Gait Analysis using a High-Resolution Spatiotemporal Pressure Sensing Insole

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Background

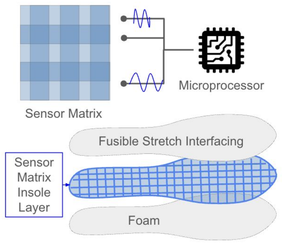
- Gait patterns are ***valuable biomarkers*** for neurological conditions such as stroke
- ***Instrumented gait analysis*** (motion capture, force plates) is infeasible outside the clinic
- The Thakor Lab has developed an insole sensor with sufficient resolution and sampling rates for ***accurate assessment of day-to-day patient gait***

Objectives

- Identify clinically relevant foot regions and derive ***novel pressure and gait metrics*** from insole data
- Assess metric ***interpretability*** and ***ease-of-adoption*** based on literature review and clinician input
- Compare metrics **across walking conditions** for **right leg paretic stroke** patient and **healthy** subject
- Analyze **left-right asymmetries, inter-subject variability**, and rank each metric's predictive value

Data Collection Methods

1



Device: High-resolution (64×16, 100Hz) pressure data collected via sensorized insoles.

Protocol: Split treadmill increasing the speed of the right foot (0.6, 1, 1.4, 1.8 m/s)

Figure 1. Hardware components of the insoles.

Calculating Gait Metrics

2

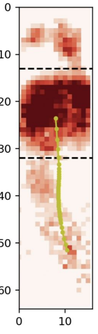


Figure 2. Trajectory of **Center of Pressure (CoP)** over 1 gait cycle.

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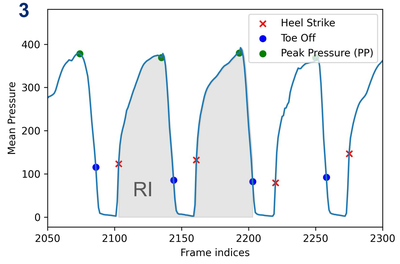


Figure 3. **Peak Pressure (PP)** and **Regional Impulse (RI)** of 2 gait cycles on plot of mean pressure.

- One-Way ANOVA Test conducted for statistical significance between different regions.

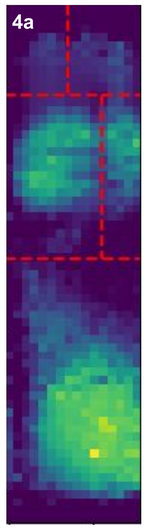
Two Methods for Region of Interest Segmentation

Bottom-Up Pressure Valley Segmentation

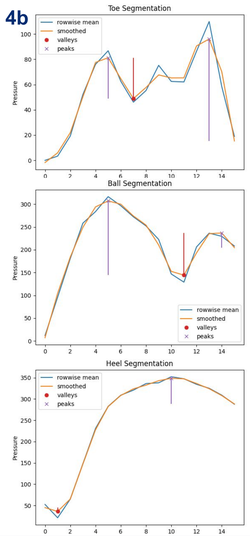
- Divides foot regions by detecting low-pressure valleys in column-wise and row-wise means
- Smooth (Savitzky–Golay and median filter) and remove outliers

Figure 4a. Pressure valley segmentation. **Figure 4b.** Smoothing filter effects on peak/valley detection.

4a

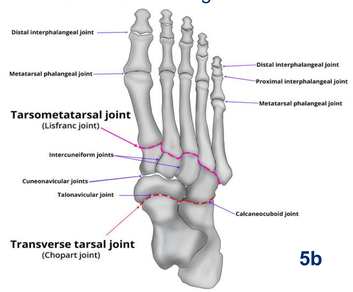


4b



Clinically Informed Anatomical Segmentation

- Anterior-Posterior axis: Forefoot, Midfoot, Hindfoot (based on joint landmarks)
- Medial and Lateral regions

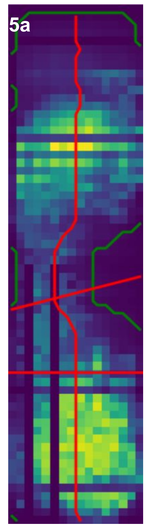


5b

Figure Citation:
Murphy A, Regions of the foot (illustrations). Case study, Radiopaedia.org (Accessed on 20 Apr 2025) https://doi.org/10.53347/rID-99469

Figure 5a. 6 anatomical regions outlined. **Figure 5b.** Locations of joint landmarks.

5a



Comparison of Stroke and Healthy Participants' Gait Using Anatomical Segmentation

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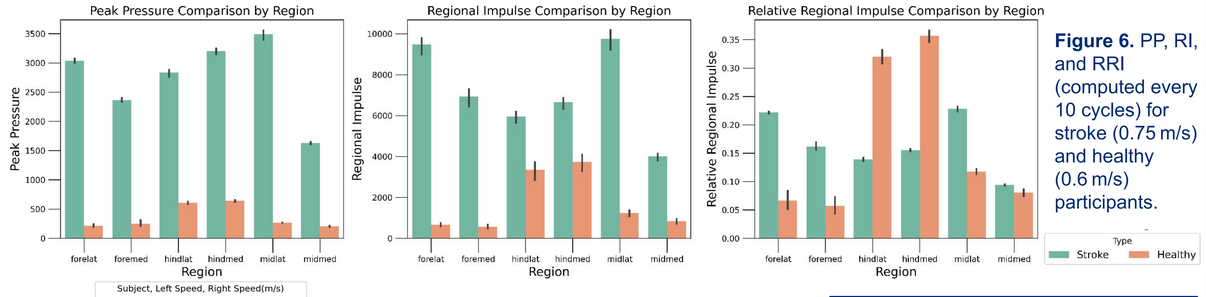

Figure 6. PP, RI, and RRI (computed every 10 cycles) for stroke (0.75 m/s) and healthy (0.6 m/s) participants.

