

Q4E Case Study 21

Gait Analysis: Effect of an unstable shoe construction

Introduction

Linear and angular kinematics during walking have been widely analysed whilst walking barefoot and in shoes (Lythgo et al. 2009) in order to establish a 'normal' model and identify any factors that may lead to injury. 'Unstable shoe constructions' were originally used clinically to help treat conditions such as plantar fasciitis, diabetes mellitus and the rehabilitation of ankle joint injuries (Hutchins et al. 2009). However they are now increasingly popular with ordinary consumers who purchase them in the belief that they will reduce stress on lower body joints and increase lower limb muscle activation thus helping to tone the lower body (Pocari et al.; Romkes et al. 2006).

The gait cycle consists of a stance and swing phase of which the shoe affects mainly the stance phase. The stance phase is again split into two phases: the braking phase and the propulsive phase.

Aim

The aim of this study is to look at the effect of three unstable shoes on gait kinematics during the stance phase of walking.

Method

Video data was collected for the three shoes and a barefoot trial for nine subjects. The subjects performed six walks in each of the shoes.

Data Acquisition

- Subjects filmed side on using Casio FH25 camera at 210 frames/sec and a shutter speed of 1/1000
- Reflective markers placed at hip, knee, ankle and metatarsophalangeal (MTP) joints.
- Hedler lamp used to ensure markers were clearly visible

Data Analysis

- Markers used to identify heel strike and toe off
- Videos calibrated and digitised in Quintic Biomechanics Software (9.03 v17) – 10 frames prior heel strike and 10 frames after toe off (figure 1)
- Linear and angular data exported to excel where means were calculated
- Multi image capture used to create photo sequence of the gait cycle

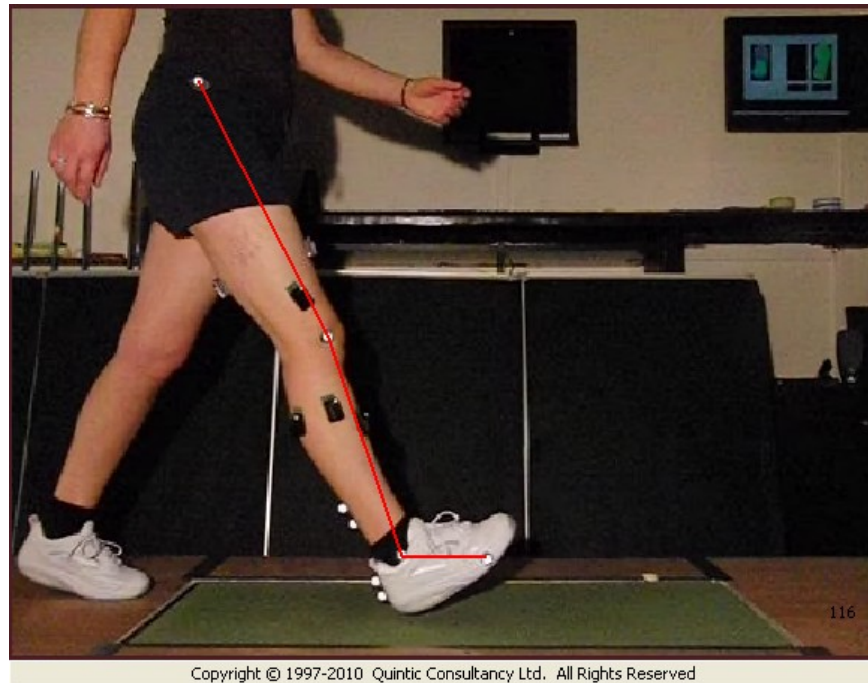


Figure 1: Video with digitisation trace

Results – Linear joint velocities

Figure 3 shows the average linear velocity of the four joints during the stance phase. Hip velocity is relatively constant throughout with a range of 0.91m/s whereas the other 3 joints display a far greater range of velocities starting around 1.30m/s then dropping to below 0.50m/s before increasing to over 2.00 m/s. Knee, ankle and MTP velocity all follow a very similar pattern: sharp decrease after heel strike, then a period of low constant velocity before a rapid and sustained increase in velocity up to toe off. The hip joint also follows this pattern but with far less severe changes in velocity.

