



OVERCOMING BARRIERS TO WORKPLACE INTEGRATION

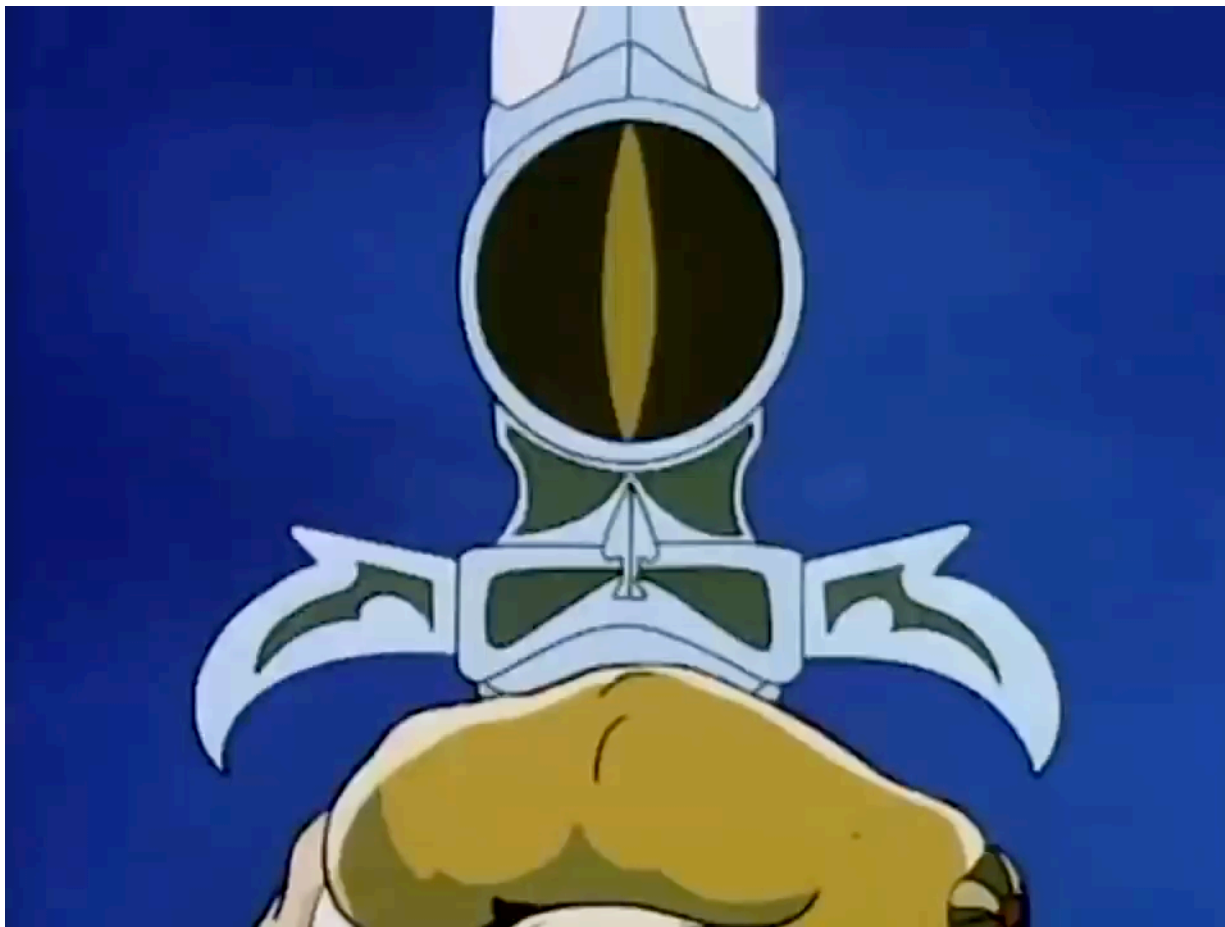
Science, Design & Evaluation of Spring-Powered Exosuits

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Thunder, Thunder, Thundercats! HOOOO!



