Changes in gait characteristics due to an unstable shoe construction.

A Pilot study performed for Freedom Shoes Ltd

February 2008

CSES
Centre for Sport and Exercise Science

Sheffield Hallam University
SHARPENS YOUR THINKING

Tim Vernon; Dr Jonathan Wheat

The Centre for Sport and Exercise Science
Sheffield Hallam University
Collegiate Hall
Collegiate Crescent Campus
Sheffield
S10 2BP

Tel: 0114 225 2544
Fax: 0114 225 4341

1.0 Introduction

This pilot study was commissioned by Freedom Shoes Ltd (London, UK) and details research performed at and by The Centre for Sport and Exercise Science at Sheffield Hallam University. This independent research presents a scientific approach to the evaluation of gait, the results of which will inform the reader regarding the effect of Freedom Soles shoes on normal gait characteristics. The advanced biomechanics technology used will help ascertain whether wearing Freedom Soles shoes effects normal gait kinematics and kinetics.

2.0 Methods

Participants

A single female participant (age 24 years, stature 1.78 m, body mass 70 kg) volunteered to take part in the study. The participant was physically active and free from musculoskeletal injury at the time of testing. The University's Ethics Committee approved the procedures, and written informed consent was gained from the participant before data collection.

Experimental set-up

All kinematic data were collected using a twelve-camera digital motion capture system (Motion Analysis Corporation, Santa Rosa, CA, USA) sampling at 200 Hz.

The twelve cameras of the motion capture system were placed in optimal positions around a calibrated measurement volume of dimensions 5.0 × 2.0 × 3.0 m in the *x*, *y* and *z* directions repectively. The measurement volume was made this size to incorporate a step both before and after the stance phase on the Kistler Type 9281CA force platform (Kistler Instrumente AG Winterthur, Switzerland) which was embedded in the laboratory floor and covered with a surface common to the entire laboratory. The force platform sampled data at 1000 Hz and was time-synchronised with the motion capture system.

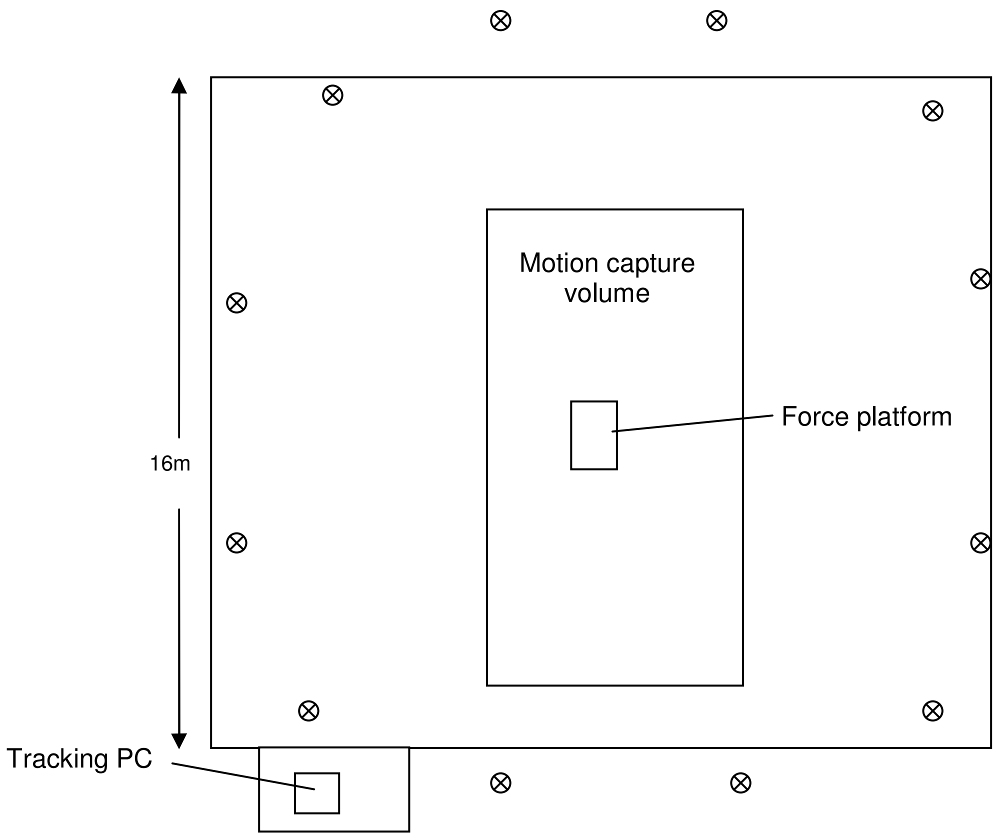

Figure 2.1: The experimental setup ⊗ - Digital motion capture camera.

