrated statistically significant differences were found between taped and non-taped conditions for pronation, supination and total subtalar ROM. Pronation ($p<0.05$) supination ($p<0.05$) and total subtalar joint ROM ($p<0.05$) decreased significantly under the taped condition compared to the non-taped condition. No statistically significant differences were however found between taped and non-taped conditions for mean subtalar joint position. These findings support previous research findings that suggest that LD taping reduces pronation at the subtalar joint. It also appears, however, that LD taping reduces supination and overall ROM at the subtalar joint. Therefore, the mechanism of action may be more related to limiting mobility in general, rather than having a specific anti-pronation effect at the sub-talar joint. Key words: Taping, CODA, pronation, subtalar

Movement Analysis in Singapore

REPUBLIC POLYTECHNIC

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Republic Polytechnic's School of Sports, Health and Leisure acquired the Codamotion motion capture and analysis system in April this year. Since its commissioning, we have built up an intensive research agenda involving its use. Here in our human performance laboratory, we mentor students from secondary schools in research projects involving gait analysis and orthotics intervention. Two of our projects were awarded distinctions in the mentoring programme hosted by the local Ministry of Education. Our other projects involve evaluating our markerless tracking system against the Coda system; load carriage analysis on an instrumented treadmill integrated with the Coda; and, drop jump analyses using the Kistler force platform also integrated with the Coda. We will be embarking on a new research agenda on sports technique analyses in 10-pin bowling, golf swing analyses and injury management programmes in the new year.

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