CARTOON SUPERHEROES CIRCA 2019

Paw Patrol... to the Lookout!



create

WhatsApp... my everyday superpower



So common & mundane we forget these are superpowers



So common & mundane we forget these are superpowers



My hope is that in 30 years when my kids are my age that exoskeletons will have reached a similar state of ubiquity



Exoskeletons = physical manifestation of superpowers



Can address pressing societal need (mobility impairment)

- 47.5 million adults in the US live with a mobility impairment
- 23.6% of all US healthcare costs for adults (\$350B annually)
- Limits societal participation, reduces quality of life



Can address industry & military pain points

- Industry: \$13.7 Billion in overuse-related injuries each year
- US Army: >370K Soldiers/year diagnosed with overuse injury¹
- Worker retention & productivity in physically-demanding jobs



¹Defense Medical Surveillance System; U.S. Army Public Health Center

However.. they're still inaccessible to many who could benefit



What factors are inhibiting broad adoption of exoskeletons?



What factors are inhibiting broad adoption of exoskeletons?

- **Too obstructive** (interferes with other tasks)
- **Too bulky** (potential safety issue)
- **Too complicated** (donning, doffing, adjusting)
- **Too uncomfortable** (poor fit, thermal, weight)
- **Too costly** (to deploy widely in some industries)
- **Too conspicuous** (e.g., for nurses)



TO OVERCOME BARRIERS

Our goal: combine best aspects of clothing & exoskeletons

	Clothing	Exoskeleton
Lightweight	✓	✗
Unobtrusive	✓	✗
Assists User When Needed	✗	✓
Offloads Muscles, Bones, Discs	✗	✓

To OVERCOME BARRIERS

Fits like clothing, assists like exoskeleton, engages on-demand

Mechanized Clothing

Lightweight



Unobtrusive



Assists User
When Needed



Offloads Muscles,
Bones, Discs



Fits like clothing (allows user to retain full range of motion)



MECHANIZED CLOTHING

Fits like clothing (allows user to sit down)



MECHANIZED CLOTHING

Assists like an exoskeleton (offloads lower back & reduces fatigue)