Seventeen retro-reflective markers (12.5 mm diameter) were attached to the participants right leg and pelvis. Markers were attached to the participants' right 2nd and 5th metatarsal head (closest approximation on the shoe), posterior aspect of the calcaneus (closest approximation on the shoe), lateral and medial malleolus, lateral and medial epicondyle, anterior superior iliac spine and sacrum. Six further markers were attached to two heat moulded plastic clusters and mounted to the right shank and thigh.

Static calibration trial

For each condition a static calibration trial was collected to allow for correct anatomical reference frame alignment. Kinematic data were collected for 5 seconds with the participant in the calibration standing position. Following this trial the lateral and medial malleolus and lateral and medial epicondyle markers were removed.

Data collection session

Prior to testing, the participant was provided with a pair of Freedom Soles shoes and instruction conforming to manufacturer's specifications.

After preparation and attachment of the marker set, the participant was required to traverse the laboratory, approximately 16 m in length, at their preferred speed while making contact with the force platform with the right foot. The participant completed twelve 'good' trials in both the Freedom Soles and normal shoe conditions.

Trials were accepted when the whole of the participant's foot contacted the force platform, without any obvious alterations to their gait. The participant was permitted as many practice trials as she required to become able to consistently achieve this prior to the onset of data collection. During each trial, five seconds of kinematic data were collected using the motion capture system along with the kinetic data from the force platform.

Standing trials

Quiet standing trials were captured for the normal and Freedom Soles condition as well as for an MBT (Masai Barefoot Technology) condition. This involved the participant standing facing the positive X direction, on the same Kistler Type 9281CA force platform sampling at 100Hz for 60 seconds. The anterior/posterior and medial/lateral centre of pressure were calculated using Bioware software (Kistler Instrumente AG Winterthur, Switzerland). Data were filtered using a 7-point moving average and graphed in Microsoft Excel software (Microsoft Corp, 2003).

Data analysis

The three-dimensional coordinate data were filtered using a second order low-pass Butterworth filter; a cut-off frequency of 6 Hz was used and was selected through visual inspection of the fit. Hip, knee and ankle Joint Coordinate System (JCS) angles (Grood and Suntay, 1983) were then calculated using customised Visual 3D software (C-Motion Inc, Rockville, MD, USA). The three-dimensional angles of the pelvis relative to the global coordinate system were also calculated using the Visual 3D software.

The resulting angular displacement profiles were then cropped to the length of one foot contact and interpolated to 100 data points. The vertical component of the ground reaction force was used to determine foot contact events - thresholds of 20 N and 10 N were used to determine foot-strike and toe-off respectively.

The Visual 3D software (C-Motion Inc, Rockville, MD, USA) was also used to calculate internal resultant joint moments at the hip, knee and ankle using an inverse dynamics technique.

3.0 Results and Discussion

Kinematics

Comparison of walking in normal and Freedom Soles shoes suggested that there were some alterations in gait kinematics.

The use of Freedom Soles elicited a decrease in the hip flexion (Figure 3.1) and ankle plantar-flexion angle (Figure 3.2) experienced at Heel strike and during weight acceptance. Most of the changes in Kinematics could be associated with a shorter stride length as promoted during the Freedom Soles training.

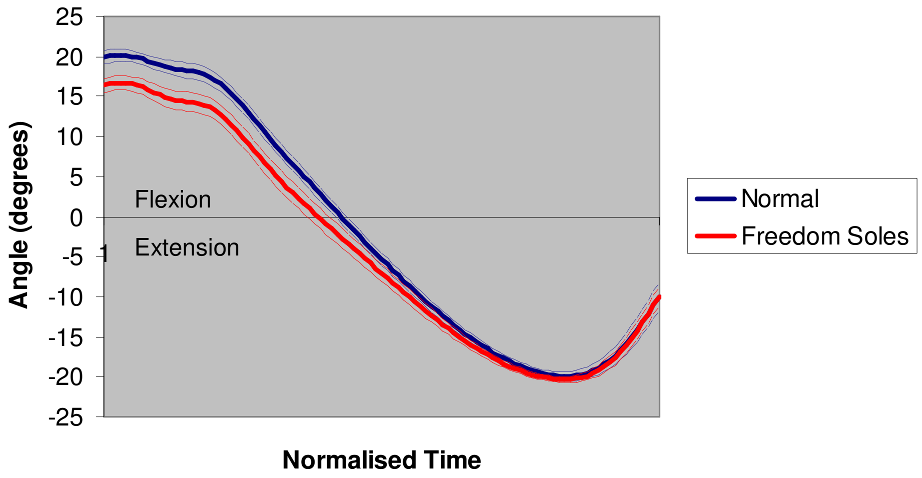

Figure 3.1: Hip angle during the stance phase of gait for the Freedom Soles and normal condition.