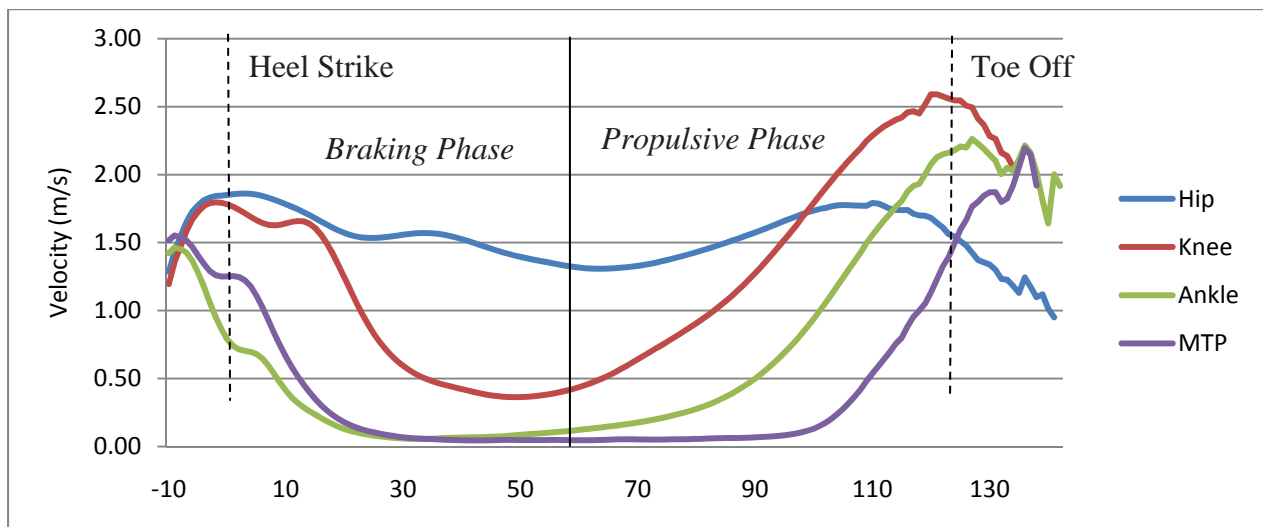


Figure 2: Overall mean velocities during the stance phase of the gait cycle

Figures 3, 4, 5 & 6 show that the barefoot condition resulted in the lowest linear joint velocities at all four joints but otherwise there is very little variation in linear velocity between the different shoes.