Mechanized clothing for the lifting, leaning & locomotion

I. Science

biological tissue loading & microdamage

II. Design

levers, springs & clutches

III. Evaluation

offloading, muscle fatigue, adaptability & inter-subject variability



Science

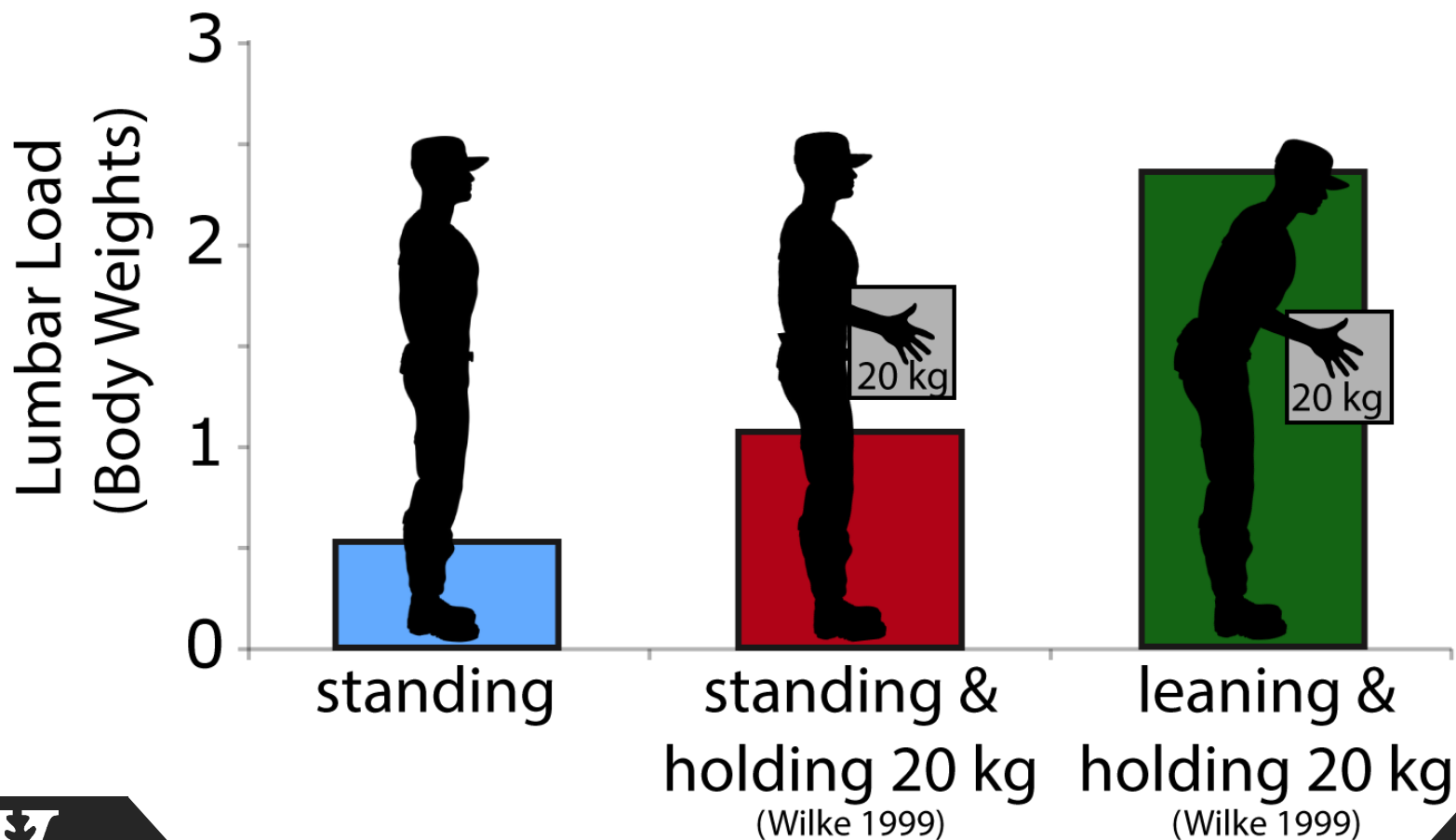


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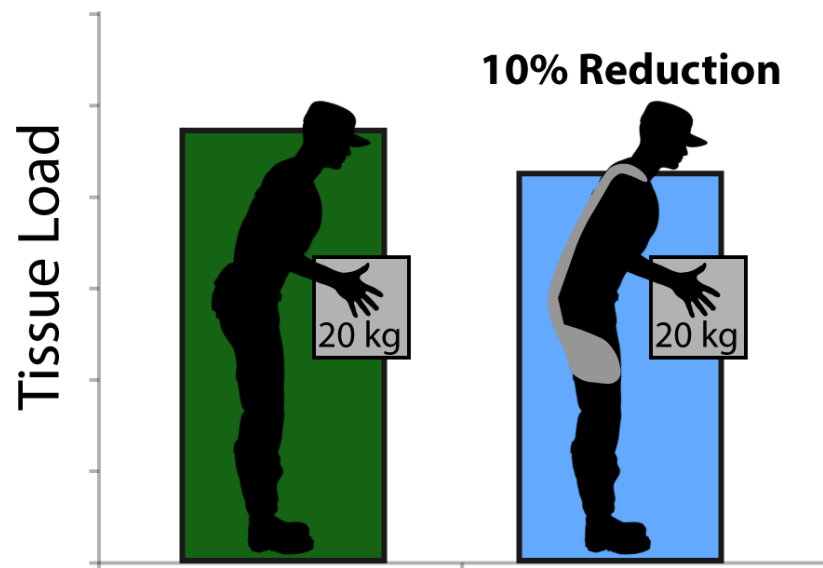
Due to repetitive musculoskeletal loading