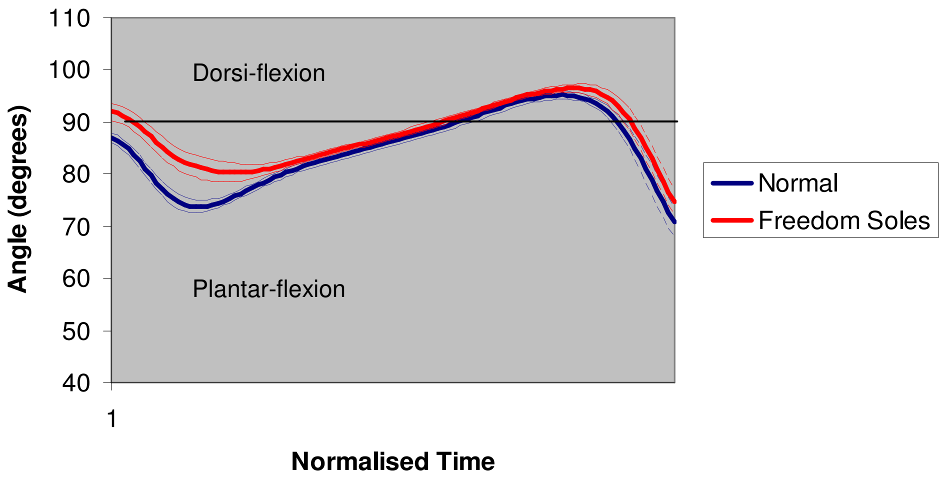

Figure 3.2: Ankle angle during the stance phase of gait for the Freedom Soles and normal condition.

Kinetics

Analysis of joint kinetics during walking showed a number of differences in the joint moments experienced during the Freedom Soles and normal conditions. At the hip (Figure 3.3), Freedom Soles shoes produced a lower extension moment during weight acceptance. The hip also exhibited lower flexion moments during terminal stance when using the Freedom Soles.

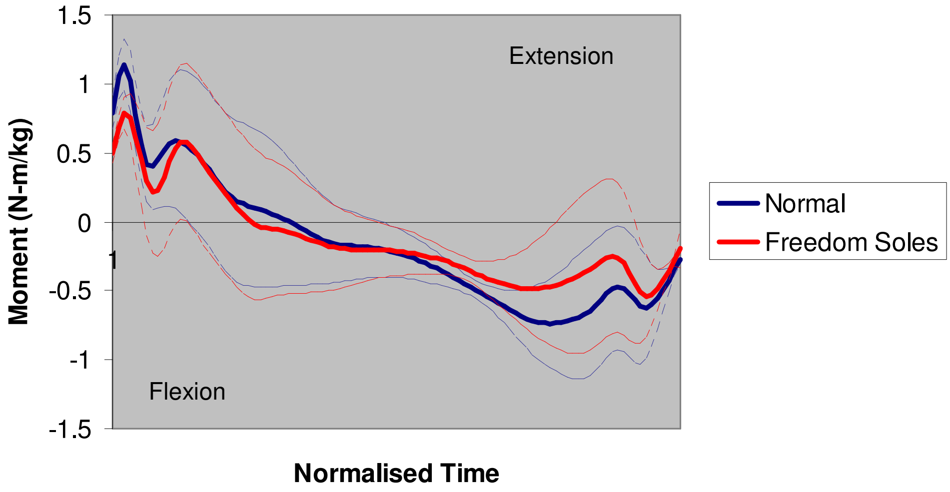

Figure 3.3: Hip flexion/extension moment during the stance phase of gait for the Freedom Soles and normal condition.

The knee (Figure 3.4) experienced lower flexion moments during initial contact and lower extension moments during weight acceptance when using Freedom Soles. However the Freedom Soles did elicit an increase in the knee flexion moment during terminal stance.

