

Submission ID #: 69182

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Project Page Link: <https://review.jove.com/account/file-uploader?src=21100558>

Title: Effect of Change of Direction (COD) Movement on Plantar Pressure and Foot Balance in Bilateral Limbs

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Author Questionnaire

1. Microscopy: Does your protocol require the use of a dissecting or stereomicroscope for performing a complex dissection, microinjection technique, or something similar? No

2. Software: Does the part of your protocol being filmed include step-by-step descriptions of software usage? **Yes**

3. Filming location: Will the filming need to take place in multiple locations? NO

4. Testimonials (optional): Would you be open to filming two short testimonial statements **live during your JoVE shoot**? These will **not appear in your JoVE video** but may be used in JoVE's promotional materials. No

Current Protocol Length

Number of Steps: 29

Number of Shots: 44

Interviews

Videographer: Obtain headshots for all authors available at the filming location.

INTRODUCTION:

~~REQUIRED: Summarize your research focus and the main questions it aims to answer.~~

- 1.1. **Haidan Wu:** Our research focuses on measuring plantar pressure and foot balance during 45-degree change-of-direction movements
 - 1.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera *Suggested B roll: 4.2.1*

~~Describe the research gap or limitation in existing methods and how this protocol addresses them.~~

- 1.2. **Haidan Wu:** Existing methods focus on peak plantar pressure values: this protocol captures continuous plantar loading throughout change-of-direction movements
 - 1.2.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

CONCLUSION:

~~What does this protocol allow researchers to study or measure?~~

- 1.3. **Haidan Wu:** This protocol allows researchers to assess bilateral plantar mechanics during sport-specific cutting movements.
 - 1.3.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

~~Describe the most important consideration or challenge when performing this protocol.~~

- 1.4. **Haidan Wu:** The key challenge while performing this protocol is controlling approach speed and ensuring complete foot contact on the pressure plate.
 - 1.4.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera *Suggested B roll: 4.4.1*

~~How can future studies build on this work? Describe the questions or research directions that can be investigated next.~~

- 1.5. **Haidan Wu:** Future studies can apply this protocol to different sports, footwear conditions, and injury-risk populations.
 - 1.5.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

Videographer: Obtain headshots for all authors available at the filming location.

Ethics Title Card

This research has been approved by the Ethics Committee of the Research Institute at Ningbo University

Protocol

***Videographer:** Please always record an audio slate while filming each shot mentioned in the shot list.*

2. Laboratory Preparation and Participant Selection for COD Testing

Demonstrator: Liu Xu

- 2.1. To begin, set up a Footscan 2-meter pressure plate sampled at 480 hertz [1]. Embed the plate flush with the surrounding runway using protective mats to eliminate step-height artifacts [2].
 - 2.1.1. WIDE: Talent positioning the Footscan 2-meter pressure plate within the surrounding runway. ***Videographer:** Please obtain a CU shot as well.*
 - 2.1.2. Talent placing protective mats around the pressure plate.
- 2.2. Zero and weight-calibrate the system according to the manufacturer's instructions [1]. Verify the connected plate's serial number and calibration file before testing [2].
 - 2.2.1. Talent zeroing and weight-calibrating the pressure plate system.
 - 2.2.2. Show the connected plate's serial number and calibration file being verified.
- 2.3. Monitor the approach speed over the final 2 meters before foot contact using dual infrared timing gates, spaced 2.0 meters apart, at a height of 80 centimeters and aligned with the runway [1]. Position the gates on both sides of the runway so they do not interfere with the change-of-direction maneuver [2].
 - 2.3.1. Talent monitoring approach speed with dual infrared timing gates aligned with the runway.
 - 2.3.2. Talent positioning the timing gates on both sides of the runway.

3. Participant Selection and Preparation for the Task

- 3.1. Recruit only right-leg dominant individuals to reduce inter-limb variability. Confirm leg dominance with the preferred kicking-leg test in at least two of three trials [1].
 - 3.1.1. Participant performing the preferred kicking-leg test across repeated trials.
- 3.2. Include only healthy Chinese adults with no history of lower limb injuries or foot deformities during the previous 6 months [1].
 - 3.2.1. Talent screening participant eligibility based on injury and foot-deformity

history.

3.3. Instruct participants to wear tight-fitting athletic pants [1]. Have participants stand barefoot on the Footscan plate with both feet positioned together [2].

3.3.1. Participant wearing tight-fitting athletic pants.

3.3.2. Participant standing barefoot on the Footscan plate with both feet together.

3.4. Collect and record anthropometric data, including height, weight, foot length, shoe size, and arch type [1]. Participants must maintain a speed of 3.5 meters per second along the approach path before stepping on the pressure plate [2].

