An Evaluation of Center of Force Trajectories for Different High-Heeled Shoes Using the **Strideway™ System**

A Study on the Effects of Heel Height on Biomechanics

Technical Whitepaper

ISO 9001 Compliant & 13485 Registered

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Introduction

Several studies have investigated the effects of high-heeled shoes on human gait. According to one study (Merrifield, H.H., et al, 1971), an increase in heel height raises the body's center of gravity, which results in less stability. In order to compensate during walking for this less stable position on a sagittal plane, the study determined that the female subject decreased in step length and stride length, which are interrelated. (1)

Additional studies have also evaluated changes in ground reaction forces (GRF), reporting increases in vertical, anteroposterior, and/or medio-lateral GRF with higher heel heights (Cronin et al., 2012; Ebbeling et al., 1994; Hong et al., 2005; Snow and Williams, 1994; Stefanyshyn et al., 2000; Yung-Hui and Wei-Hsien, 2005) (2-7).
Higher GRF can result in additional stress on the subject's spine, hip, knees, feet, ankles, and elsewhere.

The goal of this study – conducted by Tekscan applications engineers – was to measure how different high-heeled shoe heights would affect a subject's CoF trajectory (CoFT). A Strideway™ system (**Figure 1**) was used to measure and record the subject's gait pattern.

Figure 1: The Strideway modular gait analysis platform

About the Strideway

Strideway is a first-of-its-kind modular gait analysis platform used to provide objective information on plantar pressure, plus temporal (time), spatial (distance) and kinetic force (movement) parameters. The low-profile platform includes inter-connecting pressure sensing panels with automated calculation of an array of gait parameters.

While in-shoe gait analysis systems are often used in footwear assessments, the Strideway platform can provide insightful parameters to evaluate the effects of footwear. The ability to track CoF (CoF) movement provides an indication of stability. In addition, Strideway provides spatial parameters, which are useful for evaluating the effect of footwear on gait.

Experiment Summary

A healthy female subject in her 20s (52 kg weight) was instructed to make two passes (six steps total: three left foot, and three right foot) wearing the following shoe categories:

Barefoot

Sandal

Boot

Wedge

Stiletto

A four-tile Strideway model SRSW4 was used in this study (Overall dimensions: 0.91 x 3.25m; Active sensing area per tile: 0.65 x 2.6m; Resolution: 0.968 sensels/cm^2; Scanning speed: 500 Hz). Strideway software recorded each of the subject's passes across the pressure-sensitive platform, saving the pressure data in a movie format. The engineers analyzed the Strideway data for the following parameters:

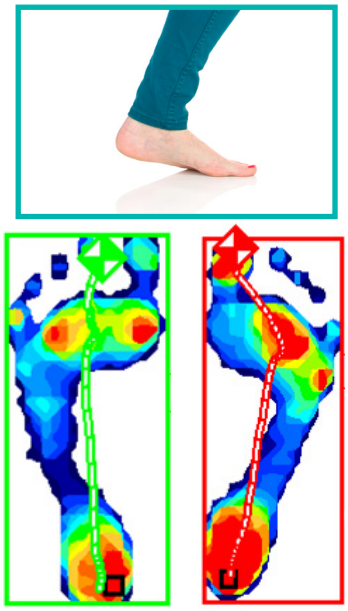
- **Plantar Pressure:** The distribution of forces over the sole of the foot; in this case, during walking. It can provide indications of foot function.

- **CoF Trajectory (CoFT):** The direction and behavior of the concentration of force as the subject completes their gait cycle. This parameter is used to identify balance control and foot function.

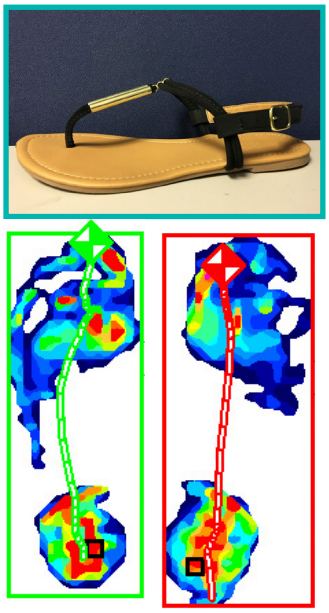
After data collection, the engineers analyzed heel, ankle, and forefoot pivot points of the subject's footstrikes while wearing the different shoe types. These parameters serve as a reliable indicator of the subject's walking behavior.