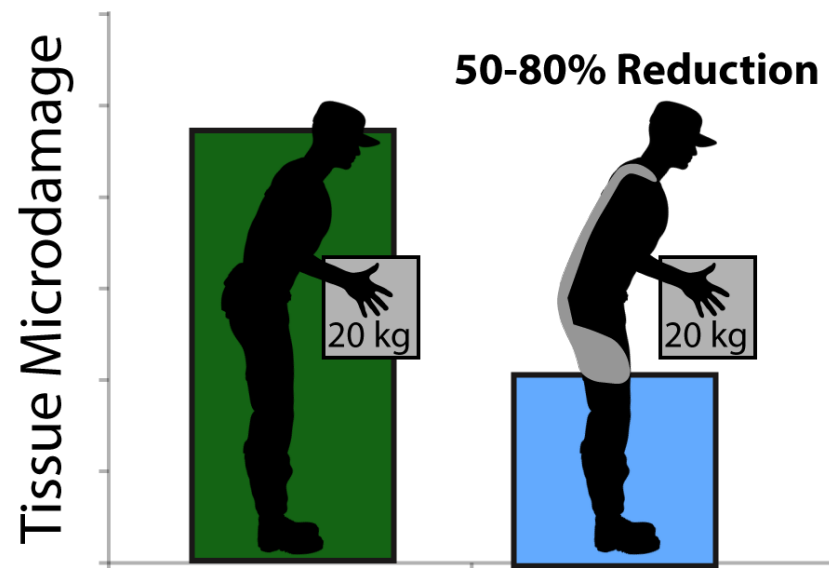
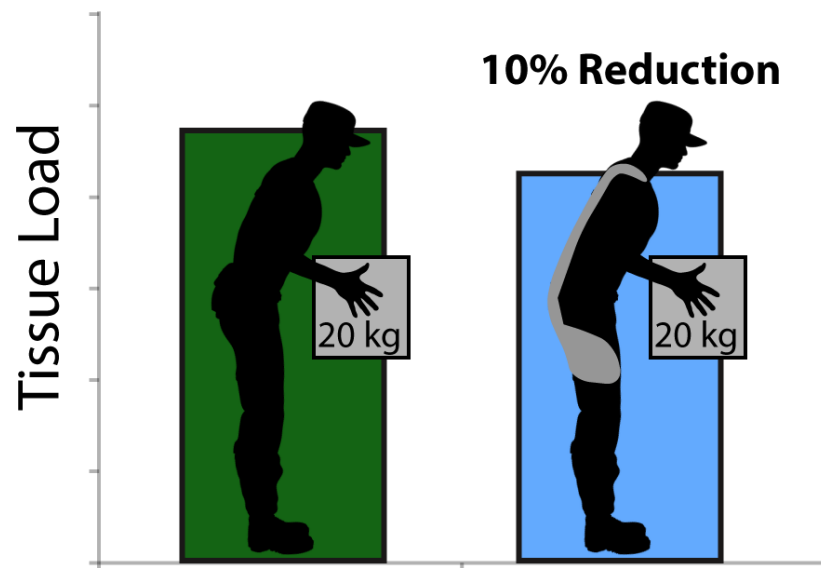
Astounding fact #1: most of loading is self-inflicted by muscles



