

Non-rigid work in human walking: Are hard collisions in fact soft?

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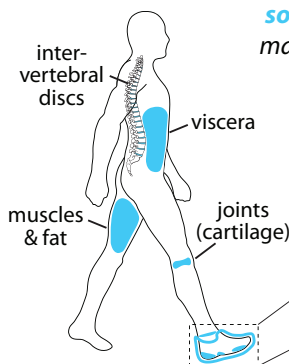
whole-body

foot

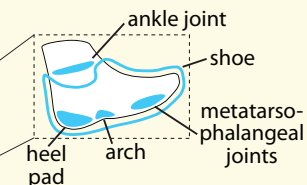
Walking is typically studied using rigid-body models to estimate work done rotationally about joints by muscles and tendons.

Other **soft tissue** deformations throughout the body may also perform substantial work in walking, but we are unable to measure it directly.

Hypothesis: Work is performed by **soft tissues** during collisions after heel-strikes and increases with speed.



soft (non-rigid) tissues may deform and do work



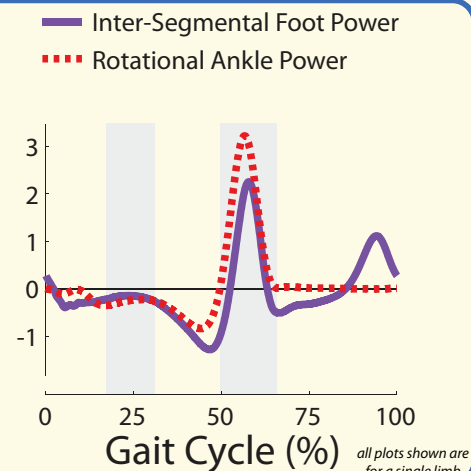
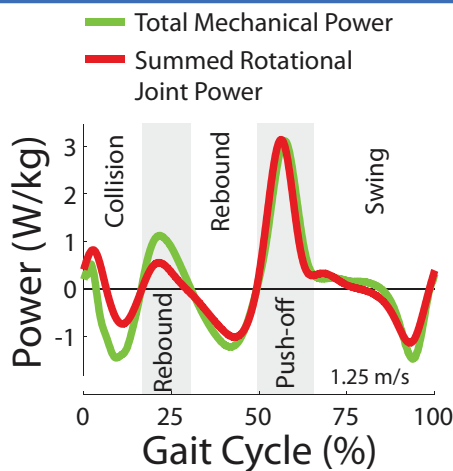
Methods: We measured healthy subjects (N=10) walking on an instrumented treadmill at 0.7–2.0 m/s. We calculated:

— Total mechanical power of the whole-body due to motion of the center-of-mass (COM), which makes no rigid assumptions, and due to motion of segments relative to the COM.

— Summed rotational joint power of the ankle, knee and hip from inverse dynamics.

— Inter-segmental foot power encompassing all energy flow out of the foot, including due to ankle rotation, deformation of ankle, foot and shoe and unmodeled joints in the foot.

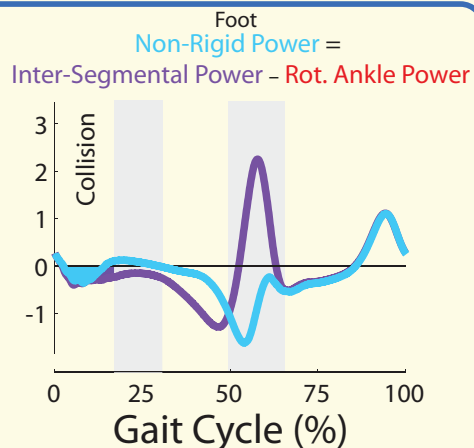
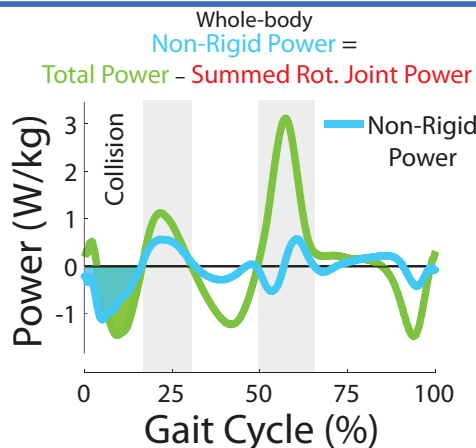
— Rotational ankle power from standard inverse dynamics.



all plots shown are for a single limb

We estimated **soft tissue** contributions as all the **non-rigid work and power**, defined as that not captured by rotational joint estimates.

We integrated powers over the Collision phase of gait, the region of negative **total mechanical power** immediately following heelstrike.



Walking Collisions are "soft":

60% of total Collision work is done by **soft tissue** deformations throughout the body, 15% by deformations of foot, ankle and shoe.

Soft tissues cushion collisions by dissipating energy, which could shield joints and muscles from high loading, but might also cause injuries in **soft tissues** themselves.