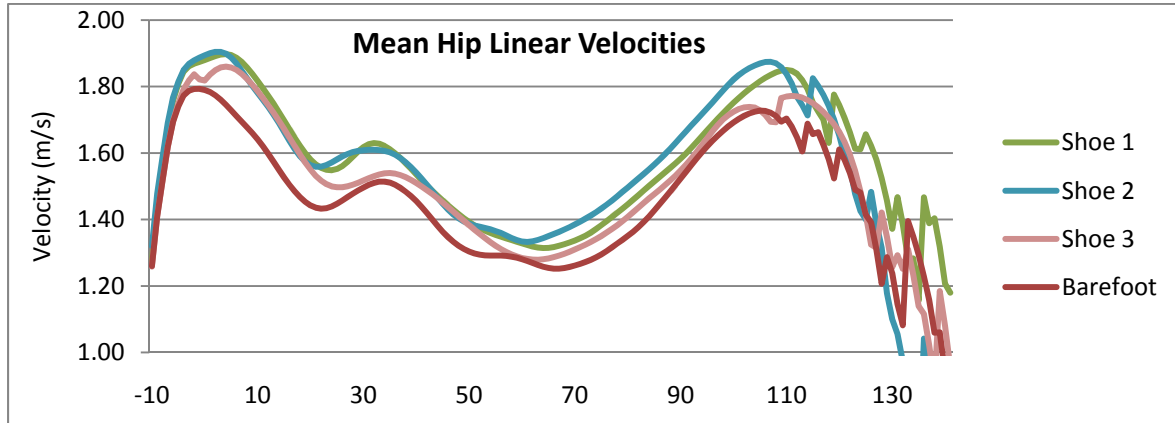


Figure 3: Mean Hip Linear Velocities for all shoes

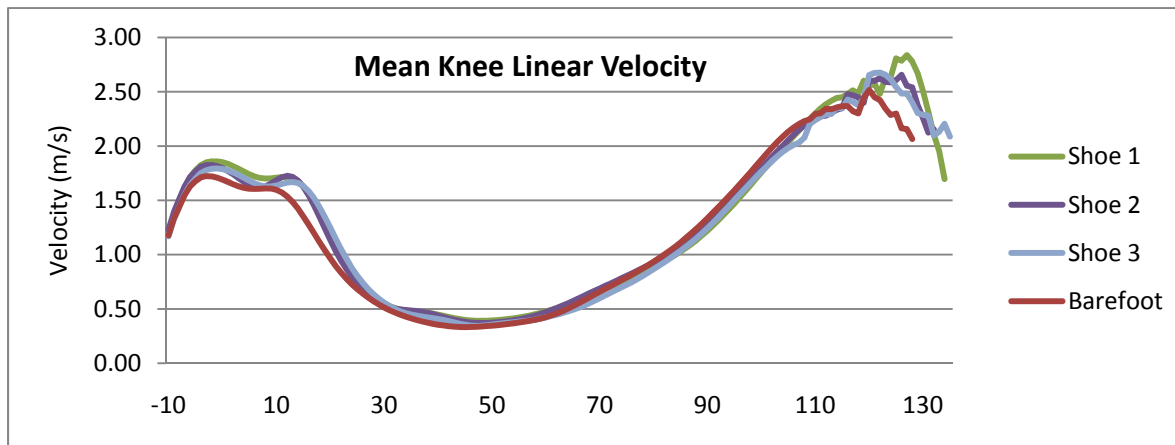


Figure 4: Mean Knee Linear Velocities for all shoes

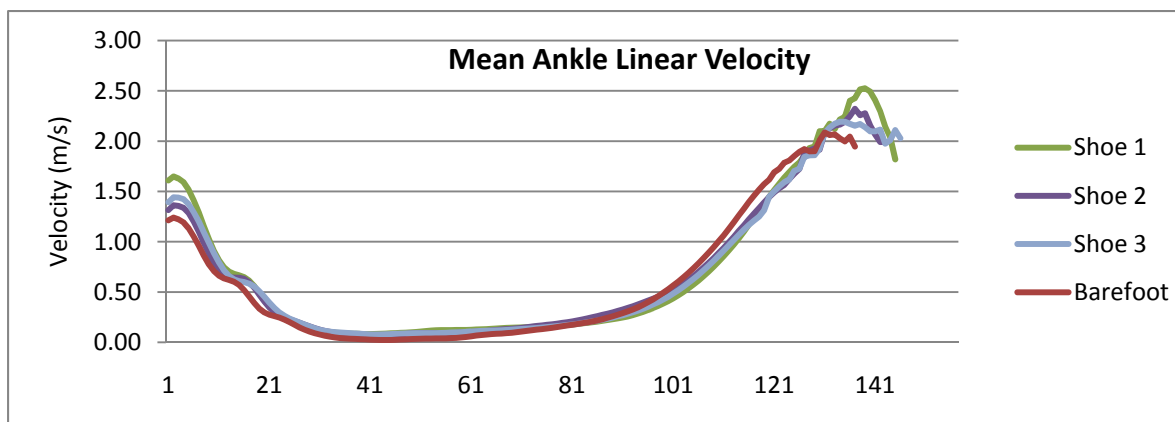


