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Multi-Segment Foot Joint Kinematics with Varying Midfoot Orthotic Postings

Hilary F. Feskanin
University of Dayton

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Multi-Segment Foot Joint Kinematics with Varying Midfoot Orthotic Postings



Honors Thesis

Hilary F. Feskanin

Department: Mechanical and Aerospace Engineering

Advisor: Joaquin A. Barrios, PT, DPT, Ph.D. and Kimberly Bigelow, Ph.D.

April 2015

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Abstract

Foot orthoses are often prescribed to prevent and treat lower limb disorders. While the success of these devices is well documented, the mechanisms behind them are unclear. Due to methodological limitations, many studies have focused on the rearfoot. This is the first study to assess the effects of midfoot-targeted orthotic strategies on midfoot and rearfoot kinematics. Gait mechanics were recorded for 19 healthy females walking in four orthotic conditions: valgus midfoot post, varus midfoot post, heel lift and standard/control. The midtarsal and ankle joint 3D kinematics for the three experimental conditions were compared to the control condition. Variables of interest included 1) initial contact angles in the sagittal, frontal and transverse planes, 2) peak dorsiflexion, eversion and abduction angles, 3) and the associated angle excursions. The orthotic postings only affected the ankle joint in the transverse plane. The heel lift and varus posts only affected the midtarsal joint in the transverse plane. The valgus post affected all three planes, but did not necessarily increase pronation as expected. Overall, the ankle joint was minimally affected by the three orthotic conditions while the midtarsal joint was affected in all three planes.

Acknowledgements

The author would like to thank Dr. Joaquin Barrios and Dr. Kimberly Bigelow for their assistance in training and writing of the report. In addition, the author would like to thank Stephanie Moeller for her assistance with gait data collection. Finally, the author would like to acknowledge the University of Dayton Honors program for their financial support of this project.



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Introduction

Foot orthoses are often prescribed to prevent and treat numerous lower limb disorders (Hume et al., 2008, Heiderscheit et al., 2001, Gross & Foxworth, 2003, Gross et al., 1991, Donatelli et al., 1988, Anderson & Stanek, 2013). Effectiveness and efficacy studies continue to validate the use of foot orthoses in clinical practice. Foot orthoses have shown a 70%-90% success rate for treating pain (Gross et al., 1991, Donatelli et al., 1988). Also, a survey study indicated that over 94% of patients report continued use of their prescribed orthoses two years after initiating use (Donatelli et al., 1988). While clinical success is well documented, the underlying mechanisms for these improvements are still unclear (Nester et al., 2003, Landorf & Keenan, 2000, Heiderscheit et al., 2001). The etiologies of many of the target disorders for which foot orthoses are used relate to overuse and aberrant biomechanics (Hume et al., 2008, Landorf & Keenan, 2000, Gross et al., 1991). Foot orthoses are thought to be effective because they aid in addressing biomechanical faults such as skeletal misalignments, limited or excessive joint motions, attenuating high loading parameters and optimizing muscle mechanics (Hirschmuller et al., 2009, Donatelli et al., 1988, Mundermann et al., 2006, Zifchock & Davis, 2008, Anderson & Stanek, 2013).

A purported primary mechanism by which foot orthoses yield improved outcomes is altering foot kinematics during the stance of gait. In many cases, additional posting strategies are a component of the orthotic strategy aimed at altering foot mechanics at a specific site or in a specific manner. Common examples include posting under the midfoot region either medially or laterally to slow or enhance overall pronation mechanics, respectively (Donatelli et al., 1988, Novick & Kelley, 1989). Heel lifts under the rearfoot are also commonly used. While these targeted strategies appear clinically effective, most kinematic studies have evaluated the effects of the devices on the rearfoot region due to methodological limitations (Ferber & Benson, 2011). Very little is known about the kinematic effects of orthoses and posting strategies on the midfoot region (Ferber & Benson, 2011). This represents a large void in the understanding of foot orthotic use, as many posting strategies target the midfoot region either in isolation or in combination with the rearfoot region. Often, the biomechanical effects of a given device

on the midfoot are assumed to be similar to the observable rearfoot effects, but this remains speculative. To date, no study has assessed the effects of midfoot-targeted orthotic strategies on midfoot and rearfoot kinematics.

To address the question of how common foot orthotic posting strategies affect the rearfoot and midfoot during shod walking, the purpose of this study was to evaluate the 3-dimensional effects of 6 degree varus midfoot posts, 6 degree valgus midfoot posts, and heel lifts using commercially available stock foot orthoses and accompanying posts. An established multi-segment foot model (rearfoot, midfoot, forefoot) in combination with a modified minimalist shoe allowed us to investigate changes to ankle and midtarsal joint angle data in multiple orthotic conditions without disturbing the foot marker configuration. The three posted conditions were compared with the unposted stock device as the control condition. We hypothesized the heel lift would cause changes in the sagittal plane changes in at both joints, while the varus and valgus midfoot postings would induce changes in the frontal plane to both joints.

Methods

Participants

Nineteen healthy females (age= 22.0 ± 1.7 years, height= 1.65 ± 0.06 m, mass= 63.63 ± 8.57 kg) were recruited and completed the study. Subjects reported no spinal or lower limb injuries or surgeries within the last year that could affect the ability to ambulate. The study was approved by the university's institutional review committee and all subjects provided voluntary written consent to participation. The right limb was used as the test limb.

Foot Orthosis and Posts

Each subject was tested using the same minimalist shoe (New Balance Minimus, Lawrence, MA, USA) and stock orthotic device (Vasyli Medical, San Rafael, CA, USA) for all orthotic conditions. The shoe was modified with marker cut-outs and a custom longitudinal zipper allowing marker visibility in shod walking and the ability to remove the foot without disturbing the marker configuration.



Figure 1: Frontal view of shoe with modified longitudinal zipper.



Figure 2: Sagittal view of shoe with marker cut outs.

The three experimental conditions were comprised of a valgus midfoot post of 6 degrees, a varus midfoot post of 6 degrees, and a 6 mm heel lift. Manufacturer instructions for applying the posts to the stock device were followed.

Data Collection Procedures

Each subject's arch height index was assessed using the Arch Height Index Measurement System (AHIMS). The subject is first seated with hip and knees flexed at 90 degrees, and feet resting on the floor. Foot boards under the rearfoot and forefoot were not necessary for any subjects. The AHI metric is then calculated by dividing dorsum height at 50% of total foot length by the truncated foot length measured from the posterior calcaneal surface to the first metatarsal head (Butler et al., 2008). The measurement is then repeated in standing with equal weight on both feet. Sitting AHI is estimated to be taken

with 10% of body weight load, and standing AHI at 50%. Previous literature has deemed the AHIMS a reliable method of measuring static foot structure (Butler et al., 2008). Mean values in recreational runners are 0.363 ± 0.030 for sitting and 0.340 ± 0.030 for standing. Previous literature has defined high and low arches when the value is at least 1.5 standards deviations above or below the normative mean, respectively (Zifchock & Davis, 2008).

The subjects were then prepared for 3D motion analysis by attaching 9 mm reflective markers directly to the skin on the right lower leg and foot. Anatomical markers were placed over the medial and lateral tibial plateaus, the medial and lateral malleoli, the first and fifth metatarsal heads, the navicular, the cuboid, the distal aspect of the shoe and over the 2nd metatarsal. A total of four tracking markers were placed over the calcaneus (medial, lateral, proximal and distal). In addition, a rigid cluster of four tracking markers were fastened with Velcro straps over the distal posterolateral shank. The foot model is a modification of the established foot model by Bruening and colleagues (2012). Once all markers were applied, the foot was inserted into the modified laboratory shoe.

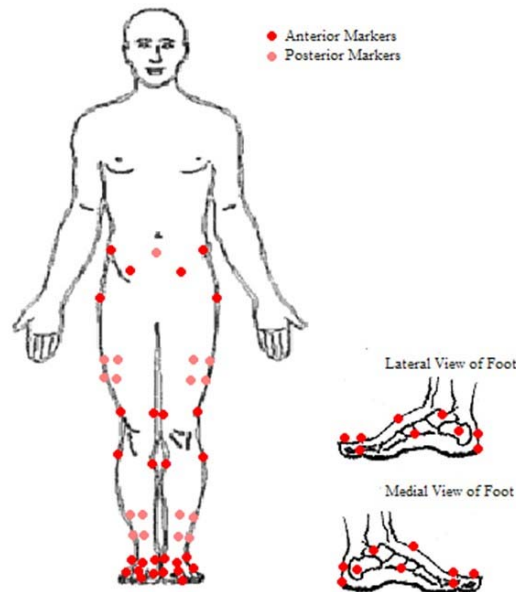


Figure 3: Anatomical marker placement.

Video data were collected using a Vicon motion capture system (VICON, Oxford Metrics, UK). Analog data were acquired from a floor-mounted force plate (BERTEC

Corp., Worthington, OH, USA). The control condition was tested first to establish preferred walking speed. The remaining three posted conditions were captured in a randomized fashion. A standing calibration trial, followed by a functional hip motion trial, were collected to establish the position and orientation for each segment coordinate system of interest (shank, rearfoot, midfoot). The anatomical markers were then removed, leaving the tracking markers for the dynamic trials. The data from the walking trials was collected as subjects walked along a 23 m walkway allowing 5% variation in walking speed using the average velocity of a sacral marker along the line of progression. For each condition, at least five usable trials were collected. No markers were moved between any conditions.

Data Processing

For the post-processing, stance-phase analog and video data for each trial were exported in C3D format for processing in Visual 3D (C-motion® Inc., Bethesda, MD, USA). The marker trajectory data were low-pass filtered using a fourth-order, phase-corrected Butterworth filter at 8 Hz, and the analog data at 50 Hz. Joint angles were derived using a Cardan rotation sequence (X-flex/extension, Y-add/abduction, Z-in/external rotation) and expressed in degrees. Discrete data points of interest were extracted from each trial using custom written code (Labview, National Instruments, Austin, TX), and averaged within each condition for each subject. Variables included 1) initial contact angles in the sagittal, frontal and transverse planes, 2) peak dorsiflexion, eversion and abduction angles, 3) and the associated angle excursions from initial contact to peak angulations.