Astounding fact #2: small reduction in load = large reduction in damage



Astounding fact #2: small reduction in load = large reduction in damage



based on Miner's rule of cumulative damage

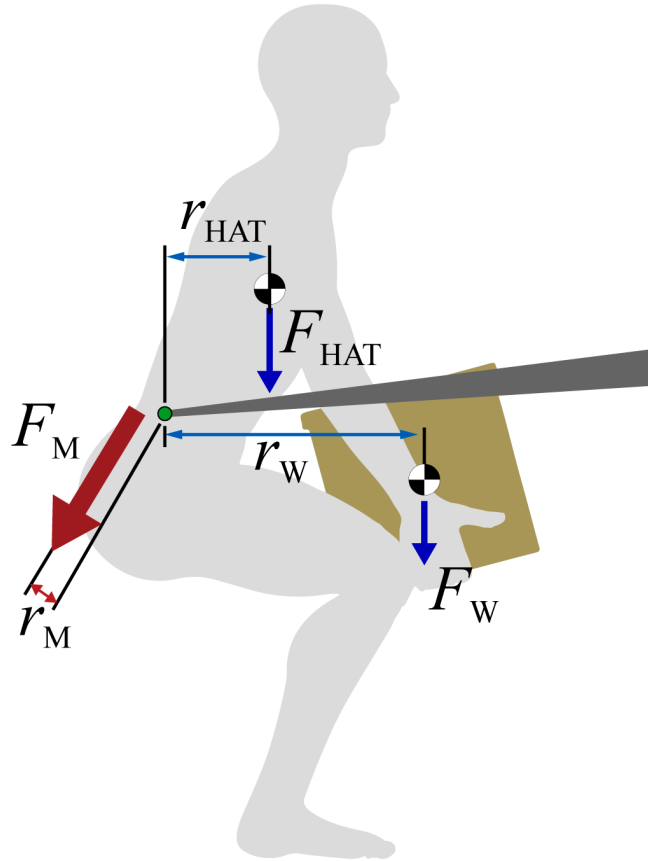
Design



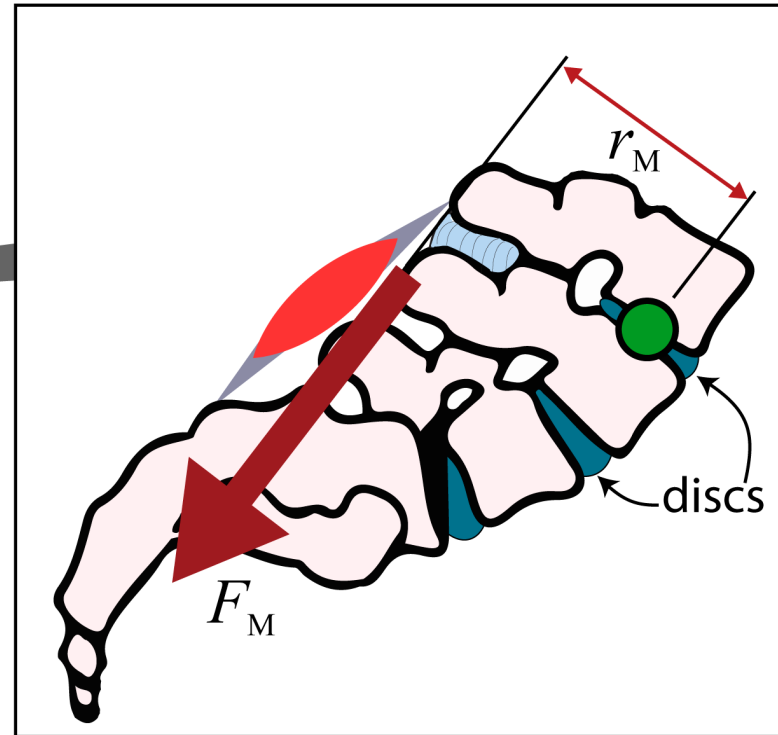
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Muscles bear high loads because they have short lever arms