Figure 5: Mean Ankle Linear Velocities for all shoes

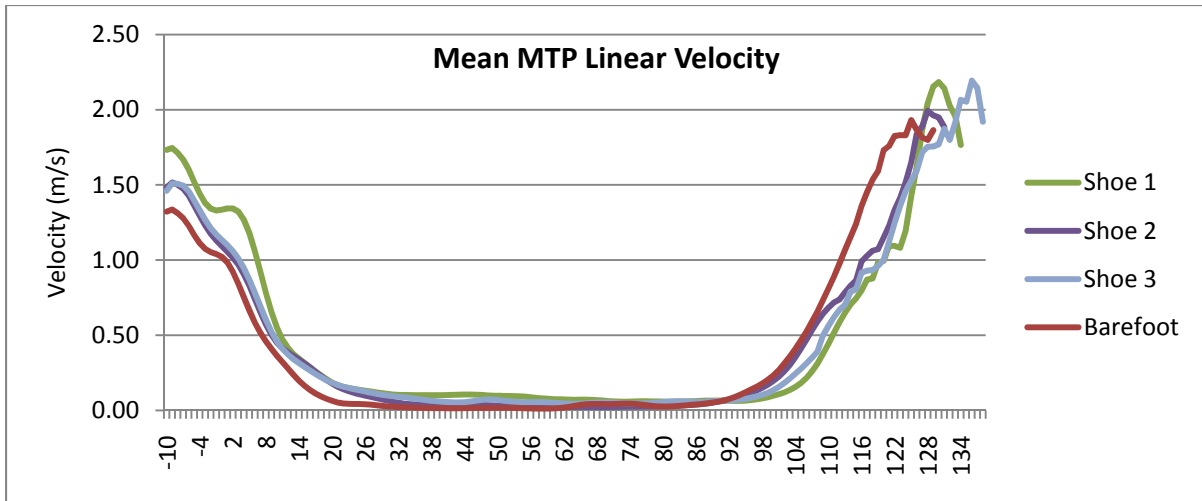


Figure 6: Mean MTP Linear Velocities for all shoes

Results – Joint angles

All shoe conditions displayed very similar knee angles throughout the stance phase (figure 7).