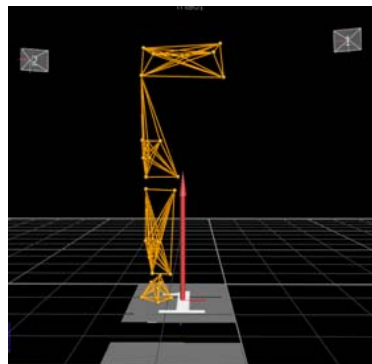


Figure 4: A rendering of a pelvis and right lower extremity model in Vicon Nexus during a standing calibration trial.

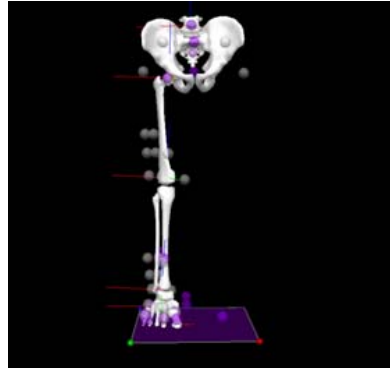


Figure 5: A rendering of a specific skeletal model based on marker locations in Visual 3D.

Statistical Analysis

Condition means and standard deviations were calculated for each target variable. Single-factor (condition) repeated measures analyses of variance with post-hoc planned comparisons were performed between each experimental condition to the unposted stock device ($\alpha = 0.05$).

Results

A summary of ankle and midtarsal joint angles for each condition is provided in Tables 2 and 3. On average, subjects landed with the ankle joint dorsiflexed, inverted and abducted. The midtarsal joint was initially plantarflexed, inverted and slightly abducted on average.

Table 1: Descriptive data for test subjects.

N=19	Mean \pm SD
Height	1.65 \pm 0.06 m
Weight	63.63 \pm 8.57 kg
BMI	23.3 \pm 3.4 kg/m ²
AHI Sitting	0.36 \pm 0.03
AHI Standing	0.32 \pm 0.03

Table 2: Mean (SD) ankle joint angles for each orthotic condition.

		Control	Heel	Varus	Valgus
Sagittal	IC	3.8 (5.4)	1.6 (8.3)	4.7 (5.0)	3.9 (4.8)
	Peak	13.7 (4.5)	14.5 (5.7)	13.9 (4.5)	13.4 (4.4)
	Exc	9.9 (6.5)	12.9 (11.2)	9.2 (4.1)	9.6 (6.6)
Frontal	IC	6.0 (4.9)	7.0 (5.8)	6.1 (4.3)	6.5 (4.7)
	Peak	-0.8 (5.8)	-1.0 (5.2)	-0.5 (4.3)	-1.2 (7.2)
	Exc	-6.9 (4.0)	-8.1 (3.5)	-6.6 (2.0)	-7.7 (4.7)
Transverse	IC	-6.2 (6.1)	-5.2* (5.6)	-5.6 (6.5)	-5.9 (6.3)
	Peak	-12.0 (6.7)	-12.8 (6.4)	-11.2* (6.7)	-11.7 (7.0)
	Exc	-5.8 (1.8)	-7.6* (1.9)	-5.7 (2.4)	-5.8 (1.8)

Angles/excursions in degrees. Significant differences
from the control condition denoted by an *.

The effects of the orthotic postings on the ankle joint were seen with the heel lift and the midfoot varus post. The heel lift decreased abduction on initial contact by 1.0° and increased the overall abduction excursion by 1.8°. The varus post decreased peak abduction by 0.8°. No ankle changes were observed for any posting condition in the frontal and transverse planes.

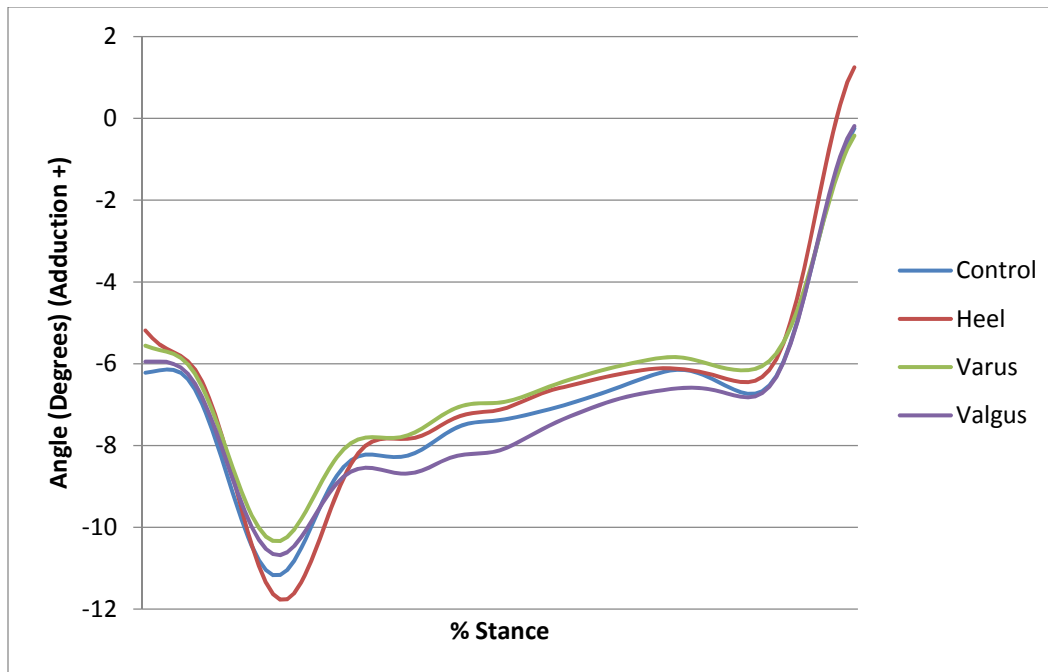


Figure 6: Mean Ankle Transverse Angle Values by Condition

Table 3: Mean (SD) midtarsal joint angles for each orthotic condition.

		Control	Heel	Varus	Valgus
Sagittal	IC	-14.0 (4.3)	-12.7 (8.6)	-15.2 (4.4)	-15.1 (4.3)
	Peak	-9.3 (3.6)	-7.1 (5.8)	-9.7 (5.1)	-8.7 (4.3)
	Exc	4.7 (2.8)	5.6 (4.3)	5.5 (2.6)	6.5* (2.6)
Frontal	IC	6.6 (4.2)	6.1 (4.7)	7.2 (4.1)	6.3 (4.3)
	Peak	3.1 (4.4)	2.5 (4.5)	3.3 (4.0)	1.7* (4.5)
	Exc	-3.4 (1.7)	-3.6 (1.8)	-3.8 (1.8)	-4.6* (2.3)
Transverse	IC	-1.3 (4.3)	-2.6* (4.4)	-2.0 (4.4)	-2.2 (4.6)
	Peak	-4.5 (5.1)	-5.3 (4.4)	-4.7 (4.6)	-5.5* (4.8)
	Exc	-3.2 (1.8)	-2.7 (1.6)	-2.7* (1.5)	-3.3 (1.8)

Angles/excursions in degrees. Significant differences from the control condition denoted by an *.

The midtarsal joint was altered by all three orthotic postings. The heel lift increased abduction at initial contact by 1.3° . The varus post decreased abduction excursion by 0.5° . The valgus post decreased dorsiflexion excursion by 1.7° , increased peak eversion by 1.4° increased eversion excursion by 1.1° and increased peak abduction by 1.0° .