A

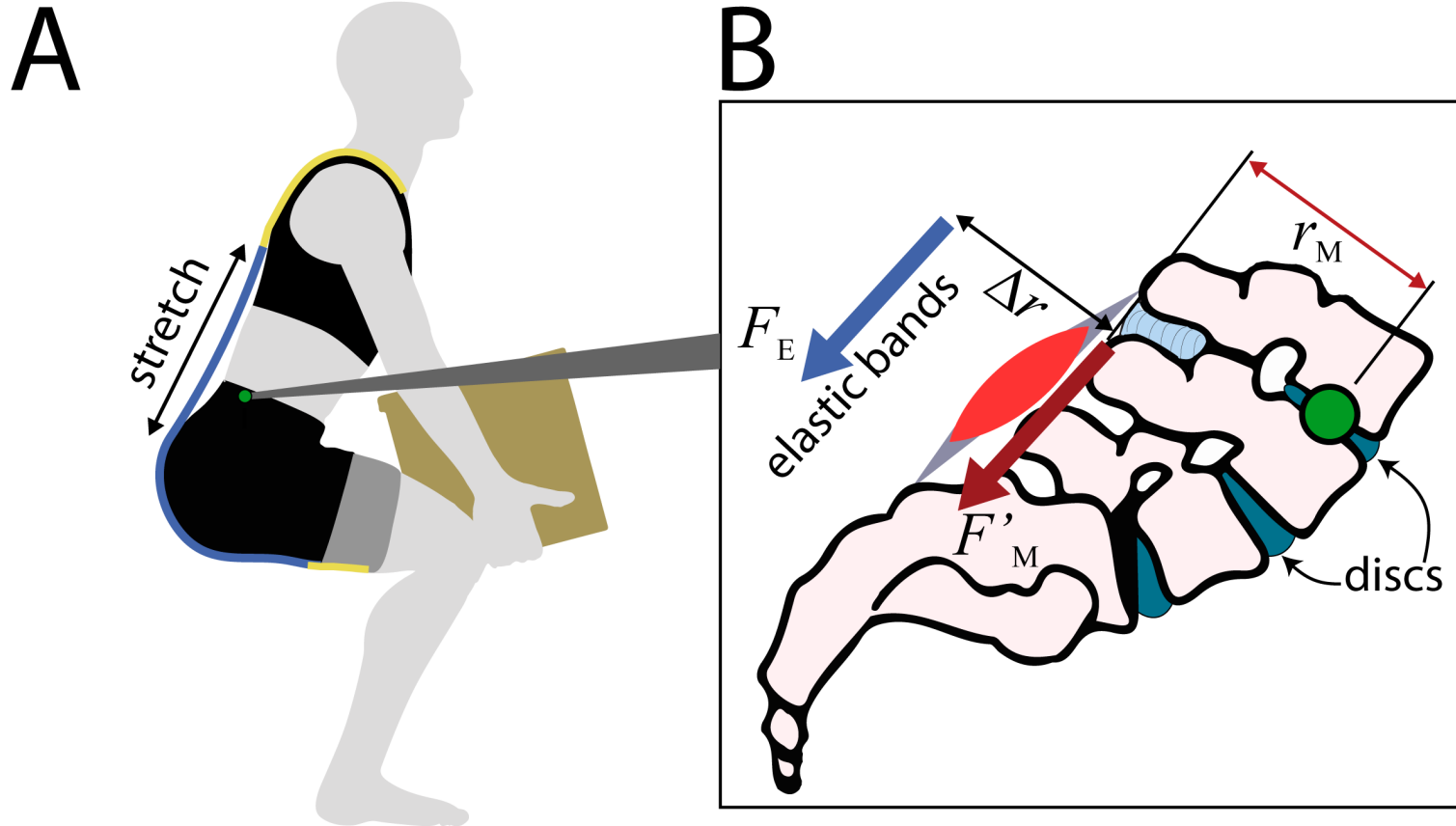


B

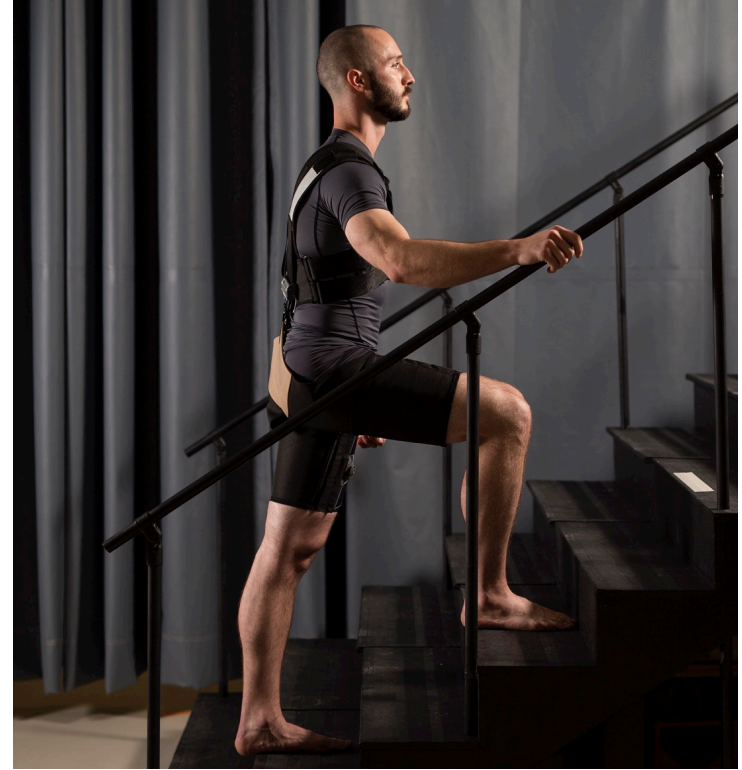


Lamers et al. 2018. IEEE TNSRE

Elastic bands bear load, extend lever arm & reduce forces on back



Clutchable spring enables device to be transparent & unobtrusive