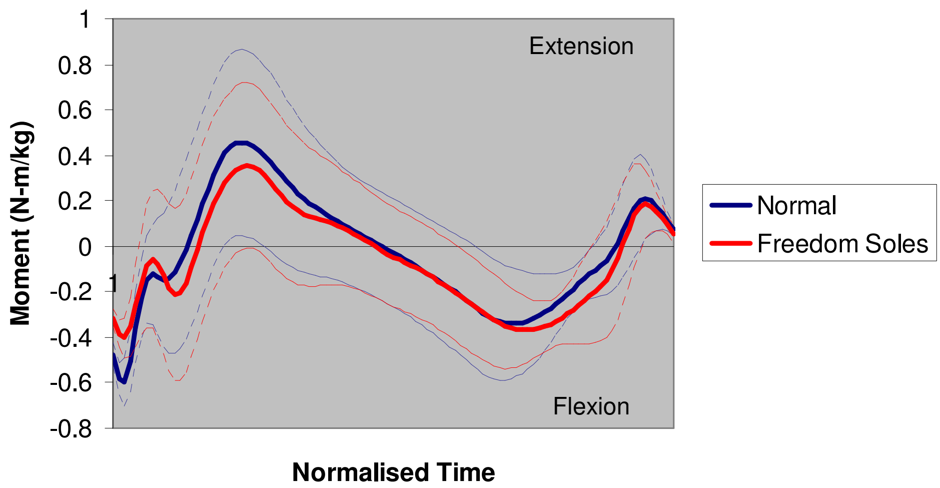

Figure 3.4: Knee flexion/extension moment during the stance phase of gait for the Freedom Soles and normal condition.

At the ankle (Figure 3.5) there were reductions in the dorsi-flexion moments experienced during initial contact in the Freedom Soles condition compared to the normal condition.

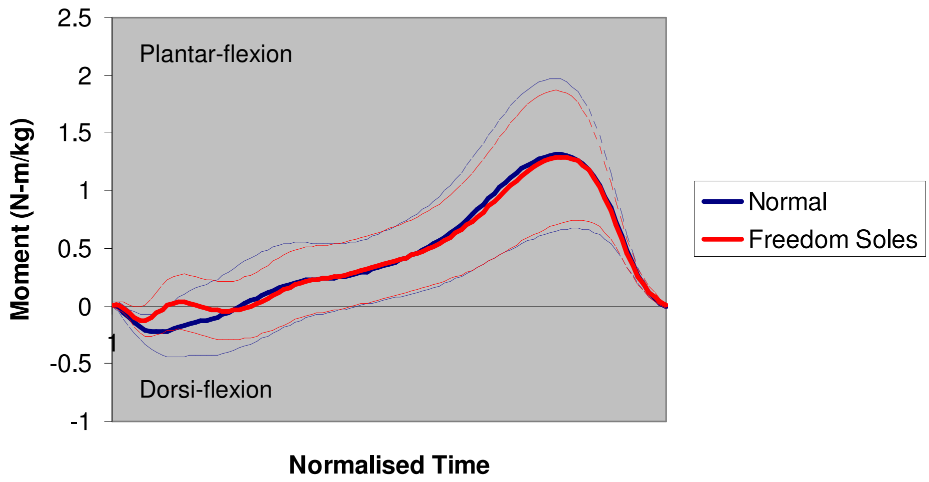

Figure 3.5: Ankle Plantar-flexion/dorsi-flexion moment during the stance phase of gait for the Freedom Soles and normal condition.

Similar to the kinematics results, the differences in kinetics could be explained by the shortened stride length.

Ground Reaction Force

Analysis of the ground reaction forces (Figure 3.5) suggested that the Freedom Soles condition elicited a decrease in the vertical impact peak. No difference was found in the magnitude of the active peaks.

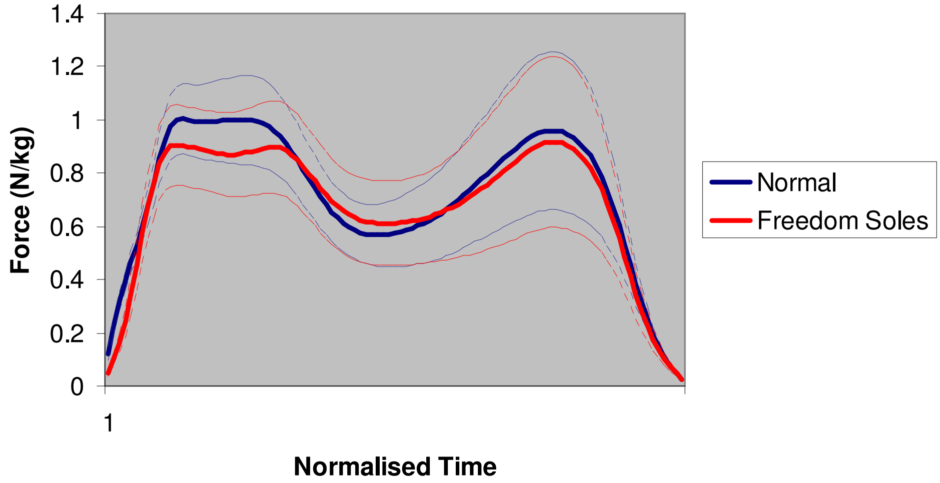

Figure 3.6: Vertical ground reaction force trace during the stance phase of gait for the Freedom Soles and normal condition.