3.4.1. Talent recording participant anthropometric measurements.

3.4.2. Talent observing the participant approaching the pressure plate at the required speed.

3.5. To assess the medial longitudinal arch height, measure the dorsum height at 50% of the total foot length [1]. Calculate the Arch Height Index by dividing dorsum height by total foot length. Values between 0.310 and 0.356 indicate a normal arch [2].

3.5.1. Talent measuring the dorsum height at 50% of the total foot length.

3.5.2. Talent calculating the Arch Height Index from the recorded measurements.

3.6. Show participants a demonstration of the required movement tasks before commencing the main trials [1].

3.6.1. Talent demonstrating the required movement tasks to participants.

3.7. Have each participant perform a 10-minute slow jog as a standardized warm-up to ensure adequate physiological readiness for static and dynamic recordings [1].

3.7.1. Talent performing a 10-minute slow jog warm-up.

4. Static Measurement

4.1. Ask the participants to stand barefoot on the pressure plate with feet shoulder-width apart, knees extended, arms relaxed at their sides, and eyes on a wall mark at eye level, 3 meters ahead [1]. Align the feet with the anterior-posterior axis of the plate [2].

4.1.1. Participant standing barefoot on the flush-mounted pressure plate in the required posture while looking at a wall mark.

4.1.2. Talent aligning the participant's feet with the anterior-posterior axis of the pressure plate.

4.2. After a 3- to 5-second quiet-standing stabilization period, record a single static snapshot of the plantar pressure distribution [1].

4.2.1. Talent recording a static plantar pressure measurement after the stabilization period.

4.3. Collect two valid repetitions per participant and allow at least 30 seconds of seated rest between trials to reduce postural drift [1].

4.3.1. Talent initiating a second static recording trial for the participant while resting in a seated position between trials

4.4. Confirm that full plantar contact of both feet is visible within the active area of the pressure plate [1]. Check for sway or step adjustments during stabilization and ensure footprints do not overlap at the plate edges. Repeat any trial that does not meet the validity criteria [2].

4.4.1. Show complete plantar footprints of both feet within the active area of the pressure plate.

4.4.2. Show plantar footprints fully contained within the plate margins without overlap or truncation.

5. Dynamic Measurement: Barefoot 45° Side-Step COD Trials

5.1. Set an individual fixed start mark for each participant to produce a right-then-left step sequence, with the left-turning step contacting the pressure plate for familiarization [1]. Have participants complete multiple familiarization runs to establish a natural and repeatable gait without visual targets on the pressure plate. Record at least 3 valid trials for each condition [2].

5.1.1. Talent sets an individual fixed start mark for the participant.

5.1.2. Participant performing familiarization runs along the runway without visual targets on the pressure plate.

5.2. For the rightward-cut condition, have the left turning foot land fully on the pressure plate [1].

5.2.1. Participant executing a rightward cut with the left turning foot contacting the pressure plate.

5.3. For the leftward-cut condition, mirror the start mark and step sequence so the right turning foot contacts the pressure plate under the same criteria [1].

5.3.1. Participant performing a leftward cut with the right turning foot contacting the pressure plate.

5.4. Monitor approach speed using two single-beam timing gates with a beam height of 80 centimeters, positioned 2.0 meters apart along the approach path [1]. Align the downstream gate with the proximal edge of the pressure plate active area to measure the final 2 meters before foot contact [2].

5.4.1. Talent monitoring participant approach speed using the timing gates.

5.4.2. Talent positioning the downstream timing gate at the proximal edge of the pressure plate active area.

5.5. Accept a trial only when the measured approach speed is 3.5 meters per second plus or minus 5% [1].

5.5.1. SCREEN: 69182_screenshot_1_speed_acceptance.mp4

6. Footscan Data Analysis

6.1. Manually process all collected data using the Footscan software after completion of the experiment [1]. Carefully examine each static and dynamic trial to identify missing data or disrupted foot-contact patterns and ensure data validity [2].

6.1.1. SCREEN: 69182_screenshot_2_trial_review.mp4 00:00-00:12

6.1.2. SCREEN: 69182_screenshot_2_trial_review.mp4: 00:18-end

6.2. Identify the left and right feet using dynamic plantar pressure images captured at foot contact [1]. Use the visual representation of peak pressure distribution and the center-of-pressure location during the stance phase to confirm foot identification [2].

6.2.1. SCREEN: 69182_screenshot_3_foot_COP.mp4: 00:06-00:22

6.2.2. SCREEN: 69182_screenshot_3_foot_COP.mp4: 00:22-00:34

6.3. Divide the plantar surface into 10 anatomical regions using the system's automated segmentation function [1]. Classify the foot into forefoot, midfoot, and rearfoot zones [2].