Unmotorized clutch: manually turn low back assistance on/off



Offload back, reduce fatigue, improve retention & productivity



Ankle assistance using spring, clutch & extended lever arm

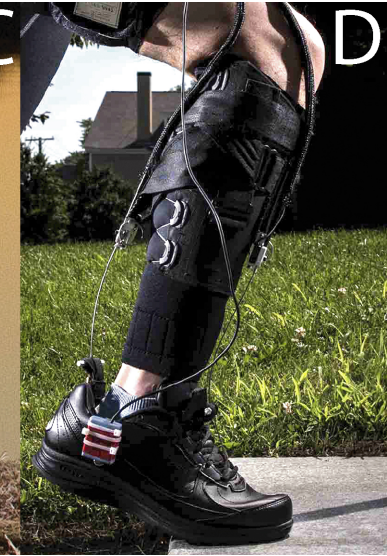
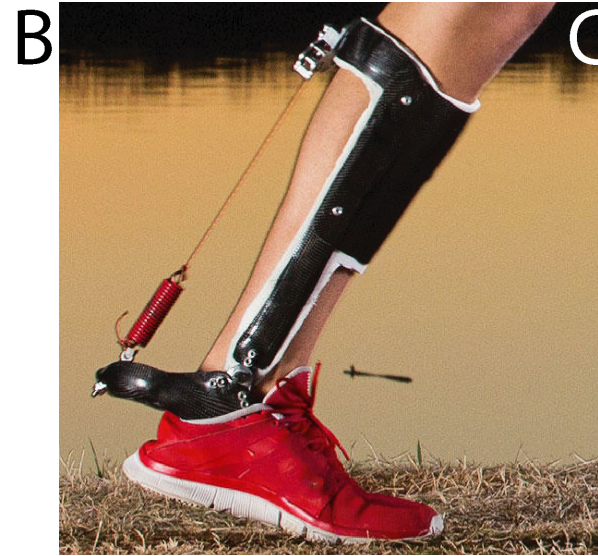