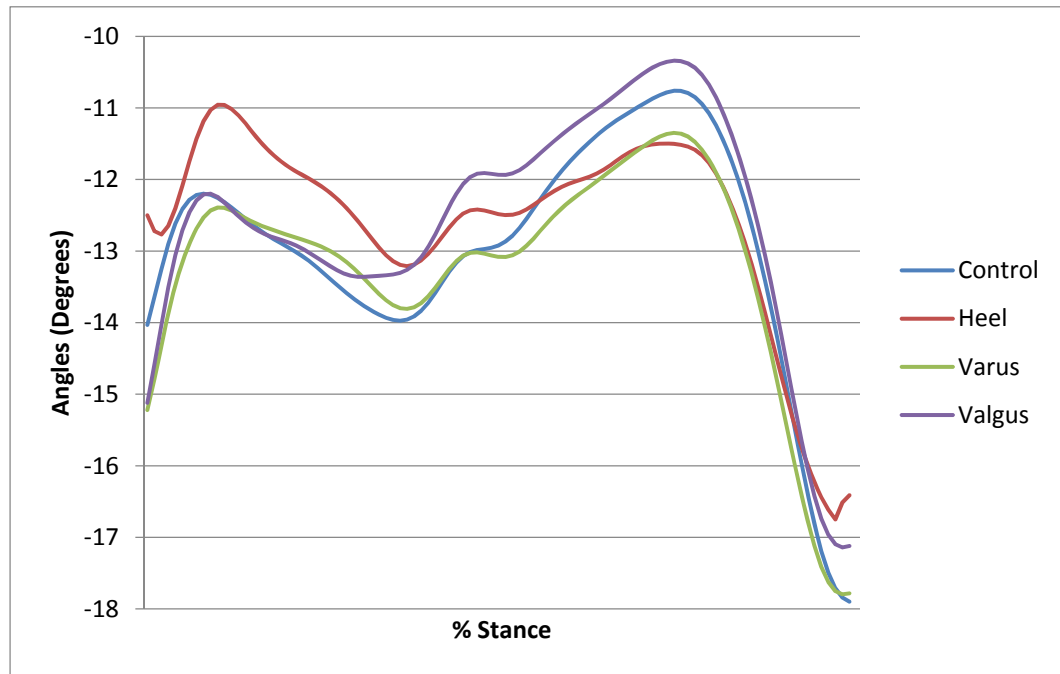


Figure 7: Mean Midtarsal Sagittal Angle Values by Condition

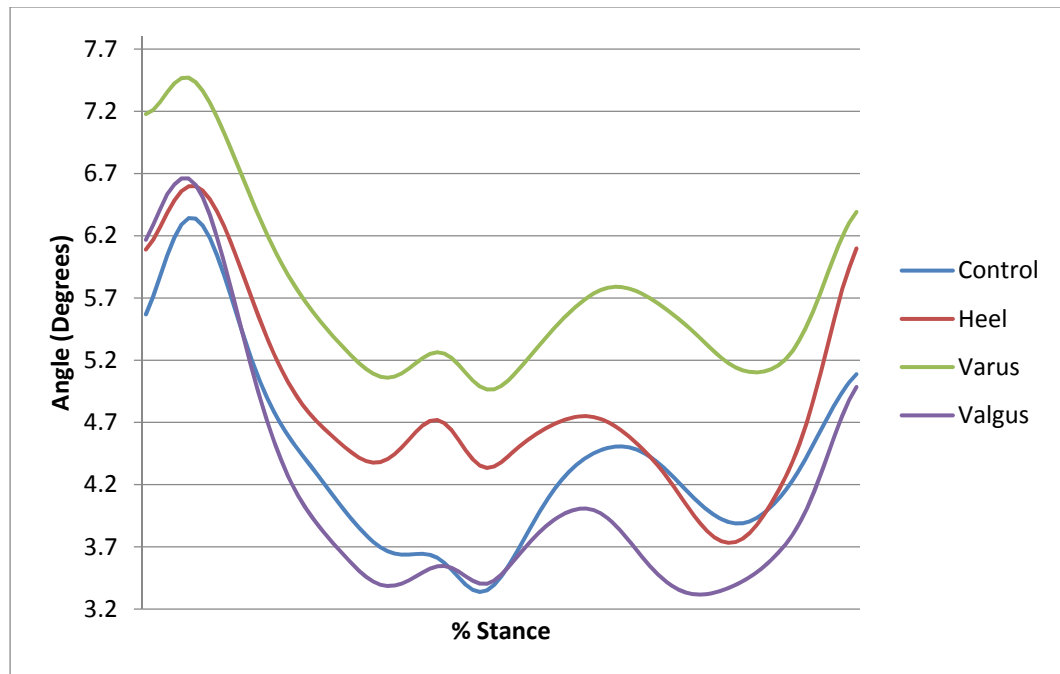


Figure 8: Mean Midtarsal Frontal Angle Values by Condition

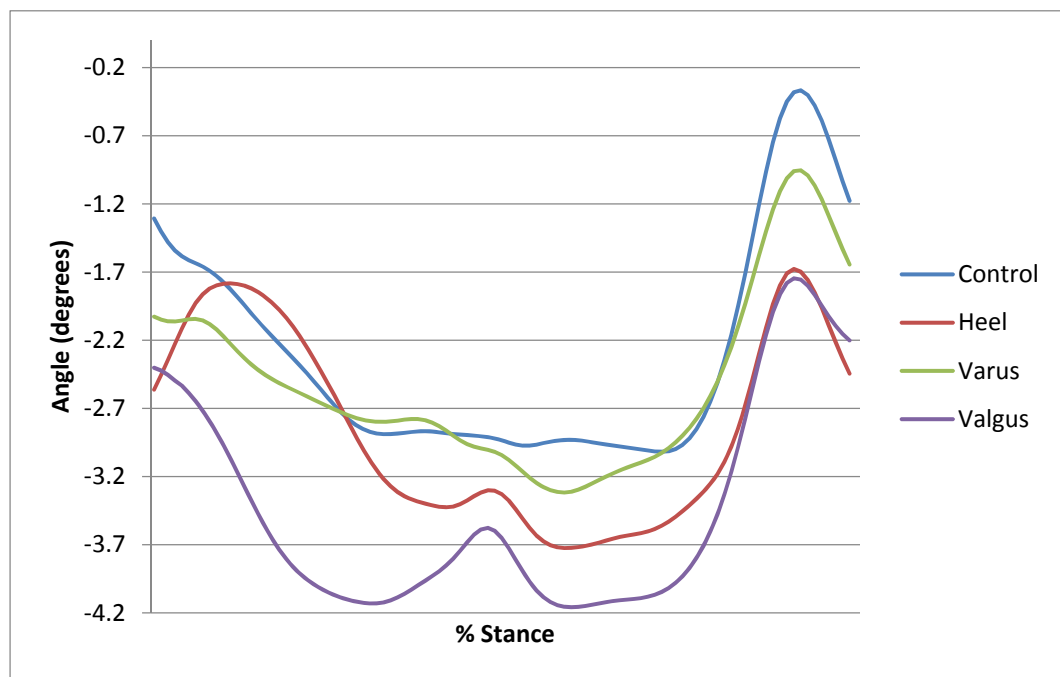


Figure 9: Mean Midtarsal Transverse Angle Values by Condition

Discussion

The primary purpose of this study was to evaluate three-dimensional joint angle changes at the rearfoot and midfoot regions due to selected common orthotic posting strategies during shod overground walking. Three posting approaches were tested against an unposted control orthotic condition: heel lifts under the rearfoot region, varus posts under the midfoot region, and valgus posts under the midfoot. A number of small but fairly consistent kinematic effects were observed, suggesting that altered kinematics may at least partly account for the improvements often observed in clinical foot orthotic studies.

A minimalist shoe was modified with marker cut-outs and a longitudinal zipper. This type of shoe was chosen because its minimal support would have the least interference with the posting and the subject's foot. The marker cut-out approach was similar in application to the study by Ferber and Benson (2011). Unlike their study, we chose to only place the device under the right foot since we were comparing between conditions and any effects from the offset would be consistent throughout the trials. We used standard manufactured devices so the results could be relevant to a larger population. Also, subjects in our trial did not walk on a treadmill, allowing for more natural gait. Perhaps the most novel experimental element in the study was the custom longitudinal zipper. The zipper allowed for the orthotic post to be changed without removing any markers. This eliminated any measurement errors associated with marker movement between conditions.

The most comparable study in the literature is a study by Ferber and Benson (2011). In that study, the authors compared the effects of an orthotic device on multi-segment foot biomechanics and its effectiveness in reducing plantar fascia strain. They chose a semi-custom device to additionally assess the changes caused by the moulding process. They found no significant changes when the device was heat moulded compared to the non-moulded condition. These results support our choice of using a standard manufactured device.

Our results indicate that the midfoot postings and the heel lift had limited effect on the ankle joint. We hypothesized that the heel lift would cause changes in sagittal plane but this outcome was not observed. It increased adduction on initial contact and increased the overall abduction motion. Since there were no changes in the peak abduction, it is reasonable to assume that the increased excursion compensated for increased adduction on initial contact. The varus post was expected to induce changes in the frontal plane but it only had significant effects in the transverse plane as well. The valgus post did not exhibit any significant effects on the ankle joint kinematics.

At the midtarsal joint, the heel lift was hypothesized to affect the sagittal plane but instead we observed significant changes in the transverse plane. Normally, we would assume the heel lift would raise the rearfoot, increasing pronation. The absence of this effect could indicate a musculoskeletal compensatory mechanism is present, increasing dorsiflexion at the midfoot and negating the effects of the heel lift in the sagittal plane. The varus post decreased the overall abduction excursion. We expected it to increase inversion but the results of the study suggest that the post actually limited pronation.

We expected the valgus post to increase pronation. While it did affect all three planes, only two of the three changes support increased pronation. Decreasing dorsiflexion does not support our expectations and may require future studies of kinetics to determine the causes of these changes.

We acknowledge some limitations present in the study. The study was limited to healthy females. The subjects also may have modified their gait due to the unfamiliar shoes and walking environment. Future research could expand on the population by choosing to study males or a specific pathology commonly treated with foot orthotic devices. As discussed earlier, assessing the kinetics involved could better explain the results of this study.

Conclusion

This study is the first to investigate the effects of midfoot-targeted orthotic strategies on midfoot and rearfoot kinematics. Our results indicate that the ankle joint only experience

minor changes due to the postings. The heel lift and varus posts affected the transverse plane, not the sagittal and frontal planes as we hypothesized. The valgus post generally affected the frontal plane as we expected.

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Appendix A

Approved IRB Application



Institutional Review Board (IRB)
 COMMITTEE FOR THE PROTECTION OF HUMAN SUBJECTS IN RESEARCH
 Dayton, OH 45469-0104
IRB@udayton.edu

Application for Non-Exempt Human Research

Instructions

Please use this form for your Institutional Review Board (IRB) application by directly entering information into each section or copying and pasting into the appropriate sections from your own document. Please direct all QUESTIONS and submit all APPLICATION MATERIALS Electronically to IRB@UDayton.edu.

~NO HARD COPY APPLICATIONS WILL BE ACCEPTED~

1a. DATE OF SUBMISSION: 2/28/2014

1b. PRIMARY INVESTIGATOR INFORMATION

Name: Joaquin Barrios, PT, DPT, PhD
 Department: Health and Sport Science (Doctor of Physical Therapy Program)
 Contact Phone: 937-229-5609
 Email: jbarrios1@udayton.edu
 Position in University (if student, must indicate faculty sponsor): Assistant Professor

2. PROJECT TITLE: Multi-segment foot biomechanics with varying foot orthotic postings

3. PROJECT TIME FRAME – Anticipated beginning and ending dates of Research Project:

Start Date: 3/10/2014

End Date: 5/31/2015

4. PROJECT EVALUATION - Please **Check** ALL of the following that apply.

Target Populations Include:

- | | |
|---|--|
| <input type="checkbox"/> Athletes | <input type="checkbox"/> Non-English speaking persons |
| <input type="checkbox"/> Children 0-12 (Parental Consent required) | <input type="checkbox"/> Military personnel |
| <input type="checkbox"/> Children 13-18 (Parental Consent required) | <input type="checkbox"/> Persons convicted of a crime |
| <input type="checkbox"/> Developmentally disabled | <input type="checkbox"/> Persons in treatment for a physical, mental, or emotional ailment |
| <input type="checkbox"/> Elderly | <input type="checkbox"/> Persons on parole |
| <input type="checkbox"/> Elected officials | <input checked="" type="checkbox"/> Persons over the age of 18 <u>ONLY</u> |
| <input type="checkbox"/> Mentally ill | <input type="checkbox"/> Persons with English as a second language |

- ☐ Physically impaired
- ☐ Political appointees
- ☐ Pregnant women
- ☐ Prisoners
- ☐ Teachers

- ☒ UD staff
- ☒ UD students
- ☒ College Students (non-UD)
- ☐ Victims of crime

Site of Data Collection:

- ☐ Classroom
- ☐ Health care facility
- ☐ Public place
- ☐ Off-campus
- ☐ Military or government-operated installation

- ☐ Non-UD campus
- ☒ UD campus
- ☒ Other – Specify: Motion Analysis Lab

Type of Data Collected/Method of Storage:

- ☐ Archives
- ☐ Audio-recordings will be made (must be noted in consent document!)
- ☐ Collection of existing data or records
- ☐ Data will be collected anonymously
- ☒ Data will be kept confidential
- ☒ Data will be linked to participants through code numbers
- ☐ Data will be linked to participants through pseudonyms
- ☐ Data will be stored anonymously

- ☐ During the data collection, participants will be deceived
- ☐ Medical records (HIPAA releases and HIPAA Training may be required)
- ☐ Photographs will be taken (must be noted in consent document!)
- ☐ Publicly available data
- ☐ Specimens or data collected for non-research purposes
- ☒ Participant data will be stored with participant's identity
- ☐ Video recordings will be made (must be noted in consent document!)