Peak CoF for All Footwear

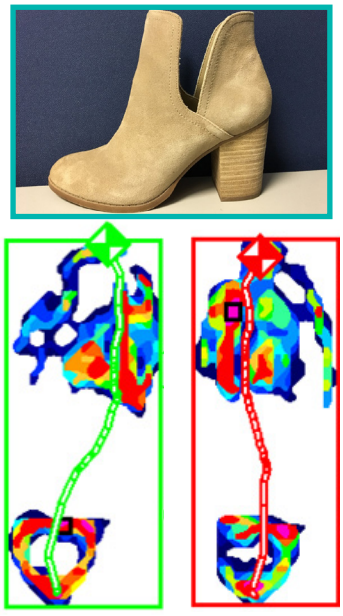
Barefoot



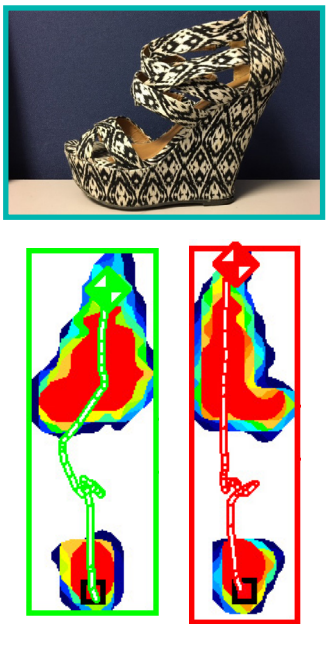
Sandal



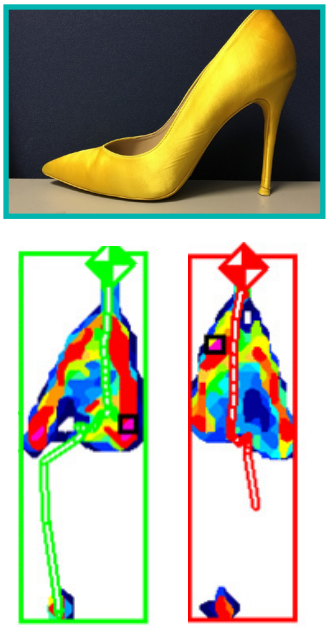
Boot



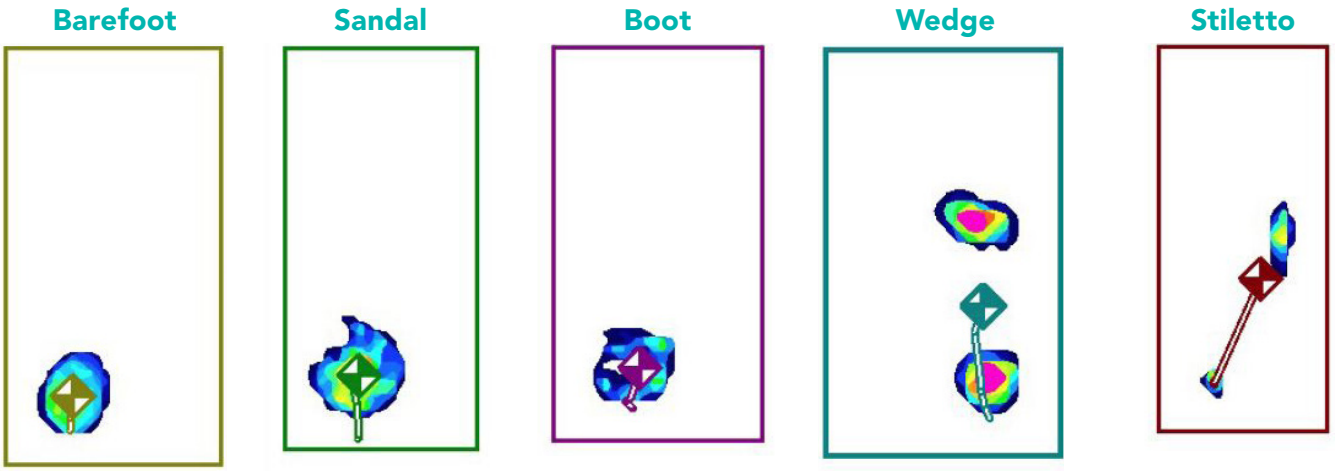
Wedge



Stiletto

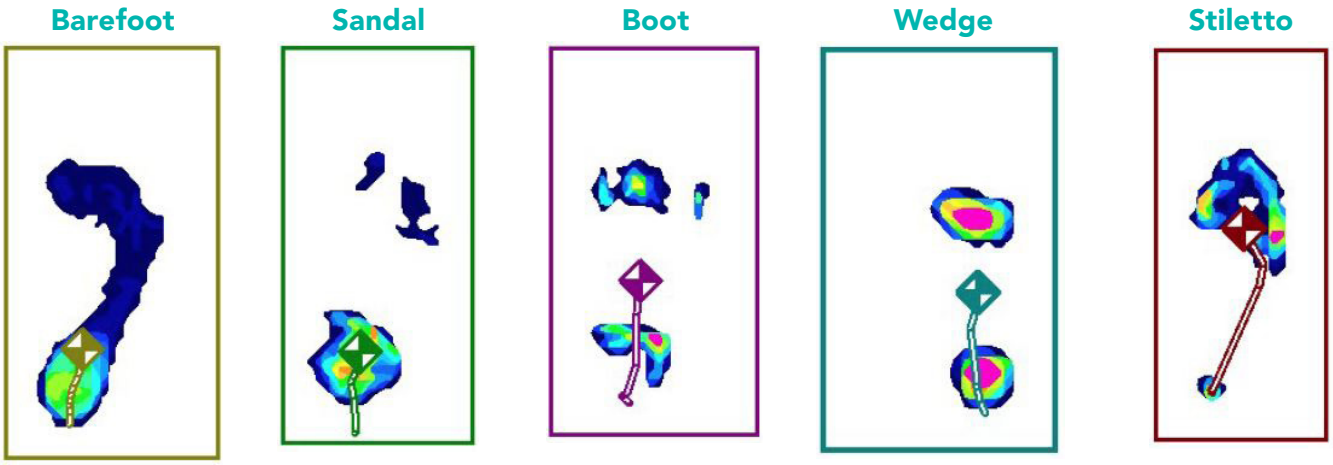


Trajectory Comparisons at 0.1 sec (13% of Full Step)



- All shoe conditions are displaying 13% of the stance phase of gait.
