# HEEL PAD COMPRESSION AND IMPACT DURING GAIT USING ULTRASONOGRAPHY AND IMU SENSORS: A PILOT STUDY

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## Introduction

In-vivo measurements of heel pad compression during gait are scarcely described. Contrasting current methods [1,2], our custom-made walkway images the heel pad in-vivo and non-invasively during gait using a receded ultrasound transducer [3]. IMU sensors allow for concurrent measurement of lower extremity loading parameters [4]. We aimed to determine associations between heel pad compression and impact parameters during gait in a healthy population.

## Methods

Sixteen healthy participants were positioned at the start of a 5.5m long walkway such that the left heel fully hit a receded ultrasound transducer (Philips Lumify) after 3.5m while walking barefoot at comfortable speed.

Ultrasound videos enabled measurements of heel pad thickness (HPT) as the shortest distance between skin and calcaneus (Fig.1) in 2 conditions: unloaded ($HPT_U$) and maximally compressed during gait ($HPT_C$). Heel pad compression (HPC) was calculated by subtracting $HPT_U$ from $HPT_C$. HPC relative to $HPT_U$ was presented as $HPC_{\%}$.

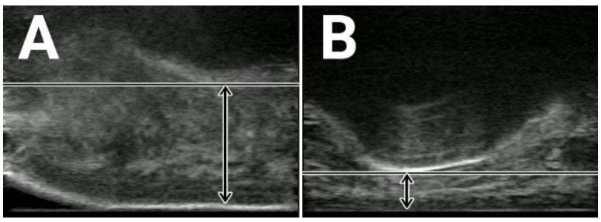


*Figure 1: Ultrasound video outtakes: uncompressed (A) and compressed (B) heel pad. Arrows indicate HPT.*

IMUs (Delsys Avanti, 370Hz) were placed on the left malleolus and sacrum. Peak resultant acceleration of the tibia ($PA_T$) and sacrum ($PA_S$) were obtained for each successful step on the transducer. Peak acceleration reduction (PAR) was calculated by subtracting $PA_S$ from $PA_T$. PAR relative to $PA_T$ was presented as $PAR_{\%}$.

Normality was tested (Shapiro-Wilk test). $HPT_U$ and $HPT_C$ were compared (t-test). HPC and $HPC_{\%}$ were correlated to PTA, PAR and $PAR_{\%}$ (Pearson test).

## Results

All participants (age: 29.9±9.9 years, weight: 73.9±12.0 kg, height: 1.75±0.09 m, BMI: 24.2±2.9) completed the protocol. Outcomes (Table 1) were normally distributed. $HPT_C$ differed significantly from $HPT_U$ ($p<0.001$). Figure 2 and Table 2 show correlation outcomes.

| Heel Pad | | Mean±SD | Unit |
|---|---|---|---|
| $HPT_U$ | Thickness, uncompressed | 15.3±2.1 | mm |
| $HPT_C$ | Thickness, compressed | 7.2±1.9 | mm |
| HPC | Compression, absolute | 8.2±2.2 | mm |
| $HPC_{\%}$ | Compression rel. to $HPT_U$ | 53.0±11.0 | % |
| **Peak Acceleration** | | **Mean±SD** | **Unit** |
| $PA_T$ | Tibia | 5.0±2.0 | $m/s^2$ |
| $PA_S$ | Sacrum | 1.6±0.3 | $m/s^2$ |
| PAR | Reduction | 3.4±1.9 | $m/s^2$ |
| $PAR_{\%}$ | Reduction rel. to $PA_T$ | 60.4±12.3 | % |

*Table 1: Outcome parameters*

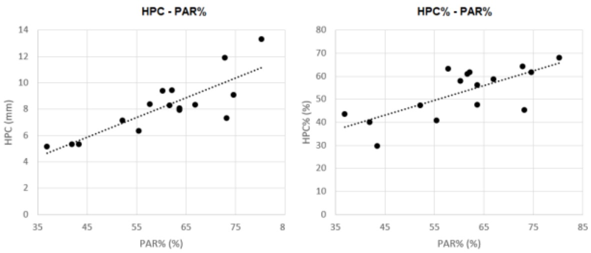


*Figure 2: Scatterplots of HPC and $HPC_{\%}$ with $PAR_{\%}$.*

| | | $PA_T$ | PAR | $PAR_{\%}$ |
|---|---|---|---|---|
| HPC | *r* | 0.606 | 0.674 | 0.828 |
| | *p* | 0.013 | 0.004 | <0.001 |
| $HPC_{\%}$ | *r* | 0.351 | 0.449 | 0.719 |
| | *p* | 0.182 | 0.081 | 0.002 |

*Table 2: Pearson correlation outcomes.*

## Discussion

Heel pad compression and impact parameters correlated positively, indicating a complementary attenuation mechanism. As expected, compression also positively correlated with peak tibia acceleration.

To further investigate the relation between $HPC_{\%}$ and $PAR_{\%}$, we recommend to study the association between the change of these parameters at different gait speeds.

Limitations include two-dimensional assessment of heel pad compression, altered gait patterns due to aiming for the transducer, and barefoot assessment on hard surfaces might not generalize well to daily life situations.

## References

1. Yang et al, Frontiers in Endocrinology, 01-14, 2022
2. Teng et al, BMC Musculoskelet Disord, 2022
3. Gerbrands, [conference abstract], WCPT 2023
4. Alem et al, SWI 2020 proceedings, 2020