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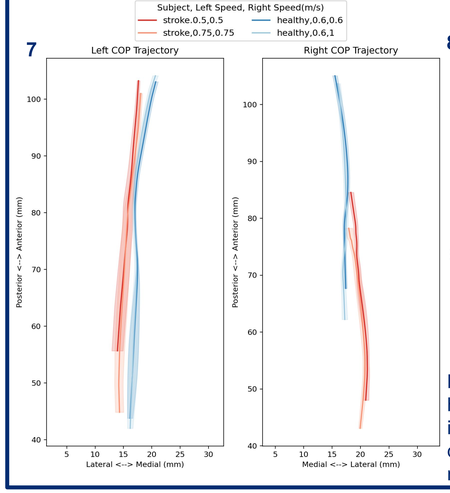

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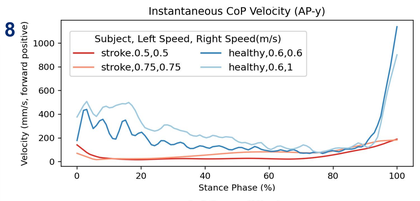

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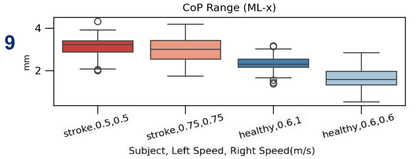

Figure 7. CoP trajectories for one gait cycle of healthy and stroke patient. **Figure 8.** CoP instantaneous velocity in anterior-posterior direction average per gait cycle. **Figure 9**. CoP range of right foot in medial-lateral direction.

Key Takeaways

- **Figure 6**: stroke patient has significantly greater pressure in all regions except hindlat and hindmid for RRI. ***medial-lateral asymmetry*** in stroke patient ↑
- **Figure 7**: stroke patient ***right foot drags behind left*** foot
- **Figure 8**: stroke patient has reduced CoP velocity at heelstrike and toe off → forward ***speed and force upon ground contact is reduced*** in stroke
- **Figure 9**: Right mediolateral CoP(x) range ↑ → ***impaired lateral stability***

Analysis on Healthy Participant Using Pressure Valley Segmentation

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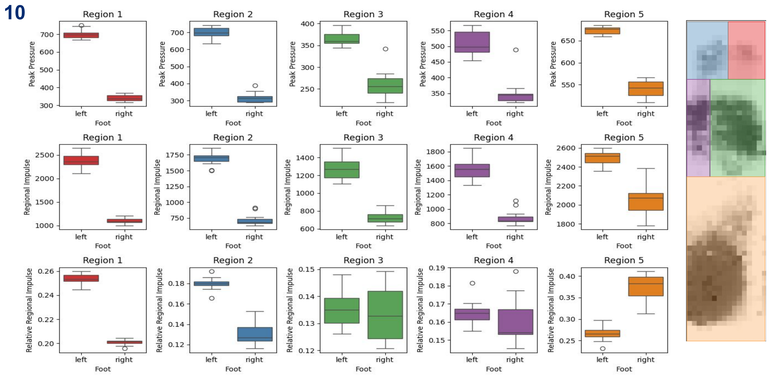

Figure 10. Left-right asymmetry in PP/RI/RRI during normal gait (0.6 m/s both feet).

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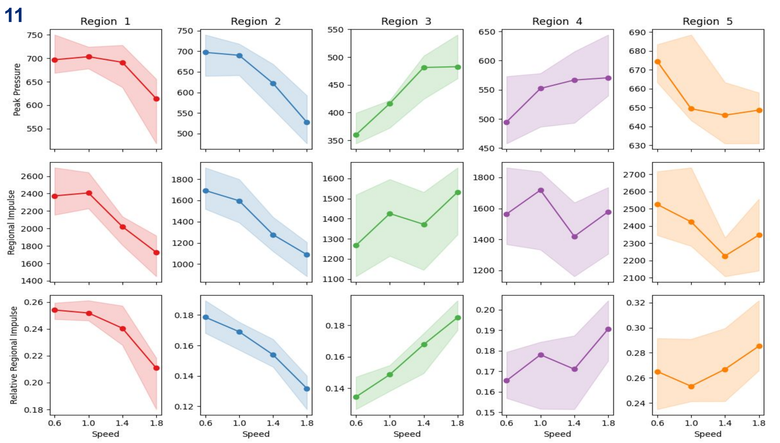

Figure 11. Effects of changing right foot speed on left foot metrics.

Key Takeaways

- **Figure 10**: Left foot pressure significantly higher than right across all regions except midfoot for relative region impulse
  → ***left foot acts as the main supporting leg*** during walking.
- **Figure 11**: Right foot speed ↑ causes ***pressure shifts from toes/heels to midfoot*** *in* ***left foot***
  → enhance stability with balance and propulsion at higher speeds

Conclusions and Next Steps

- High-resolution, high-frequency foot pressure data reveals ***meaningful gait differences*** across and within individuals
- These insights ***align with clinical expectations*** and may support personalized diagnosis and rehabilitation planning
- This approach shows ***promise for precision gait therapy***

Next Steps:

- Use dynamic threshold and more conservative filtering
- Recalculate pressure timing with speed-dependent shifts in mean pressure changes