

# THE EFFECT OF UNSTABLE SHOES ON KNEE JOINT CONTACT FORCE

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## INTRODUCTION

The use of rocker bottom shoes has become very popular in recent years. It is thought that these types of shoes may be beneficial in enhancing lower extremity muscle tone, reducing pressure on the feet, and providing an added exercise benefit during walking [1,2]. Furthermore, it has been suggested that these types of shoes may be beneficial for diseased populations such as knee osteoarthritis (OA).

Our lab has conducted comprehensive gait analyses on two generations of rocker bottom shoes (Dockers Active Balance) designed as dress shoes for men. In the previous studies, inverse dynamics was used to determine joint moments and joint reaction forces, however, a more accurate estimate of knee joint forces is necessary to get a better understanding of the loads the knee experiences during walking. Therefore, the purpose of this study was to use previously collected data from healthy adult males to compute vertical knee contact forces during walking while wearing the unstable shoe (figure 1a) compared to a control shoe (figure 1b). It was hypothesized that wearing the test shoe would result in a decrease in vertical knee joint contact force compared to the control shoe.

## METHODS

14 males (age:  $45.6 \pm 8.4$  yrs; height:  $1.81 \pm 0.07$  m; mass:  $80.6 \pm 9.4$  kg; BMI:  $24.7 \pm 2.2$ ) participated in a previous study. Each subject performed 5 walking trials in a control shoe and an unstable shoe at 1.3 m/s.

A nine-camera motion analysis system (240 Hz, Vicon Motion Analysis Inc., UK) was used to track reflective markers placed on the trunk, pelvis, and bilateral thighs, shanks, and feet. Two force platforms (1200 Hz, Advanced Mechanical Technology Inc.) were synchronized with the

motion analysis system to measure the ground reaction forces. Visual3D software suite



Figure 1. Unstable test shoes (A) and control shoes (B).

(C-Motion, Inc.) was used to compute inverse dynamics of the knee joint. EMG data were recorded for 4 muscles of the lower extremity including Gastrocnemius, rectus femoris, biceps femoris, and tibialis anterior.

Five trials of unstable shoe walking and 5 trials of control shoe walking were exported from Visual 3D to OpenSim for 1 subject. The gait2392 Opensim model was scaled to reflect the subject mass characteristics. Residual reduction algorithm (RRA) was performed on the scaled model to minimize the effects of modeling and marker processing errors and to make the model more dynamically consistent with ground reaction force data. Computed muscle control (CMC) was then used to compute muscle forces during the walking trial. Finally, the vertical knee joint contact force was computed from internal (muscle) and external

(GRF) forces. Data were processed during the stance phase for the right leg; heel strike to toe off.

## RESULTS

For this particular participant, the 1<sup>st</sup> peak vertical knee joint contact force decreased by about 0.5 to 1 body weight (BW) in the test shoe (figure 2a) compared to the control shoe (figure 2b). However, the 2<sup>nd</sup> peak remained unchanged.

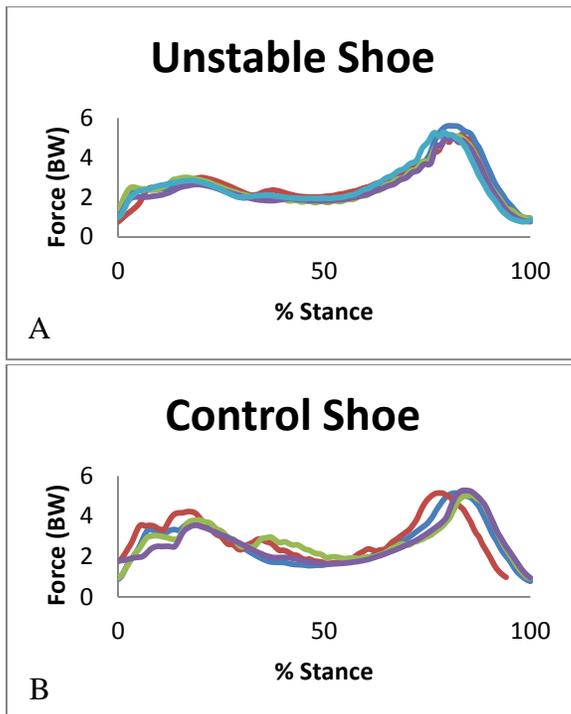


Figure 2. Vertical knee joint contact force while wearing test shoes (A) and control shoes (B).

In comparison with the GRF and joint reaction force (JFR) calculated by inverse dynamics, the knee joint contact force was about 3 times as large in the 1<sup>st</sup> peak and about 5 times as large in the 2<sup>nd</sup> peak. Additionally, CMC and EMG data profiles were similar across muscles except for the rectus femoris which had a large spike at the end of the CMC profile which was not present in the EMG profile.

## DISCUSSION

Wearing the test shoes did appear to decrease the vertical knee joint contact force for this particular subject, but only during the 1<sup>st</sup> peak of stance. Interestingly, the 2<sup>nd</sup> peak was much greater than the first peak in both shoe conditions which was contrary to what previous authors have reported [3-5]. Intuitively, the magnitude of the 2<sup>nd</sup> peak should not be larger than the 1<sup>st</sup> peak unless the participant suddenly increased their speed during

the push off phase of stance. The ground reaction force profile clearly shows that the participant did not speed up so some other phenomenon is occurring and requires explanation.

It is possible that the larger 2<sup>nd</sup> peak occurred because of the activated rectus femoris muscle at the end of stance as calculated by CMC. Another study also reported on the muscle activation [5] which more closely matched the EMG data and not the CMC data presented in this study. This may be an indication that problems exist in the current study in which the activation for the rectus femoris muscle was not accurately calculated. This may be a result of the RRA analysis inability to adequately make the model more dynamically consistent with the GRF data.

It is thought that the big picture problem lies in the amount of force plates used for this study. The focus of this project was the right foot during stance. However, since walking has double support phases, there were times when the left leg was on the ground but no GRF information was available. This was not a problem when the left foot was the leading leg (recordings were made from 2 force plates), but it was a problem when the left foot was the trailing leg. This is in contrast to an activity such as running which only contains a single support phase (i.e. never have both feet on the ground at the same time). It is possible that if 3 force plates were available, then accurate GRF information from the contralateral leg would be available for use in the RRA and CMC analysis.

## CONCLUSION

In conclusion, it appears that the test shoes were effective in reducing the knee joint contact force for this particular subject. However, it is not clear if these results would be different if three force plates were available for testing.

Future research in this area should analyze other activities such as stair walking, cycling, and elliptical machine. Additionally, future work would incorporate separate contact surfaces in the knee model to be able to calculate medial and lateral compartment loads.

## REFERENCES

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