Instrument/Method of Data Collection:

- ☐ Deception will be used
- ☐ Focus groups
- ☐ Includes follow-up contact with participants
- ☐ Includes interaction with children
- ☐ Includes observation of children
- ☐ Interviews – e-mail/text/on-line
- ☐ Interviews – face to face
- ☐ Interviews -- telephone
- ☐ Non-UD personnel will collect data

- ☐ Observation of public behavior
- ☐ Oral History
- ☐ Psychological tests
- ☐ Questionnaires
- ☐ Cognitive Performance Tests
- ☒ Physical Performance/Endurance Tests
- ☐ Research on established educational practices, using normal educational practices

- ☒ Students will collect data
- ☐ Participants will be compensated
- ☐ Surveys - anonymous
- ☐ Surveys – online

- ☐ Surveys - paper
- ☐ Uses educational or aptitude tests
- ☐ Use of physiological device

Reason for Research:

- ☒ Faculty/Staff research
- ☒ Undergraduate honors thesis
- ☐ Undergraduate research
- ☐ Graduate research – master's thesis

- ☐ Graduate research – doctoral dissertation
- ☐ Graduate research – non-thesis
- ☐ Classroom project
- ☐ Other reason for research (specify)

Does Your Research Involve Any of the Following Topics?

- ☐ Alcohol use
- ☐ Drug use
- ☐ Emotional stress
- ☐ Illegal activities
- ☐ Gambling
- ☐ Law enforcement
- ☐ Public welfare programs
- ☐ Sexual habits
- ☐ Sexual orientation

5. PROJECT STAFF

Please list personnel, including students, who will be working on this protocol (insert additional rows as needed). This includes anyone who interacts with participants or handles non-anonymous data. All personnel conducting non-exempt research must have completed CITI Program Training in Human Research Protections within the past three years.

Name, Title & Degree	Role (Specify whether person is authorized to obtain consent)	Date of CITI Training (Attach certificates)
Joaquin Barrios	Primary Investigator	On File
Hilary Feskanin	Student Investigator	4/26/2014

6. SITE INFORMATION:

Where will data be collected? (include ALL locations!) NOTE: Documentation of site approval is required for all off-campus data collection! If such documentation is not practical, please contact IRB IRB@udayton.edu to request a waiver. If multiple IRBs are reviewing this application, which IRB will have major oversight? Indicate if the PI is the lead investigator.

Location(s): Motion Analysis Laboratory, College Park Center RM 220F, University of Dayton, 45469-2925

Multi-Site Studies (if applicable): N/A

7. RESEARCH ABSTRACT: Please provide a brief description in LAY language of the aims of this project. Use the following headings: Background and Purpose, Participants, Methods. (Suggested length 1 page)

Background/purpose: Orthotic devices are often used to treat overuse injuries, running-related musculoskeletal injuries, over-pronation and various other pain-related issues. Clinical documentation shows the effectiveness of foot orthoses but there is little understanding of the mechanisms behind these outcomes. Previous studies of foot orthoses have historically collected data on rearfoot biomechanics due to methodological challenges. However, foot orthoses are aimed at altering whole-foot mechanics, not just rearfoot mechanics. There is minimal research on whether orthoses alter midfoot kinematics. Therefore, the purpose of this study is to assess 3D lower extremity joint mechanics in response to various types of foot orthotic postings to determine how the midfoot is affected. It is possible that a better understanding of the effects of medial, lateral and posterior orthotic postings can lead to more effective treatments for patients with

foot disorders. We hypothesize that directional movement patterns of the midfoot will be based on the location and type of posting.

Participants: Twenty-four healthy females.

Methods: Subjects will have reflective markers placed on their right limb. 3D joint mechanics will be captured as subjects walk and run through an instrumented motion capture volume (8-camera Vicon System and Bertec Force Plate). They will complete at least five usable trials per condition. The first orthotic conditions will be a standard unaltered device. The three altered device conditions will be the 2) varus wedge, a 3) valgus wedge, and a 4) heel lift. The participants will wear New Balance Minimus shoes and will run and walk at controlled speeds. Each participant's arch height will be also measured using the Arch Height Index Measurement System.

8. RESEARCH QUESTION OR HYPOTHESIS: *What question do you hope to answer with your research? Are you expecting a certain result? (Please limit to 1 – 2 sentences!)*

Question: How does the midfoot region respond to various types of orthotic postings?

Hypothesis: We expect directional movement patterns based on the location and type of posting or lift. We expect those patterns to be different from baseline.

9. LITERATURE REVIEW: *Please provide a brief review of the literature that provides support for the research question being asked and methods being used. List references at end of application (section 20). (Please limit to 1 – 2 pages.)*

Response:

Foot orthotic devices are often used to treat overuse injuries, over- or under-pronation of the foot, knee pain and other disorders. Overuse injuries are the most common pathologic condition which prevents runners from training. The number of occurrences has been on the rise for the past three decades (Hirschmuller et al., 2009). Common overuse injuries include patellofemoral pain syndrome, plantar fasciitis and tibial stress syndrome. Foot orthoses are thought to be effective in treating overuse injuries because they aid in correcting the biomechanics and minimize muscle work (Hirschmuller et al., 2009).

Plantar fasciitis often causes heel pain in adults (Young et al., 2001). The body cannot easily repair the microtears that cause tissue pain, and clinicians often resort to treating by an external device. Individuals with excessively high or low arches can be at an increased risk for developing plantar fasciitis due to their reduced ability to absorb the forces upon impact (Young et al., 2001). Collapsed arches cause atypical weight bearing within the foot which can lead to ankle, knee and hip problems (Zifchock & Davis, 2008). Studies have also found that people with pes planus or pes cavus have an increased risk of developing a stress fracture (Kaufman et al. 1999). Foot orthoses are often prescribed to

correct the abnormal weight-bearing and gait conditions that variable arch height can cause (Zifchock & Davis, 2008).

Foot orthoses can also treat patellofemoral pain syndrome. Orthoses can cause changes in the foot's function and these alterations can affect other lower extremity regions (Gross & Foxworth, 2003). Studies indicate that excessive foot pronation could be associated with a less varus or increased valgus position of the tibiofemoral joint (McClay & Manal, 1998). This rotation can increase the contact forces or pressures on the lateral patellofemoral articulation. By adding a varus or valgus foot orthotic posting, the effects of misalignment can be mitigated.

Foot orthoses have shown a 70%-90% success rate for treating pain (Eggold, 1981). Research specific to how various orthotic postings affect the midfoot is very sparse (Brown et al., 1995). Therefore, the biomechanical effects that orthotic devices induce on the midfoot are often based on the assumption that observable rearfoot changes are similar in effect to less observable midfoot changes. While orthotic devices often exhibit positive clinical outcomes, there is limited understanding of the associated biomechanical changes (Ferber & Benson, 2011).

Previous studies have focused on rearfoot mechanics and the results of these studies can greatly vary. Some studies conclude no effect on rearfoot control (Brown et al., 1995) while others result in significant effects on rearfoot kinetics (Huerta, 2009). Additional research on the mechanical effects of orthoses is suggested (Brown et al., 1995). Therefore, we propose to evaluate the midfoot effect of 6 degree lateral, medial and posterior wedging using a multi-segment foot model.

10. PROCEDURES and METHODS: *Describe in detail all procedures involving human participants for this protocol. Include electronic copies of all surveys and outcome measures used. Include here all tests, measurements, equipment, interventions, manipulations, etc. used in data collection. Use as much space as required to provide a complete description of the procedures proposed.*

The testing will be conducted in the Doctor of Physical Therapy Program's Motion Analysis Laboratory at the University Of Dayton in Dayton, Ohio. The cumulative testing time should not exceed 2 hours. First, the subject will be briefed on the testing procedures verbally. They will be informed that they have the right to withdraw from the study at any point of time. The subjects will read and sign a consent form prior to participation.

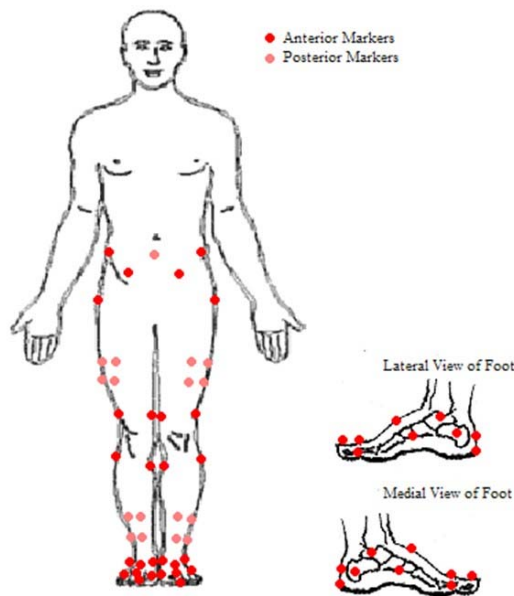
First, arch height of the test limb will be measured using the Arch Height Index Measurement System. For this measurement, the subject is first seated with hip and knees flexed at 90 degrees, feet resting on the floor. The value is then calculated from measurements obtained for dorsum height and the truncated foot

length. The measurement is then repeated in standing. The values generated in each condition are used for analysis.

The subjects will then be prepared for gait analysis. Using skin-safe tape, anatomical markers will be placed by Hilary Feskanin, the student investigator, over the anterior superior iliac spines, the iliac crests, and the greater trochanters. Individual tracking markers will be placed on the L5-S1 interspinous space, the medial and lateral femoral condyles, the medial and lateral tibial plateaus, the medial and lateral malleoli, the first and fifth metatarsal heads, and the distal aspect of the shoe. A total of three tracking markers will be placed on the rear foot over the shoe. In addition, rigid clusters of four tracking markers will be fastened with Velcro straps on the distal posterior shank and the distal posterolateral thigh of the right leg.