6.3.1. SCREEN: 69182_screenshot_4_segmentation_6.3.mp4: 00:17-00:26

6.3.2. SCREEN: 69182_screenshot_4_segmentation_6.3.mp4: 00:00-00:17

6.4. Extract pressure values from each segmented region based on the final segmentation and generate regional pressure-time curves for further analysis [1].

6.4.1. SCREEN: 69182_screenshot_5_pressure_curves.mp4: 00:08-00:30

6.5. Export plantar pressure data separately for static and dynamic conditions, including foot angles, axes, balance, and zone-specific pressure values [1].

6.5.1. SCREEN: 69182_screenshot_6_export_6.5.mp4: 00:08-00:24

6.6. Extract time-series plantar force and pressure data from 10 plantar regions to examine plantar load distribution during stance [1]. Time-normalize the force-time and pressure-time curves to 101 points to ensure temporal comparability across trials [2].

6.6.1. SCREEN: 69182_screenshot_7_normalization_6.6.mp4: 00:12-00:38

6.6.2. SCREEN: 69182_screenshot_7_normalization_6.6.mp4: 00:44-01:11

6.7. Standardize regional forces to the average vertical force during stance to reduce inter-subject variability, as defined by the provided equation [1].

6.7.1. TEXT ON A PLAIN BACKGROUND

$$Z_{avg} = \frac{1}{N} \sum_{t=1}^N F_z(t)$$

$F_z(t)$ = vertical ground-reaction force at frame t

N = Number of stance frames.

6.8. Calculate the foot balance index to assess foot pronation and foot supination during the stance phase using the presented equation [1].

6.8.1. TEXT ON A PLAIN BACKGROUND

$$FBI = \frac{(F_{medial} - F_{lateral})}{F_{avg}} \times 100$$

F_{medial} = summed plantar forces from medial (M1, M2, MH) regions

$F_{lateral}$ = summed plantar forces from lateral (M3–M5, LH) regions

6.9. To determine the foot axis angle, identify the midpoint of the heel and the midpoint of the gap between the second and third metatarsals [1]. Connect these two points to define the foot axis [2].

6.9.1. SCREEN: 69182_screenshot_9_axis_angle_6.9&6.10.mp4: 00:00-00:06

6.9.2. SCREEN: 69182_screenshot_9_axis_angle_6.9&6.10.mp4: 00:06-00:16

6.10. Define the line of direction of movement relative to the foot axis as the foot axis angle [1].

6.10.1. SCREEN: 69182_screenshot_9_axis_angle_6.9&6.10.mp4: 00:16-00:26

Results

7. Results

- 7.1. The dominant foot showed greater force values than the non-dominant foot in the M1 region [1] and MF region [2], particularly during the mid-to-late stance phase, but these differences were not statistically significant according to statistical parametric mapping analysis [3].
 - 7.1.1. LAB MEDIA: Figure 2. *Video editor: Highlight the M1 Force graph and show the black line positioned above the red line*
 - 7.1.2. LAB MEDIA: Figure 2. *Video editor: Highlight the MF Force graph and show the black line positioned above the red line*
 - 7.1.3. LAB MEDIA: Figure 2. *Video editor: Show the SPM panel beneath the force graphs and indicate that the black curve remains below the red significance threshold line.*
- 7.2. The dominant foot showed greater pressure values than the non-dominant foot in the M2 region [1], M3 region [2], and M4 region [3], but these differences were not statistically significant according to statistical parametric mapping analysis [4].
 - 7.2.1. LAB MEDIA: Figure 3. *Video editor: Highlight the M2 Pressure graph and show the black line positioned above the red line*
 - 7.2.2. LAB MEDIA: Figure 3. *Video editor: Highlight the M3 Pressure graph and show the black line positioned above the red line*
 - 7.2.3. LAB MEDIA: Figure 3. *Video editor: Highlight the M4 Pressure graph and show the black line positioned above the red line*
 - 7.2.4. LAB MEDIA: Figure 3. *Video editor: Show the statistical parametric mapping panel beneath the pressure graphs and indicate that the black curve remains below the red significance threshold line.*
- 7.3. Unadjusted analyses suggested a higher FBI maximum [1] and FBI range in the non-dominant limb, but these effects were not statistically significant after correction for family-wise error [2].
 - 7.3.1. LAB MEDIA: Table 1. *Video editor: Highlight the row "FBI Max" and compare the values 35.33 (20.09) for the left foot and 31.44 (19.76) for the right foot, along with the P-value column.*
 - 7.3.2. LAB MEDIA: Table 1. *Video editor: Highlight the row "FBI Range" and compare the values 110.00 (35.50) for the left foot and 71.05 (23.45) for the right foot, along with the P-value column.*

7.4. The time-continuous statistical parametric mapping analysis revealed no supra-threshold clusters over stance, indicating no statistically significant temporal differences under the present testing conditions [1].