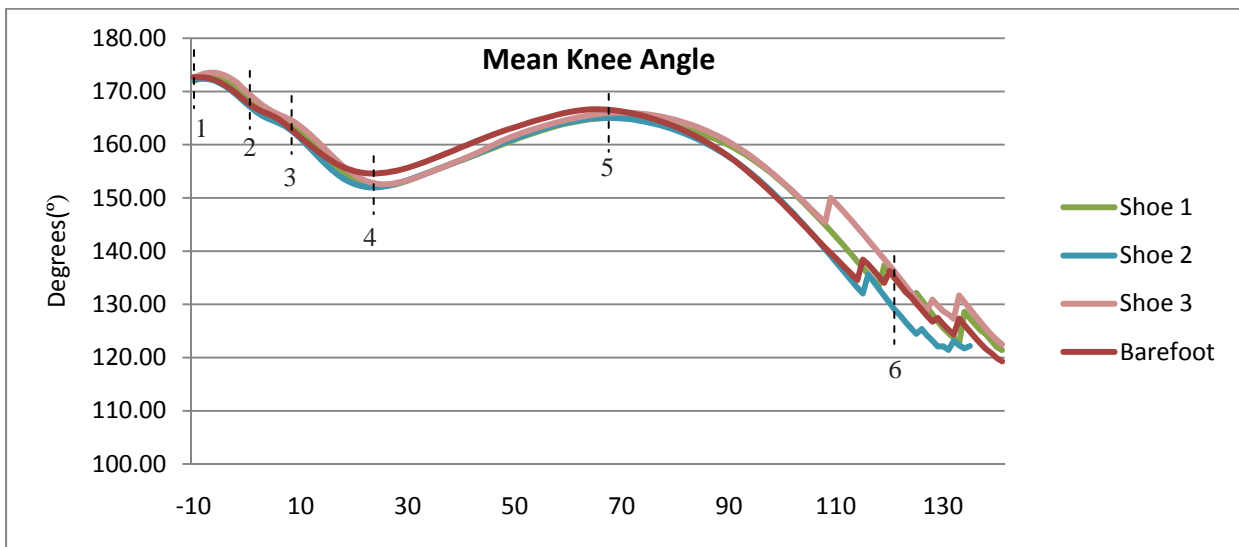


Figure 7: Mean knee angles during the stance phase

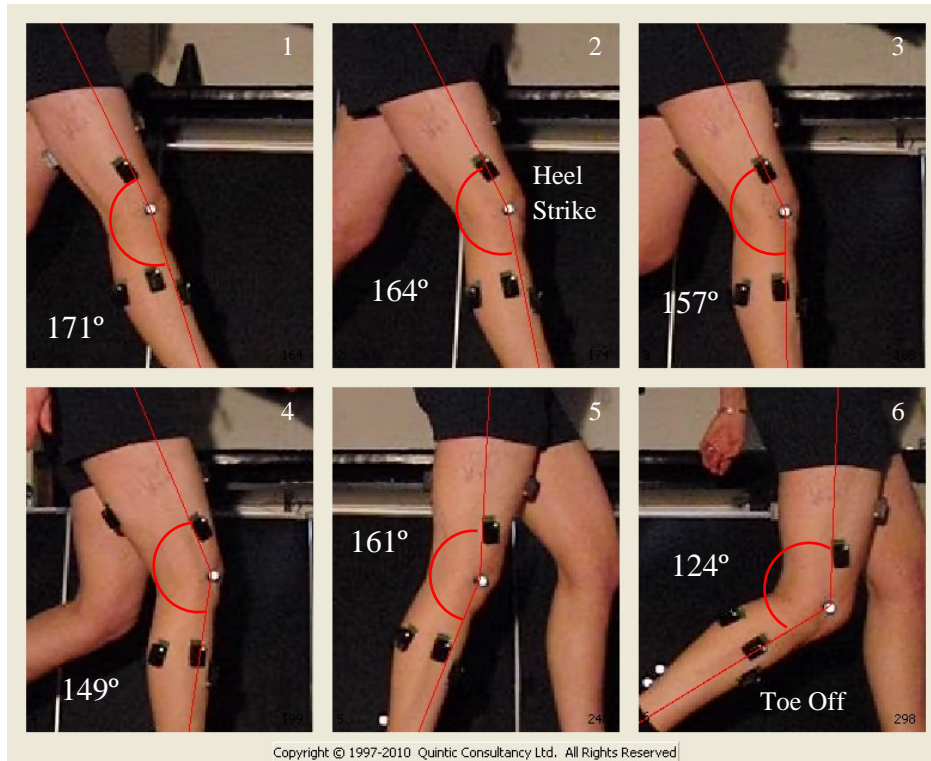


Figure 8: Mean knee angles for a subject at six points during the stance phase.

Figure 8 provides a visual representation of the knee angle during the stance phase.

1. **10 frames prior to heel strike** - knee is almost fully extended – between 171°-174°
2. **Heel strike** – knee starts to flex to absorb impact forces of heel strike
3. **End of braking phase** – Knee continues to flex
4. **Midstance** – knee reaches maximum degree of flexion
5. **Propulsive phase** – knee extends to support bodyweight and centre of gravity passes in front of the mid foot
6. **Toe off** – weight transferred to opposite leg and knee flexes as it enters the swing phase

The ankle angle through the stance phase followed the same pattern in all four trials but there were differences in the absolute values (figure 9). Shoe 1 displayed the most acute angle (96° at frame 90) and shoes 2 the least acute ankle angles throughout the stance phase.