Three-dimensional data tracking will then begin. Data will then be collected using a Vicon three dimensional motion analysis system (VICON, Oxford Metrics, UK). Analog data from a floor-mounted force plate (BERTEC Corp., Worthington, OH, USA) will be captured. A standing calibration trial, as well as a hip motion trial, will then be collected to establish the position and orientation for each segment coordinate system. The anatomical markers will then be removed, leaving the tracking markers for the dynamics trials.

The data from the walking trials will be collected as subjects walk along a 23 m walkway at 1.5 m/s ($\pm 5\%$). Next the subjects will run along the 23 m walkway. Four orthotic conditions will be captured in a randomized fashion, in order to eliminate any order effects. The complete set of conditions will be comprised of lateral wedging at 6 degrees, medial wedging at 6 degrees, a heel lift and no post/lift. Each subject will be tested using the same shoe and stock device (Vasyli Medical, San Rafael, CA, USA) for each orthotic condition (New Balance Minimus, Lawrence, MA, USA). For each condition, at least five usable trials will be collected.



Study Design: Cross-sectional laboratory study comparing lower extremity and foot biomechanics associated with four foot orthotic conditions.

Outcome Measures - Surveys, Questionnaires, Physical or Cognitive Performance Measures (include copies of forms with your application):

Materials, Instruments and Equipment:

Vicon 8-camera motion capture system
 Bertec Force Platform
 Vasyli Red $\frac{3}{4}$ length orthoses
 Vasyli Heel Lift
 Vasyli Forefoot Valgus post
 Vasyli Forefoot Varus post
 New Balance Minimus Shoes

Deception: *Will the participants be deceived in any way? Please explain why deception is necessary and justify its use. Fully describe the nature of any deception either by actively misleading or lying to the participant, or through the omission of pertinent information.*

No

11. STUDY POPULATION, RECRUITMENT PROCEDURES, SCREENING PROCEDURES: *Attach electronic copies of advertisements/brochures used for recruitment.*

Method of Participant Identification and Recruitment: UD community and surrounding areas verbal, electronic and paper advertisement

Total number of Participants: N=24

Age range of Participants: 18-35

Inclusion Criteria: Healthy females who fit women's sizes 7-9.

Exclusion Criteria: Injuries or surgeries within the last year that affect the lower limb anatomy or the ability to perform the required tasks

12. RISKS AND BENEFITS:

Potential Risks *(these should be listed in the consent document!):*

This is a study with minimal overall level of risk to the subject. For example, it is possible that a subject could slip, trip, or fall while walking through the laboratory. We will take measures to prevent such occurrences. There is also a risk that the participant could feel some level of discomfort from the altered foot mechanics during trials.

Steps taken to minimize risk:

The experimental area will be kept clean, dry, and clear of obstructions. Subjects will also be given the opportunity to practice walking through the laboratory area to familiarize them with the testing environment. To avoid excessive discomfort, we will only use degrees of wedging which are routinely prescribed and studied.

Potential Benefits:

There are no immediate or long-term expected benefits for the subjects.

Use of Deception, if applicable: *Investigators cannot deceive participants about significant aspects of the study that would affect their willingness to participate such as physical risks, etc. When participants are deceived, they must be offered the opportunity to withdraw their data from the study during the debriefing.*

N/A

Emergency procedures, if applicable *(must address if research is greater than minimal risk):*

N/A

13. COMPENSATION: *Will participants be compensated for participation? If so, please include details. Please review the IRB Guidance on Tax Implications of Research Incentives. Describe in detail how compensation will be administered. Describe how recordkeeping will be handled. What is the source of the funds?*

No

14. DATA:

Sample Size Determination (if applicable):

Previous literature in gait mechanics has used 15-30 test subjects. Therefore a convenient sample of 24 healthy individuals will be recruited for this study from the local community.

Data Analysis: SPSS

Data Management, Storage and Destruction:

Participation in this study is voluntary and confidential, and individual identities will not be revealed in any publication or document resulting from this research. Data will be anonymously recorded by use of an assigned identification number only known to the primary investigators of this study. All research related materials will be kept under the control of the researcher. The document linking the individual subject's name with an identification number will be stored in the primary investigator's office. All data from this study will be kept confidential. Information derived from this study will be used for research purposes but will be kept on file for further appropriate use.

15. CONFIDENTIALITY: *How will participant identity and confidentiality be protected? Will participants be audiotaped, photographed or videotaped during this study? (must be mentioned in consent document!) How long will identifiable data be kept?*

Response:

No audio, photo or video will be used. Identification numbers will be used to maintain confidentiality.

16. ATTACHMENTS/APPENDICES. Send by e-mail to IRB@udayton.edu. (You must include all that apply)

- ☒ Documentation of Training in Human Research Protections (i.e. CITI training).
- ☒ Consent forms (Use UD consent form template; for anonymous surveys, use introduction template only, and do not ask for signatures!). If you do not plan to use Consent Forms, you **MUST** justify your request for a waiver.
- ☒ Data collection forms to be used in this research, if applicable.
- ☒ Advertisements used to recruit participants (e-mail, brochure, fliers, etc.)

17. OTHER APPROVALS - Submit ALL that apply with application.

- ☐ Has this protocol been submitted to any other IRBs? If so, please list along with protocol title, number, and expiration date. Please submit all the associated documentation with your application.
- ☐ If you will be collecting data OFF-CAMPUS, you will need to provide documentation of approval by an administrator at that site (e.g., school principal, clinic director). This can be sent by e-mail to IRB@udayton.edu. If such documentation is not practical, please contact IRB@udayton.edu to request a waiver.
- ☐ If you are a STUDENT, you will need to provide documentation that your faculty advisor (1) has read your IRB application, and (2) approves of the research as proposed. This can be sent by e-mail by the faculty advisor to IRB@udayton.edu.

18. IS THIS PROJECT EXTERNALLY FUNDED? *(If so, please list the funding source, award number, award period, award title)*

Response:

Project is partially funded through the University of Dayton Honors Program

19. DISCLOSURE OF FINANCIAL INTERESTS - *Investigator(s) must identify any financial interests or relationships related to this research. All researchers must disclose any personal financial interest (i.e. income, honoraria or other payment for services), equity (i.e., stock, stock options or other ownership interests, and royalties) for the researcher or his/her spouse or domestic partner and dependent children, or relationship with a for-profit company that either directly supports research being conducted by that individual or is related to research being conducted by that individual, such as financial interests that are related to federally funded studies. All personal financial interests related to research activities must be reported, regardless of dollar amount.*

Response: None

20. REFERENCES *(list references used in your literature review here)*

- Brown, G. P., Donatelli, R., Catlin, P. A., & Wooden, M. J. (1995). The Effect of Two Types of Foot Orthoses on Rearfoot Mechanics. *J Orthop Sports Phys Ther*, 21(5), 258-267.
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- Ferber, R. (2007). The Influence of Custom Foot Orthoses on Lower Extremity Running Mechanics. *Int SportMed*, 8(3), 97-106.
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- Hirschmuller, A., Baur, H., Muller, S., Helwig, P., & Dickhuth, H.-H. (2009). Clinical effectiveness of customised sport shoe orthoses for overuse injuries in runners: A randomized controlled study. *Br J Sports Med*, 959-965.
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- Kaufman, K. R., Brodine, S. K., Shaffer, R. A., Johnson, C. W., & Cullison, T. R. (1999). The effect of foot structure and range of motion on musculoskeletal overuse injuries. *The American Journal of Sports Medicine*, 27(5), 585-593.
- MacLean, C. L., Davis, I. S., & Hamill, J. (2009). Influence of Running Shoe Midsole Composition and Custom Foot Orthotics Intervention on Lower Extremity Dynamics During Running. *Journal of Applied Biomechanics*, 54-63.
- McClay, I., & Manal, K. (1998). A comparison of three-dimensional lower extremity kinematics during running between excessive pronators and normals. *Clin Biomech*, 195-203.
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- Zifchock, R. A., & Davis, I. (2008). A comparison of semi-custom and custom foot orthotic devices in high- and low-arched individuals during walking. *Clinical Biomechanics*, 1287-1293.

UNIVERSITY OF DAYTON - CONSENT TO PARTICIPATE IN RESEARCH**Appendix A- Informed Consent****TITLE OF STUDY:** Multi-segment foot biomechanics with varying foot orthotic postings

You are asked to participate in a research study conducted by Dr. Joaquin Barrios, Department of Health and Sport Science, and Hilary Feskanin, Department of Aerospace and Mechanical Engineering at the University of Dayton. Your participation in this study is voluntary. Read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

SPONSOR OF STUDY

University of Dayton Honors Program

PURPOSE OF THE STUDY

You have been invited to participate in this study because you are a healthy individual between 18 and 35 years old. The main goal of this study is to evaluate the effects of different foot orthotic devices on foot mechanics. To accomplish this, we will have you walk and run in the following foot orthotic conditions in random order: wedging under the arch (medial), the outside of your foot (lateral) and your heel (posterior) and record the movement patterns. These results will help identify characteristics of inserts that are mechanically helpful.

PROCEDURES

Subjects in this study are between the ages of 18-35, and have not had injuries or surgeries within the last year that affect the lower limb anatomy or the ability to perform the required tasks. This study will take place at the Doctor of Physical Therapy Program's Motion Analysis Laboratory at the University of Dayton.

First we will measure your arch height using an Arch Height Index Measurement System. For this measurement, you will first be seated with your hip and knee bent at 90 degrees, feet resting on the floor. Next you will stand and we will repeat the measurement.

We will then evaluate your movement patterns. Markers will be placed by Hilary Feskanin, the student investigator, on your legs per figure 1 with skin-safe tape, and we will record your leg mechanics as you walk and run along a 75 ft walkway. We will test your movements with the different orthotic wedges. Up to 50 total trials will be captured. Your height will also be recorded.

The single visit to the laboratory should not exceed 2 hours. Up to 30 individuals will participate in this study.