7.4.1. LAB MEDIA: Figure 4. *Video editor: Show the lower statistical parametric mapping graph and highlight the black curve.*

1. Footscan
Pronunciation link: <https://www.howtopronounce.com/footscan>
IPA: /'fɒt skæn/
Phonetic Spelling: fut·skan
2. Calibration
Pronunciation link: <https://www.merriam-webster.com/dictionary/calibration>
IPA: /,kæl.ə'breɪ.ʃən/
Phonetic Spelling: kal·uh·bray·shuhn
3. Infrared
Pronunciation link: <https://www.merriam-webster.com/dictionary/infrared>
IPA: /,ɪn.frə'red/
Phonetic Spelling: in·fruh·red
4. Dominance
Pronunciation link: <https://www.merriam-webster.com/dictionary/dominance>
IPA: /'dɑː.mə.nəns/
Phonetic Spelling: dah·muh·nuhns
5. Variability
Pronunciation link: <https://www.merriam-webster.com/dictionary/variability>
IPA: /,vər.i.ə'bɪl.ə.tɪ/
Phonetic Spelling: vair·ee·uh·bil·uh·tee
6. Anthropometric
Pronunciation link: <https://www.merriam-webster.com/dictionary/anthropometric>
IPA: /,æn.θrə.pə'me.trɪk/
Phonetic Spelling: an·thruh·puh·met·rik
7. Dorsum
Pronunciation link: <https://www.merriam-webster.com/dictionary/dorsum>
IPA: /'dɔr.səm/
Phonetic Spelling: dor·suhm
8. Physiological
Pronunciation link: <https://www.merriam-webster.com/dictionary/physiological>
IPA: /,fɪz.i.ə'lɑː.dʒɪ.kəl/
Phonetic Spelling: fiz·ee·uh·loj·i·kuhl
9. Stabilization
Pronunciation link: <https://www.merriam-webster.com/dictionary/stabilization>

- IPA: /ˌsteɪ.bə.ləˈzeɪ.ʃən/
Phonetic Spelling: stay·buh·luh·zay·shuhn
10. Plantar
Pronunciation link: <https://www.merriam-webster.com/dictionary/plantar>
IPA: /ˈplæn.tər/
Phonetic Spelling: plan·tar
11. Anterior-posterior
Pronunciation link: <https://www.merriam-webster.com/dictionary/anterior>
IPA: /ænˈtɪr.i.ə/ ; /pɑːˈstri.i.ə/
Phonetic Spelling: an·teer·ee·er ; pah·steer·ee·er
12. Familiarization
Pronunciation link: <https://www.merriam-webster.com/dictionary/familiarization>
IPA: /fəˌmɪl.jə.əˈzeɪ.ʃən/
Phonetic Spelling: fuh·mil·yur·uh·zay·shuhn
13. Dynamic
Pronunciation link: <https://www.merriam-webster.com/dictionary/dynamic>
IPA: /daɪˈnæm.ɪk/
Phonetic Spelling: dye·nam·ik
14. Segmentation
Pronunciation link: <https://www.merriam-webster.com/dictionary/segmentation>
IPA: /ˌseg.mənˈteɪ.ʃən/
Phonetic Spelling: seg·muhn·tay·shuhn
15. Metatarsals
Pronunciation link: <https://www.merriam-webster.com/dictionary/metatarsal>
IPA: /ˌmeɪ.əˈtɑː.səl/
Phonetic Spelling: met·uh·tar·suhl
16. Pronation
Pronunciation link: <https://www.merriam-webster.com/dictionary/pronation>
IPA: /ˌproʊˈneɪ.ʃən/
Phonetic Spelling: proh·nay·shuhn
17. Supination
Pronunciation link: <https://www.merriam-webster.com/dictionary/supination>
IPA: /ˌsuː.pəˈneɪ.ʃən/
Phonetic Spelling: soo·puh·nay·shuhn
18. Statistical
Pronunciation link: <https://www.merriam-webster.com/dictionary/statistical>
IPA: /stəˈtɪs.tɪ.kəl/
Phonetic Spelling: stuh·tis·ti·kuhl
19. Parametric
Pronunciation link: <https://www.merriam-webster.com/dictionary/parametric>
IPA: /ˌper.əˈme.trɪk/
Phonetic Spelling: pehr·uh·met·rik
20. Supra-threshold
Pronunciation link: <https://www.howtopronounce.com/suprathreshold>

IPA: /ˌsuː.prəˈθreʃ.hoʊld/

Phonetic Spelling: soo·pruh·thresh·hohld