- Notice the position of the CoF, in the Barefoot, Sandal, and Boot conditions, the CoF position in the middle of heel strike
- The Wedge and Stiletto condition, which have quite a high heel height, project the CoF forward almost immediately possible due to the instability of the narrow heel design in the Wedge and Stiletto shoe conditions.

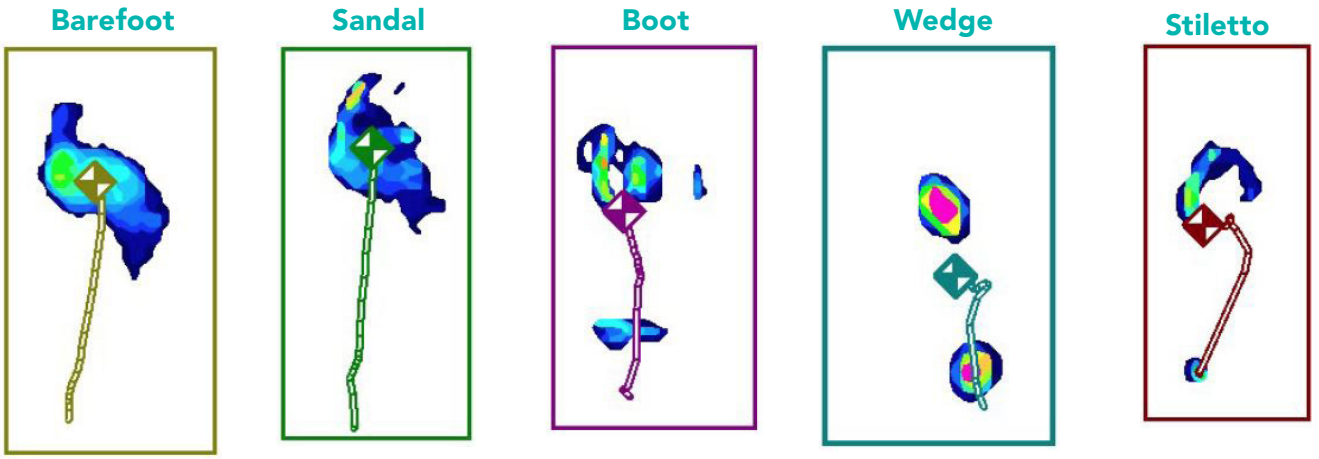
Trajectory Comparisons at 0.18 sec (23% of Full Step)