Postural Sway

Analysis of the centre of pressure showed that there was less sway during standing when wearing normal shoes compared to Freedom Soles and Massai Barefoot Technology shoes (Swiss Masai AG, Switzerland). Freedom Soles exhibited less centre of pressure movement than MBT's in both the anterior/posterior and Medial/lateral direction.

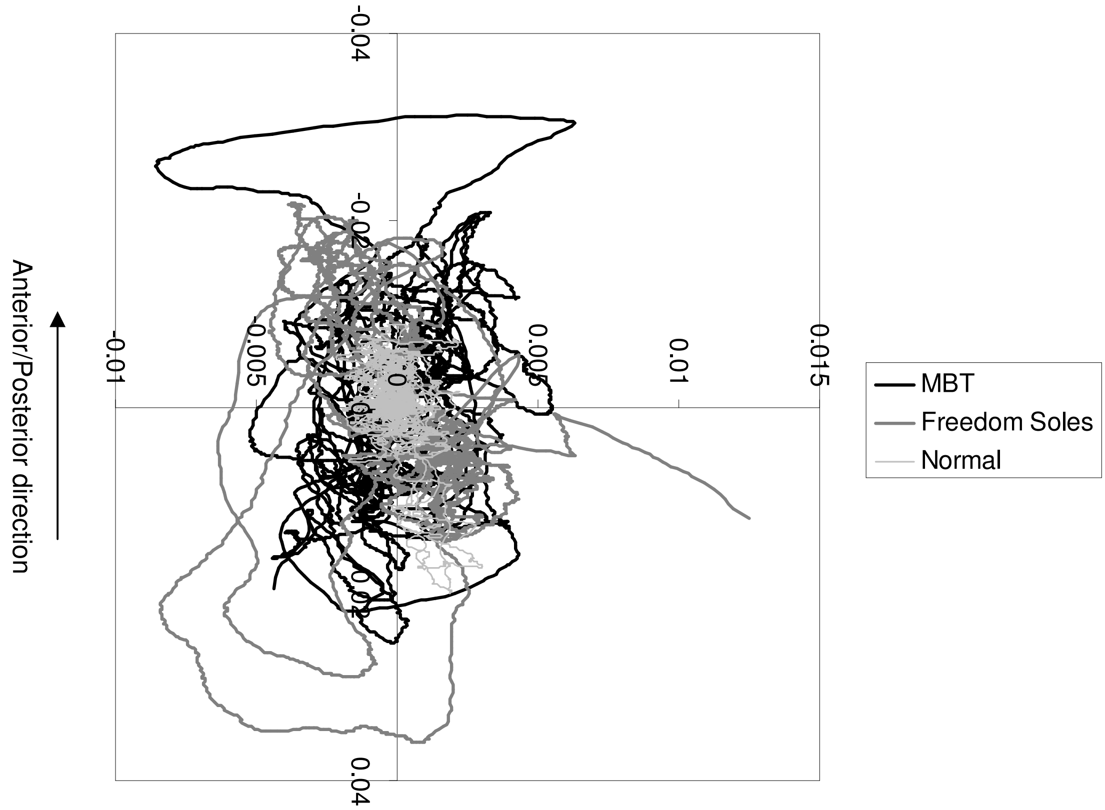

Figure 3.7: Centre of pressure distribution during standing during normal, Freedom Soles and MBT conditions.

4.0 Summary

In Summary; Freedom Soles do have an effect upon the lower limb kinematics and kinetics of gait for the participant used during this pilot study. The results suggest a reduction in some of the joint moments experienced at the hip knee and ankle and a reduction in ground reaction force impact peak. These results could be largely attributed to a decrease in stride length inherent in the Freedom Soles walking technique; however this will need further investigation.

During standing, these initial pilot results suggest that Freedom Soles are less stable than normal shoes but more stable than MBT's in both the anterior/posterior and medial/lateral directions.

Importantly, these results only reflect the changes seen in the one participant included in this study and, as such cannot be generalised. More research should be conducted with a greater number of participants. Furthermore resarch using electromyography techniques should be performed to ascertain differences in muscle activation during different conditions.