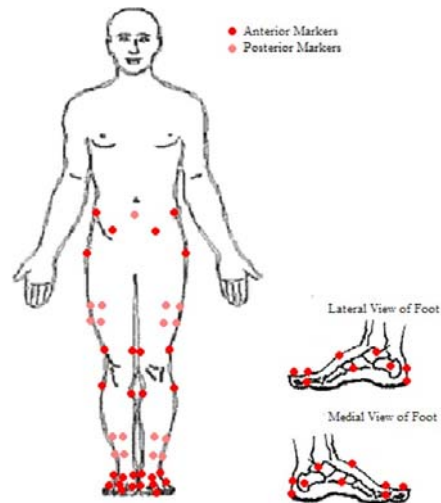


Figure 1

POTENTIAL RISKS AND DISCOMFORTS

There are minor risks associated with this program. For example, it is possible that you could slip, trip, or fall while walking through the laboratory. There is also a risk that the participant could feel some level of discomfort from the altered foot mechanics during trials. We will take measures to prevent such problems. The experimental area is clean, dry, and clear of obstructions. You will practice walking through the data collection area to familiarize yourself with the testing environment. To minimize the chance for excessive discomfort, we will only use degrees of wedging which are routinely prescribed and studied.

ANTICIPATED BENEFITS TO PARTICIPANTS

There are no immediate or long-term expected benefits for the subjects.

PAYMENT FOR PARTICIPATION

There is no compensation for participating in the study.

IN CASE OF RESEARCH RELATED INJURY

If you become ill or are injured as a result of this study, you should seek medical treatment through your doctor or treatment center of choice. You agree to promptly tell the Principal Investigator about any illness or injury: [Joaquin Barrios, 937-229-5609].

You do not waive any liability rights for personal injury by signing this form."

CONFIDENTIALITY

Information and measurements obtained from you during this study will be kept confidential and only personnel collaborating with Dr. Joaquin Barrios' lab, or associated with the human subjects review board are permitted to view the research records. Data may be used for publication purposes, but a code number will be assigned to your data in

order to maintain confidentiality in reporting results. After the study is over, the data will be stored indefinitely for future reference, but confidentiality will be maintained.

PARTICIPATION AND WITHDRAWAL

Your participation in this research is voluntary. If, at any point, you do not wish to continue with the study, you may stop your participation. There are no consequences to stopping, and you are not required to provide a reason for stopping your participation. **IDENTIFICATION OF INVESTIGATORS**

If you have any questions about this research, please contact one of the investigators listed below.

Principal Investigator:	Joaquin Barrios, PT, DPT, PhD University of Dayton Department of Health and Sport Science 937-229-5609 jbarrios1@udayton.edu
CO-Investigator:	Hilary Feskanin University of Dayton 330-696-3217 feskaninh1@udayton.edu

RIGHTS OF RESEARCH PARTICIPANTS

If you have questions regarding your rights as a research participant, you may contact the Chair of the Institutional Review Board (IRB) at the University of Dayton: Dr. Mary Connolly, (937) 229-3493, Mary.Connolly@notes.udayton.edu.

Appendix B- Data Collection Sheet

Data Collection Sheet

DATE: ____/____/____ Age____ Subject code: _____

Initials of person collecting data: _____ Subject height: _____

Trial #	Description & notes	Walk Speed (s) (1.39 m/s - 1.53 m/s)	Frame #s (saved)
1	Standing Calibration	N/A	
2	Hip Functional Trial	N/A	
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			

Appendix C- Arch Height Index Measurement

Arch Height Index Measurement

Subject: _____ **Date:** _____ **Side:**

Sitting

Standing

Arch Height

Foot Length (FL)

AH (@ ½ FL)

Truncated Foot Length (TFL)

AHI (AH/TFL)

Appendix B

IRB Approval Letter



Institutional Review Board (IRB)

COMMITTEE FOR THE PROTECTION OF HUMAN SUBJECTS IN RESEARCH

Dayton, OH 45469-0104

IRB@udayton.edu

March 13, 2014

Joaquin Barrios
Hilary Feskanin
University of Dayton
300 College Park
Dayton, OH 45469

SUBJECT: "Multi-segment foot biomechanics with varying foot orthotic postings"

Dear Joaquin and Hilary,

The subject proposal has been reviewed through expedited procedures, as described in **45 CFR 46.110 Category (4)**.* I am pleased to **approve** your IRB Application with revisions, and you may begin your data collection immediately.

REMINDERS TO RESEARCHERS:

- If this study is not completed by **(3/12/2015)** you are required to seek re-approval from the IRB prior to that time. You can find the Application for Renewal/Closure on the IRB web site (see link below).
- The IRB must approve all changes to the protocol prior to their implementation, unless such a delay would place your participants at an increased risk of harm. In such situations, the IRB is to be informed of the changes as soon as possible.
- The IRB is to be informed immediately of any ethical issues that arise in your study. Adverse Event forms can be found on the IRB web site.
- You must maintain all study records, including consent documents, for three years after the study closes. These records should always be stored securely on campus.
- It is the researcher's responsibility to notify the IRB when this study is closed. You can find the Application for Renewal/Closure on the IRB web site.

Please let me know if you have any questions. Best of luck in your research!

Best regards,

Mary S. Connolly, PhD

Chair, Institutional Review Board (IRB)

Office for Research

University of Dayton

Dayton, OH 45469

(937) 229-3493

[\(937\) 620-7151](tel:(937)620-7151) cell

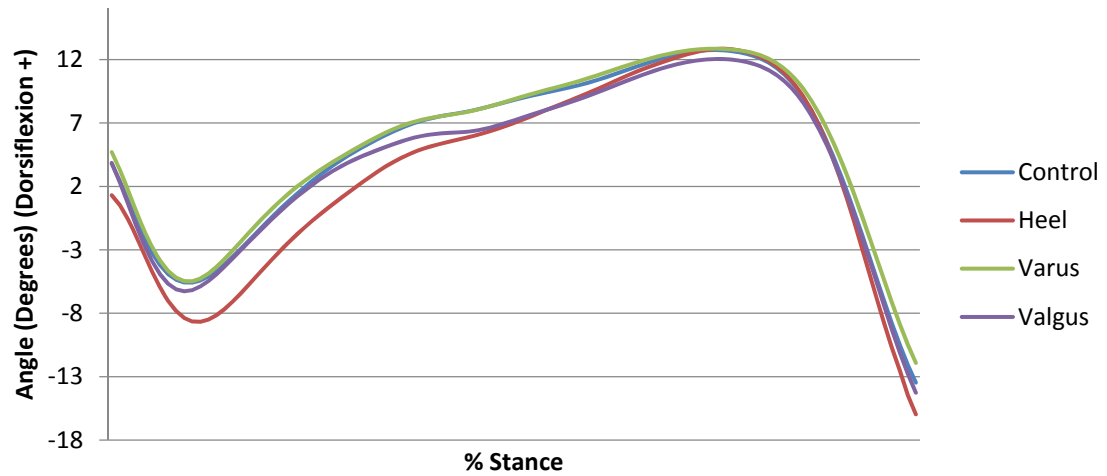
Email: IRB@udayton.edu

<http://www.udayton.edu/research/compliance/irb/index.php>

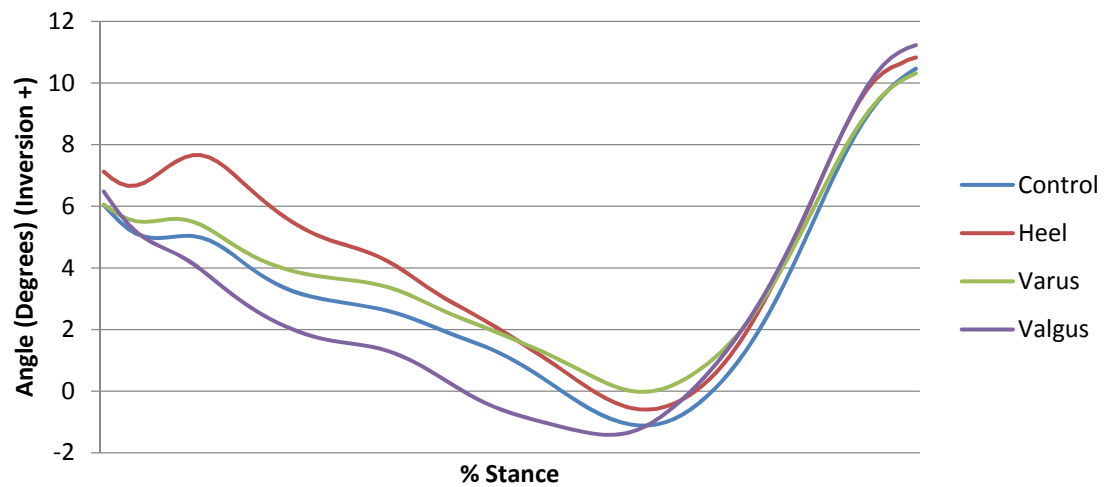
Appendix C

Summary of Graphical Results

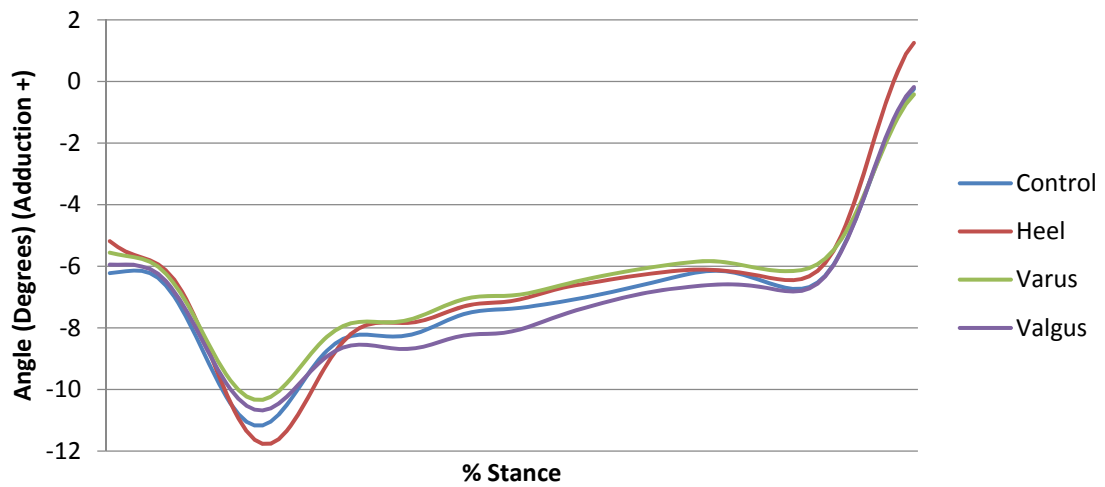
Mean Ankle Sagittal Angle Values by Condition