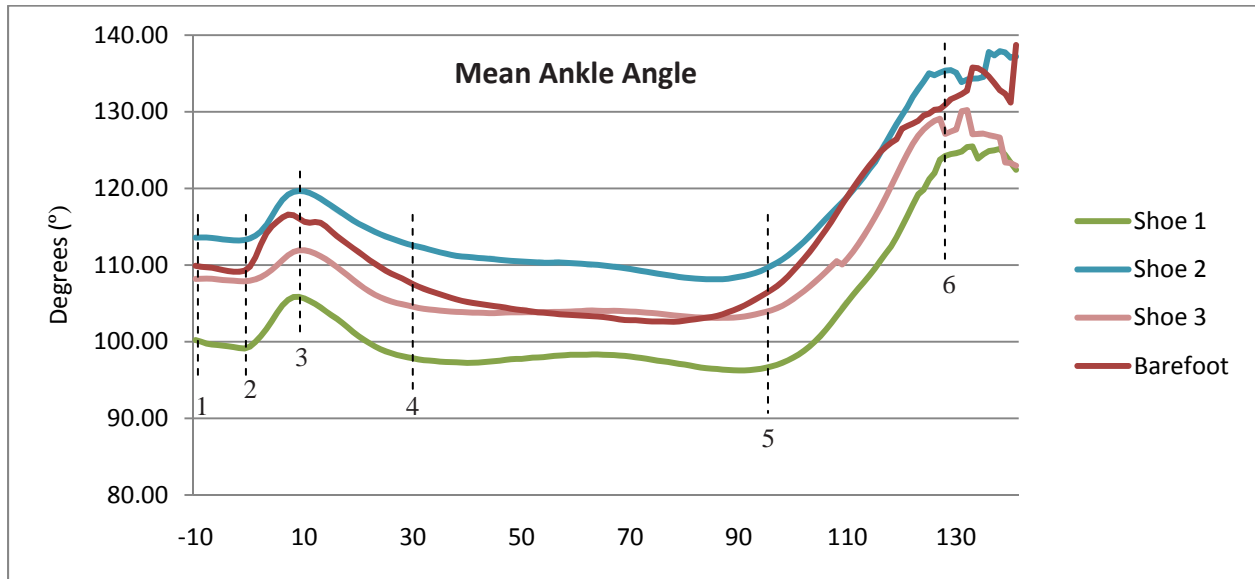


Figure 9: Mean ankle angles during the stance phase

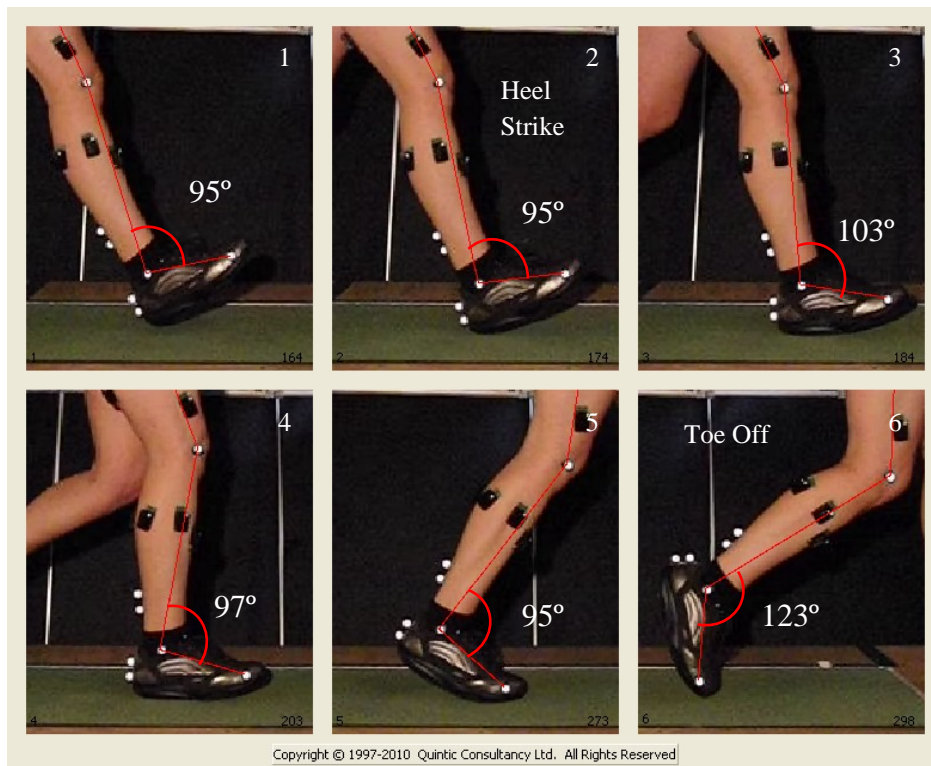


Figure 10: Mean ankle angles for a subject at six points during the stance phase.

Again figure 10 displays the ankle position throughout the stance phase.

1. **10 frames prior to heel** strike – ankle in neutral position ~ 90°
2. **Heel strike** – ankle in neutral position ~ 90°
3. **End of braking phase** – ankle plantar-flexes
4. **Midstance** – ankle returns to neutral position
5. **Propulsive phase** – Slight dorsi-flexion
6. **Toe off** – Rapid plantar-flexion helps propel subject forwards

Discussion

The results from this study would indicate that there is a difference in linear velocity between walking barefoot and with shoes on. This is probably because the shoes provide a cushioning effect and so subjects can walk faster without risk of injury. However the type of shoe seems to have little effect on the linear velocity of the four joints detailed in this study or the angular displacement of the knee and this is consistent with findings from other studies (Hutchins et al. 2009; Nigg et al. 2006).

Interestingly there was a clear variation in the ankle kinematics of shoes 1, 2 & 3 despite the similarity of their rocker soles. This difference is most likely due to differing midsole densities which provide different levels of support during the stance phase and thus influence the level of dorsi/plantar-flexion occurring.

From the results of this study it is feasible that lower leg muscles (gastrocnemius, tibialis anterior, etc.) may be more active during the stance phase as different ankle kinematics will require different muscle activation. However it seems that, above the ankle, shoe construction has little impact on gait kinematics and so the EMG activity is unlikely to differ significantly.

Any further study should focus on the EMG activity of the lower limbs and further quantify the effect of differing midsole densities on ankle kinematics.

References

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