INTRODUCTION
Adults and children walk in footwear that is described as being either ‘flat’ or having a ‘heel’. Footwear with a heel has a positive ‘heel sole differential’ (HSD): the difference between the height of the heel (the rearfoot height) and the thickness of the sole of the footwear at the metatarsal phalangeal joints (the forefoot height). When walking in footwear with a positive HSD the sagittal kinematics of the base of the footwear appears to mimic the kinematics of the foot in normal barefoot walking creating an ‘effective foot’ that is separate from the ‘actual foot’. Furthermore, sagittal lower leg or shank, thigh, and trunk kinematics appear to remain unchanged. In fact, when observed by eye, walking in footwear with a positive HSD is virtually identical to walking barefoot except when very high heeled shoes are worn. These observations require description and quantification as they are an important phenomenon for both orthotic and prosthetic practice. Hence, the purpose of this study was to assess the effect of footwear with different HSDs on the sagittal shank and foot segment kinematics of walking in able-bodied persons.

METHOD
Subjects: A convenience sample of 10 nondisabled adult female volunteers experienced in walking with shoes with different HSDs were retrospectively assessed (Hansen and Childress, 2004).

Apparatus: Gait data were recorded using an eight-camera motion analysis system (Motion Analysis Corporation). Motion data were sampled at 120 Hz. A modified Helen Hayes marker set was used.

Procedures: Gait data were collected while subjects walked with no-heel, mid-heel and high-heel shoes, for at least five trials of each condition.

Data Analysis: Data were used to calculate the shank segment angle with respect to the vertical of the laboratory frame (the shank-to-vertical angle) and the actual foot segment angle with respect to the horizontal of the laboratory frame, (the foot-to-horizontal angle), as a function of the gait cycle (GC). Stride lengths were measured as well as the footwear HSD’s. The degree of pitch of the footwear was calculated. A one-way multivariate analysis of variance (MANOVA) was conducted for segment kinematics and an ANOVA for stride lengths.

RESULTS
The mean HSD of the footwear were: no-heel shoes 0 ± 0 mm, mid-heel shoes 37 ± 10 mm, and high-heel shoes 71 ± 17 mm. For the three footwear conditions there was no significant difference in stride lengths (p = 0.056). From 0-50% GC there was also no significant difference in shank kinematics with changes in HSD, F (6, 52) = 2.025, p=0.079; Pillai’s Trace = 0.993; partial eta squared = 0.189. There was however, between 0-50%GC, a significant difference in actual foot kinematics with changes in HSD, F (6, 52) = 8.182, p=0.000; Pillai’s Trace = 0.971; partial eta squared = 0.486. The actual foot segment angle increased with increasing HSD and pitch.

DISCUSSION
In terms of HSD, the no-heel condition was equivalent to barefoot walking. Shank kinematics during 0-50% gait cycle were similar regardless of the footwear HSD. The no-heel foot kinematics were being produced by an ‘effective foot’ on the bottom of the heeled shoes, the actual foot shifting its angle by the degree of pitch of the footwear and the ankle joint adapting its kinematics so that shank segment kinematics remained invariant (Owen, 2010). These findings are consistent with research findings on roll-over shapes (Hansen & Childress, 2004) and ankle kinematics in footwear (Murray, 1967). Further research is needed to compare segment kinematics of the effective foot, thigh, pelvis and trunk in varying HSDs to segment kinematics when walking barefoot.

CONCLUSION
During 0-50% gait cycle stance phase shank kinematics do not change with changes in HSD. Actual foot angles do change, increasing with increasing HSD of footwear and by the angle of pitch of the footwear.

CLINICAL APPLICATIONS
Many patients will be able to walk with normal effective foot and shank kinematics when a short calf muscle or restricted ankle joint movement is present if footwear with an appropriate HSD is provided. It is also possible to incorporate these principles into other orthotic and prosthetic designs.

REFERENCES