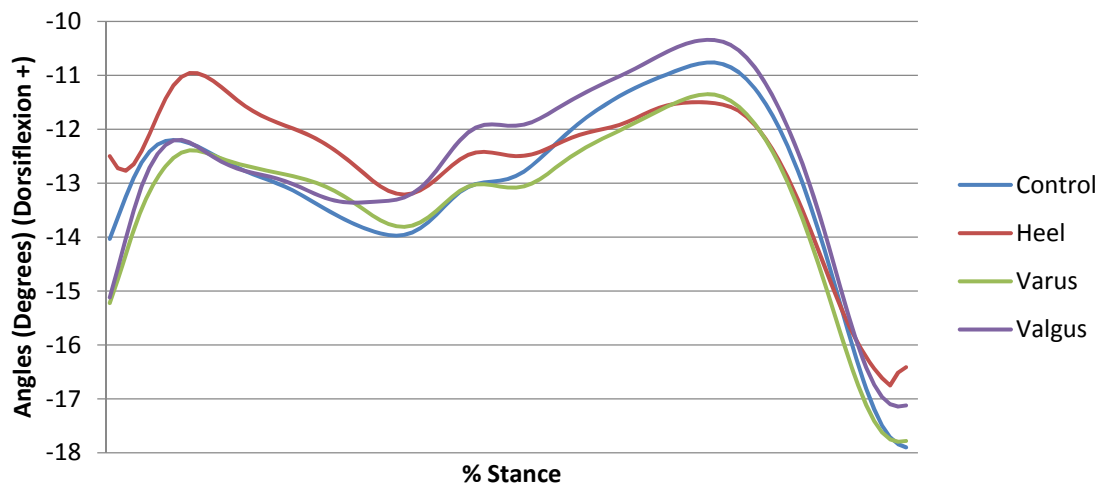
Mean Ankle Frontal Angle Values by Condition



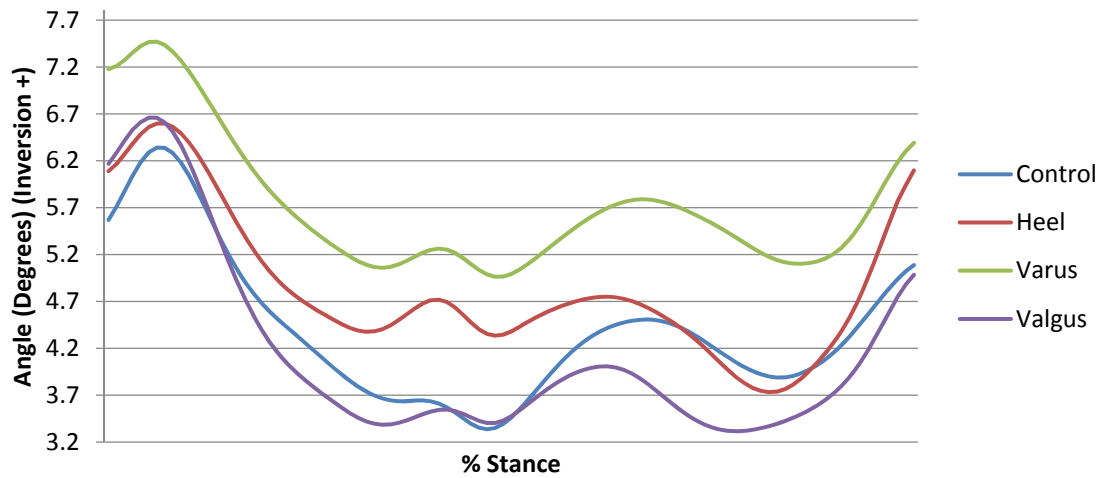
Mean Ankle Transverse Angle Values by Condition



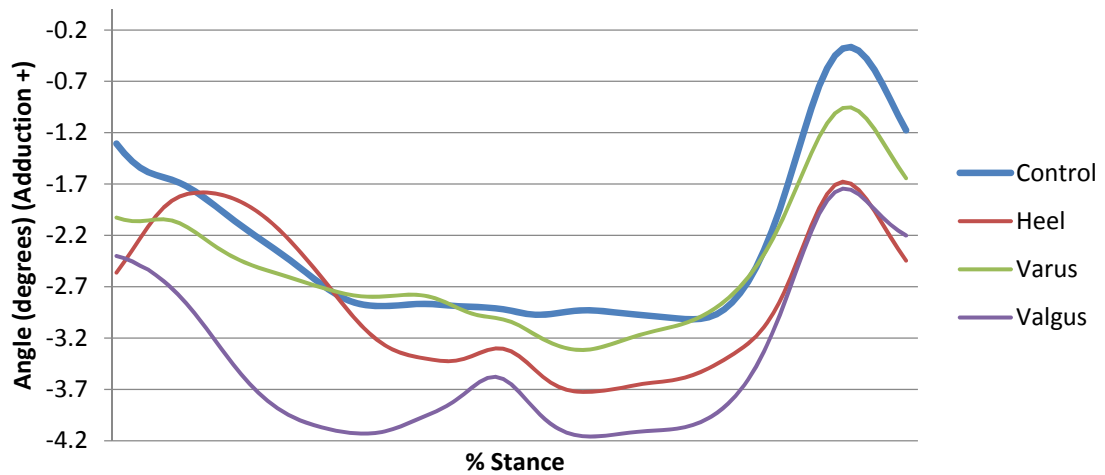
Mean Midtarsal Sagittal Angle Values by Condition



Mean Midtarsal Frontal Angle Values by Condition



Mean Midtarsal Transverse Angle Values by Condition



Appendix D

Honors Student Symposium Presentation

Multi-Segment Foot Joint Kinematics with Varying Midfoot Orthotic Postings



Hilary Feskanin
Joaquin A. Barrios, PT, DPT, PhD
Kimberly Bigelow, PhD

Lower limb disorders

- Foot orthotic devices are often used to help treat:
 - Foot/ankle disorders
 - Plantar fasciitis
 - Achilles tendinitis
 - Over- or under-pronation of the foot
 - Rearfoot region
 - Midfoot region
 - Knee disorders
 - Patellofemoral pain
 - Medial knee osteoarthritis

Treatment mechanisms

- Clinical success has been observed with foot orthoses
 - The mechanisms behind the success are not fully understood
- The methods to assess foot mechanics with the orthoses have been historically limited to the rearfoot
- We need to be able to study interventions with more focus on the specific effects of orthoses

Purpose

- The purpose of this study was to compare the three-dimensional ankle and midtarsal joint kinematics during walking using a standard foot orthosis and additional posts
 - Heel lift
 - Midfoot varus
 - Midfoot valgus
- We hypothesized that the heel lift would produce changes in the sagittal plane and the varus and valgus posts would cause changes in the frontal plane

Subject characteristics

- Sample size estimation
 - Based on previous gait mechanics literature, 19 subjects would produce accurate results
- Inclusion/exclusion criteria
 - Healthy adults, ages 18-35
 - No injuries or surgeries within the last year that affect the lower limb anatomy or the ability to perform the required tasks

Materials

- 8 camera (VICON, Oxford Metrics, UK) motion analysis system (100 Hz) and floor mounted force plate (BERTEC, Columbus, OH) (1500 Hz)
- Shoe with a modified longitudinal zipper and holes cut at marker locations (New Balance Minimus, Lawrence, MA, USA)



Materials

- 6 degrees forefoot valgus post, 6 degrees forefoot varus post, a heel lift and a $\frac{3}{4}$ length orthoses (Vasyl Medical, San Rafael, CA, USA)



Heel Lift



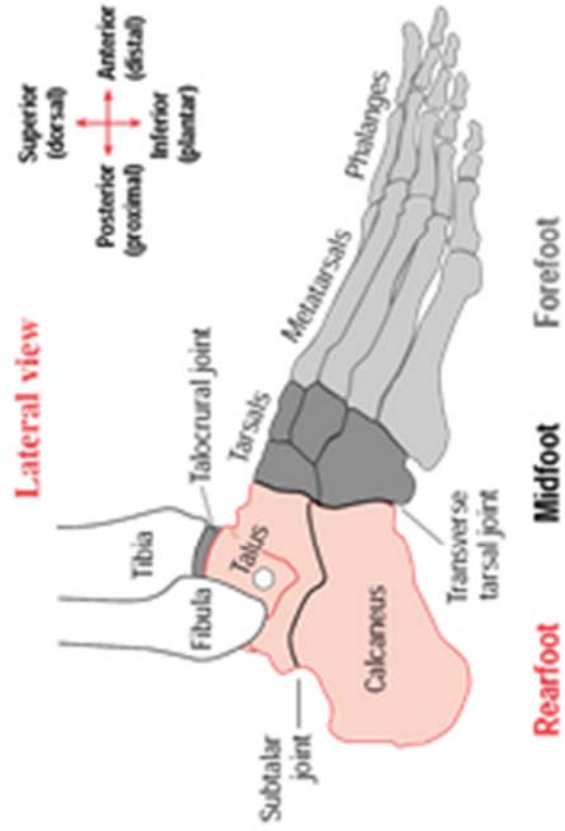
Varus



Valgus

Subject preparation

- We placed reflective markers using a combination of a recently established multi-segment foot model (Bruening et. al, 2012) and a well-established lower extremity model
 - The multi-segment foot model allows us to study the foot in terms of the rearfoot, midfoot and forefoot