Area: 65.29 cm | Area: 34.32 cm | Area: 25.03 cm | Area: 17.03 cm | Area: 29.68 cm

- As the foot progresses through the stance phase, the Barefoot and Sandal conditions follow similar trends.
- In the Boot, Wedge and Stiletto conditions, the CoF is much further forward than the Barefoot and Sandal conditions.
- There is also a lateral pitch of the CoF in the Stiletto condition. This could be the indication of the subject correcting their balance.

Trajectory Comparisons at 0.4 sec (51% of Full Step)



Area: 45.16 cm | Area: 40.00 cm | Area: 27.10 cm | Area: 13.16 cm | Area: 14.71 cm

- Now at approximately 50% of the stance phase, the similarities continue between the Barefoot and Sandal conditions, with the heel now completely off the ground.
- In the Wedge and Stileto conditions, the CoF is actually stalling, possibly due to some instability as they transition to lift the heel in the propulsion phase of gait.
- The Boot condition seems to slow down its CoF progression though the middle of the stance phase as well. However, since the heel of the Boot is bigger, there appears to be less instability than in the Wedge and Stiletto.

Trajectory Comparisons at 0.56 sec (72% of Full Step)

Barefoot

Area: 39.74 cm

Sandal

Area: 36.39 cm

Boot

Area: 31.23 cm

Wedge

Area: 9.81 cm

Stiletto

Area: 21.68 cm

- At this point in the stance phase of gait, all conditions are in propulsive phase.
- All shoe conditions now have concentrated forces/pressure in the forefoot.
- There are clear differences in the trajectories of the CoF.
- The Barefoot and Sandal condition show similar shapes for the CoF progression with similar spacing between hash marks signifying a fairly steady forward pace.
- The Boot, Wedge, and Stiletto conditions show CoF progression that clearly spend less time in the heel region (due to the heel height pitching the body forward).
- The Boot, Wedge, and Stiletto condition also seem to push the CoFs more lateral than the Barefoot and Sandal conditions, with a reduction in CoF progression around the mid point of the stance phase. This is possibly due to instability created from the heel height.

Conclusions

Based on the Strideway data, heel height had a significant effect on the subject's gait pattern and CoFT. The subject demonstrated shorter stride lengths while wearing high heels, and stepped with greater force on the front of her foot. In particular, the Wedge and Stiletto data displayed significant asymmetries. Over time, this activity could prompt discomfort to the subject's ankles, hip, and spine.

Moreover, shoe designers and manufacturers have an effective tool to measure the impacts of their design decisions with the help of the Strideway modular pressure mapping platform.

References

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(5) Snow RE, Williams KR. *High heeled shoes: their effect on center of mass position, posture, three-dimensional kinematics, rearfoot motion, and ground reaction forces.* Arch Phys Med Rehabil 1994;75(5):568–76.

(6) Stefanyshyn DJ, Nigg BM, Fisher V, O'Flynn B, Liu W. *The influence of high heeled shoes on kinematics, kinetics, and muscle EMG of normal female gait.* J Appl Biomech 2000;16(3):309–19.

(7) Yung-Hui L, Wei-Hsien H. *Effects of shoe inserts and heel height on foot pressure, impact force, and perceived comfort during walking.* Appl Ergon 2005;36(3):355–62.

For More Infomation on Strideway, and Other Tekscan Gait Analysis Technologies,

Consider These Free Resources:

"Data to Complete Your Gait Analysis" is an eBook exploring complementary technologies to enhance your gait lab, and enable a full complete picture of data for various applications.

Download Now!

The **"Introduction to Gait Analysis with Technology"** is an on-demand webinar narrated by Marshall Kendall, PhD, shares different gait analysis tools, and ways you can improve your evaluations with objective data.

Watch Now!

"An Insider's Look into Modular Gait Analysis Technology" is another on-demand webinar providing a first-hand look into the analysis capabilities of the Strideway system.

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