# Soft tissue work in early stance of human walking: Partitioning foot vs. rest-of-body contributions

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## Summary

Soft tissues throughout the human body are known to perform negative work (i.e., energy absorption) through wobbling and deforming, particularly following foot impacts with the ground (e.g., in walking). But it is not known which tissues/locations in the body are responsible for most of this soft tissue work. The purpose of this study was to quantify how much of the soft tissue work after foot contact was due to the foot and shoe, vs. from tissues elsewhere in the body, and how this distribution of work changed with walking speed and slope. We found that 60-70% of the soft tissue work in early stance during level and uphill walking was due to the foot and shoe, and this rose to 80-90% during downhill walking.

## Introduction

Soft tissues located throughout the human body are known to perform substantial work, particularly following foot impacts with the ground. Studies estimate ~60% of the negative work done by the body after foot contact during walking is due to soft tissue deformation [1]. However, it is not known which soft tissues in the body perform the majority of this work. Recent studies suggest that the deformation of the foot and shoe may be responsible for a considerable amount of the soft tissue work [2]. Therefore, the purpose of this study was to quantify the amount of work done by foot and shoe deformation vs. work done by soft tissues elsewhere in the body (in early stance phase of walking), and how this distribution of work changed with walking speed and slope.

## Methods

Ten healthy subjects (age: 22±2 years, height: 1.7±0.1 m, mass: 68.5±13.7 kg) provided informed consent and participated in a gait analysis study. Subjects walked at five speeds and on seven slopes on a force-instrumented treadmill. Reflective markers were used to track whole-body motions.

Soft tissue power contributions were estimated with an Energy-Accounting analysis [3], as shown in Fig. 1 and detailed hereafter. We computed Center-of-Mass (COM) power from both lower-limbs, bilateral lower- and upper-limb segment Peripheral powers as well as bilateral lower- and upper-limb six degree-of-freedom joint powers. Bilateral foot and shoe powers were estimated with a Distal Foot power calculation. The rest-of-body (ROB) Soft Tissue power (net soft tissue power outside of the feet) was estimated by subtracting the summed joint powers plus Distal Foot powers from the summed COM powers plus Peripheral powers.

We computed the Foot Soft Tissue work (i.e., leading limb Distal Foot work) and ROB Soft Tissue work during Foot Absorption (0% to ~15% of stride, Fig. 1). The percentage of total Soft Tissue work done by the Foot (including the shoe) was computed. Trends with increasing speed and slope were evaluated with a Spearman's rank correlation (α=0.05).

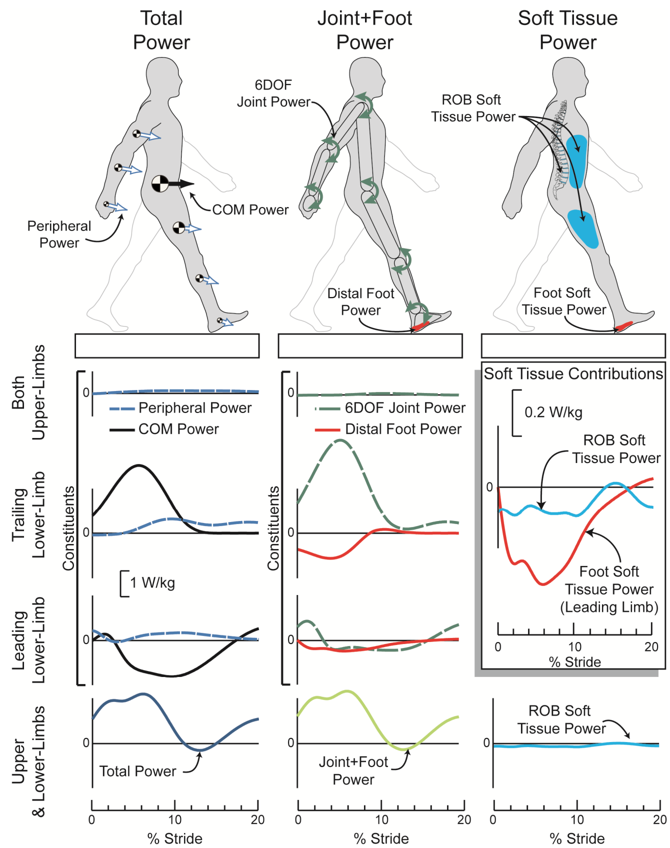


**Figure 1**: Energy-Accounting analysis used to estimate Foot vs. Rest-of-Body (ROB) Soft Tissue power contributions ($N$ = 10). The inset plot shows that most of the Soft Tissue power is due to the foot/shoe.

## Results and Discussion

The Foot Soft Tissue work in early stance was between 1.7 J (slow uphill walking) and 7.5 J (fast downhill walking). During level and uphill walking the percentage of Soft Tissue work done by the foot and shoe was ~60-70%, and increased to ~80-90% during downhill walking. This was a significant trend with changing slope ($p$<0.003). This percentage did not vary significantly with increasing speed ($p$>0.06). These results provide new insight into how mechanical work is distributed amongst various tissues in the human body.

## Conclusions

In summary, we found that most of the soft tissue work that occurs after foot contact was due to foot/shoe deformation.

## Acknowledgments

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## References

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[2] Kelly et al. (2018). *Sci Rep*, **8**: 10576.
[3] Honert and Zelik (2019). *Hum Mov Sci*. In Press.