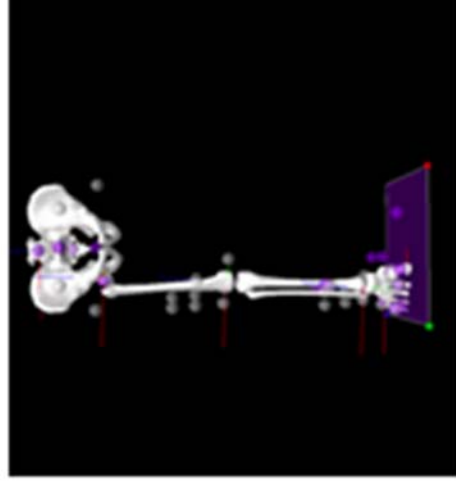
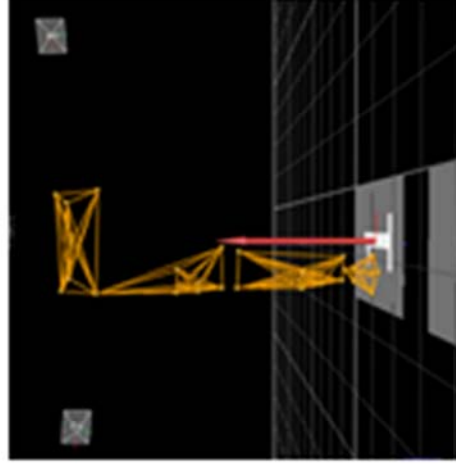


Conditions

- Subjects were first fitted with the standard orthotic condition to establish a natural walking speed
 - A static calibration and functional hip motion trial were completed in the standard orthotic condition
- The three additional post conditions were then tested in random order

Gait data processing

- Post processing of stance data was performed using Visual 3D, Version 4.0 (C-Motion, Bethesda, MD)
- Target variables extracted using custom written code (Labview, National Instruments, Austin, TX) and averaged over five usable trials



Kinematic variables

- Joint angles determined using Cardan rotation sequence (order: flexion/extension, adduction/abduction, internal and external rotation)
 - Ankle joint angles (rearfoot relative to shank)
 - Midtarsal joint angles (midfoot relative to rearfoot)

Target variables

- Initial contact (IC) angles in the sagittal, frontal and transverse planes (°)
- Peak dorsiflexion (DF), eversion (Ev), and abduction (Abd) angles (°)
- Dorsiflexion, eversion and abduction excursions (Exc) (°)



Statistical analyses

- Condition means and standard deviations
- Condition differences for each target variable were assessed using single-factor repeated measures analyses of variance with post-hoc pairwise comparisons ($\alpha = 0.05$)

Subject demographics

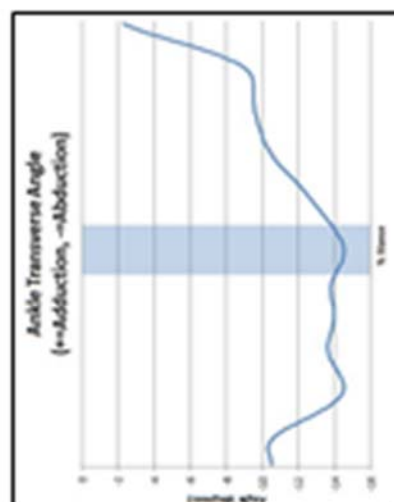
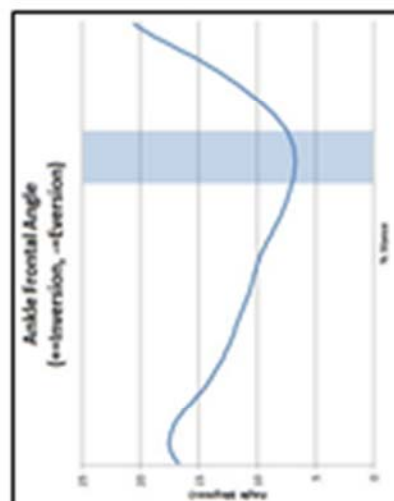
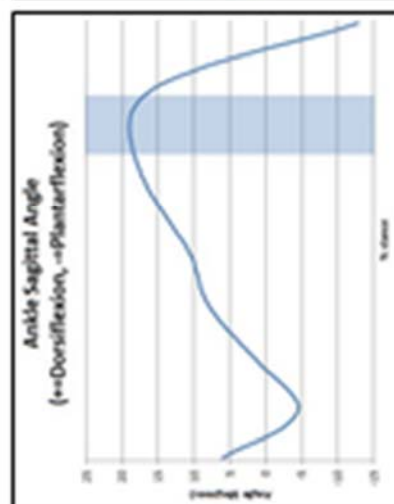
n= 19	Mean ± SD
Sex	19 females
Age	22.0 ± 1.7 years
Height	1.65 ± 0.06 m
Weight	63.63 ± 8.57 kg
BMI	23.3 ± 3.4 kg/m ²
AHI Sitting	0.36 ± 0.03
AHI Standing	0.32 ± 0.03

Notes on Pronation

- We generally expect pronation throughout stance
- Pronation consists of dorsiflexion, eversion and abduction
- The orthotic devices change the amount of pronation we see
 - Greater amounts of DF, Ev, and Abd enhance pronation

Baseline ankle 3D angles

Ankle Joint Angles for the Standard Condition			
	Initial Contact	Peak	Excursion
Sagittal	3.80	13.68	9.88
Frontal	6.04	-0.84	-6.88
Transverse	-6.23	-12.01	-5.78



Ankle angles

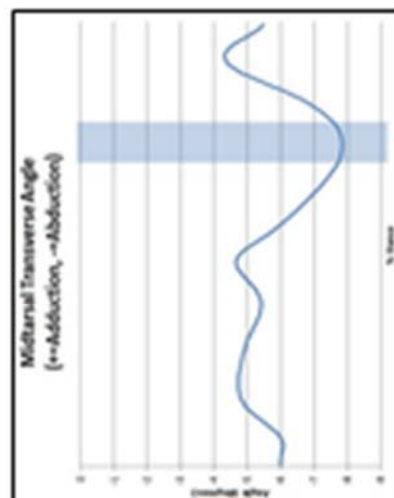
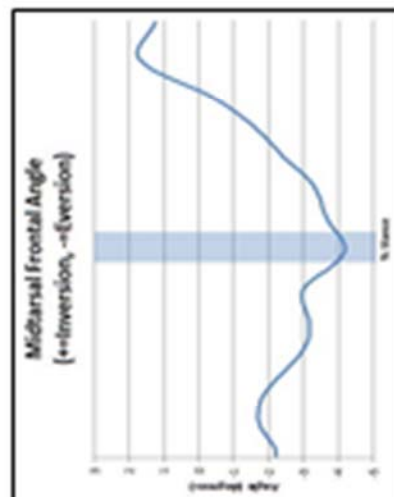
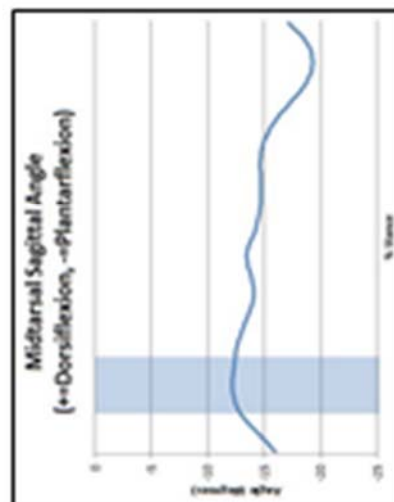
Ankle Joint Angles for the Heel Lift			
	Initial Contact	Peak	Excursion
Sagittal	1.56	14.48	12.93
Frontal	7.05	-1.01	-8.06
Transverse	-5.19	-12.77	-7.59

Ankle Joint Angles for the Varus Post			
	Initial Contact	Peak	Excursion
Sagittal	4.70	13.86	9.16
Frontal	6.06	-0.52	-6.58
Transverse	-5.56	-11.21	-5.66

Ankle Joint Angles for the Valgus Post			
	Initial Contact	Peak	Excursion
Sagittal	3.85	13.43	9.58
Frontal	6.48	-1.25	-7.73
Transverse	-5.95	-11.72	-5.77

Baseline midtarsal 3D angles

Midtarsal Joint Angles for the Standard Condition			
	Initial Contact	Peak	Excursion
Sagittal	-14.00	-9.25	4.75
Frontal	6.56	3.11	-3.45
Transverse	-1.28	-4.49	-3.21



Midtarsal angles

Midtarsal Joint Angles for the Heel Lift			
	Initial Contact	Peak	Excursion
Sagittal	-12.72	-7.11	5.61
Frontal	6.09	2.54	-3.55
Transverse	-2.56	-5.26	-2.70

Midtarsal Joint Angles for the Varus Post			
	Initial Contact	Peak	Excursion
Sagittal	-15.22	-9.70	5.53
Frontal	7.18	3.33	-3.85
Transverse	-2.03	-4.70	-2.67

Midtarsal Joint Angles for the Valgus Post			
	Initial Contact	Peak	Excursion
Sagittal	-15.12	-8.65	6.47
Frontal	6.31	1.74	-4.57
Transverse	-2.20	-5.49	-3.29

Ankle joint changes

- Note the generally limited effects of the orthotic postings on the ankle joint
- Only the transverse plane was affected
 - Heel lift increased adduction on IC and increased the overall abduction excursion
 - The varus post decreased peak abduction



Impact of a heel lift at midtarsal joint

- The heel lift did not affect the sagittal plane as we expected
 - A direct result is the rearfoot raising, increasing plantarflexion
 - Musculoskeletal compensation is likely present
 - Further studies on kinetic data may help explain these findings
 - Led to more abduction at initial contact

Impact of a varus post on midtarsal joint

- Varus post affected the transverse plane
 - Decreased abduction excursion
- Did not affect frontal plane as expected
 - Limited pronation

Impacts of a valgus post on midtarsal joint

- The valgus post affected all three planes
 - Decreased dorsiflexion excursion on the sagittal plane



- Increased eversion peak and excursion for the frontal plane



- Increased peak abduction on transverse plane

Limitations

- Healthy subjects only
- Only females
- The subjects were not walking in their normal shoes or natural environment and thus may have modified their gait
- Skin-based markers tracking does not always cleanly reflect underlying skeletal motion
- Three-segment model still does not account for all individual bony motions

Current and future directions

- Study other orthoses or posting strategies
- Pathologic populations
- Conditions other than walking
- Kinetics
- Different shoes
- Study male populations

Conclusions

- The effects appear to be localized to the region changed by the orthotic posting
- The ankle joint only experienced minor changes due to the postings
- The heel lift and varus posts affected the transverse plane
 - Not the sagittal and frontal planes as expected
- The valgus post generally affected the frontal plane as expected

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