Unpowered ankle exoskeleton reduces metabolic cost of walking

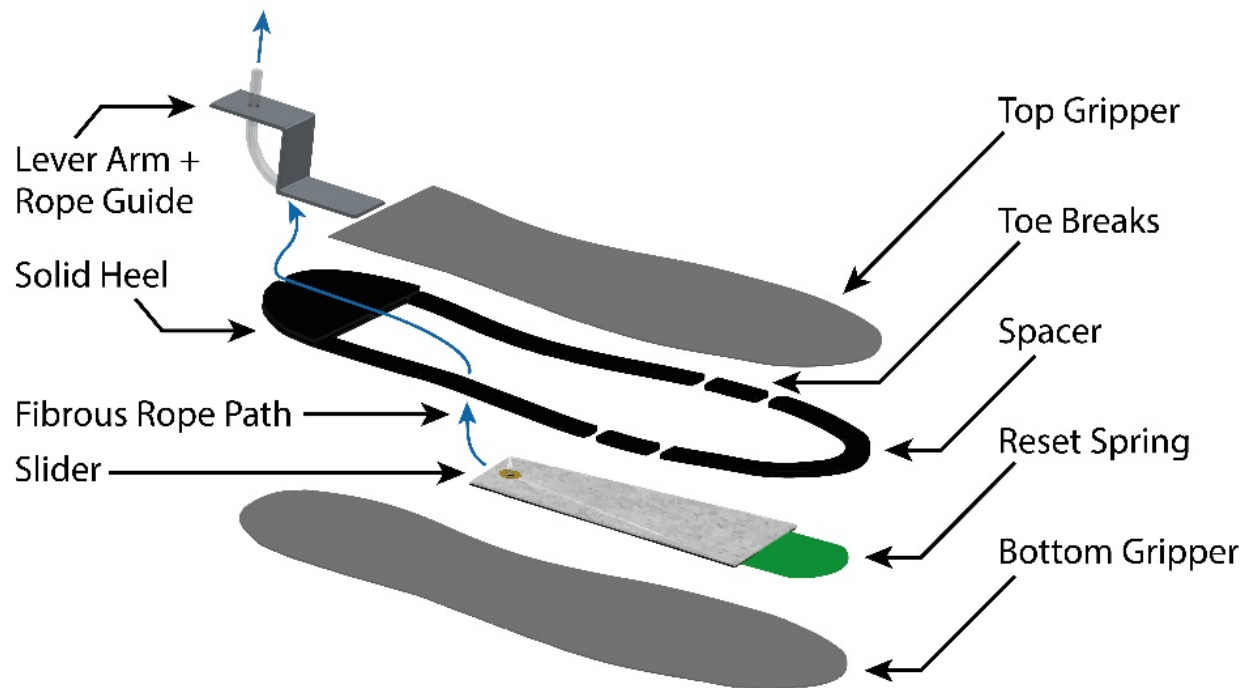
Collins, Wiggin &
Sawicki 2015



A host of clever assistive ankle exoskeletons



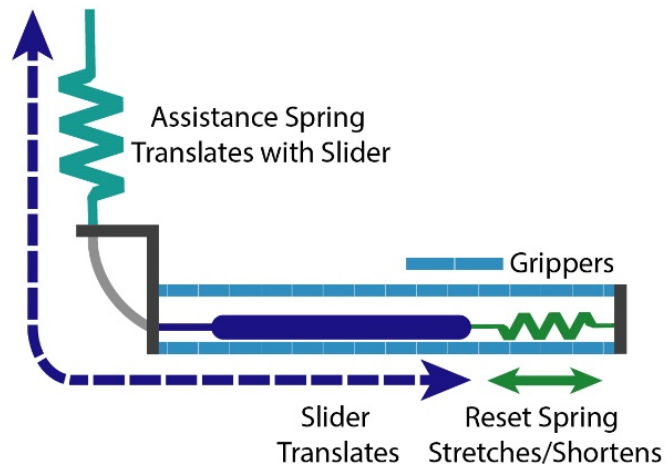
Unmotorized clutch under foot: automatically on in stance, off in swing



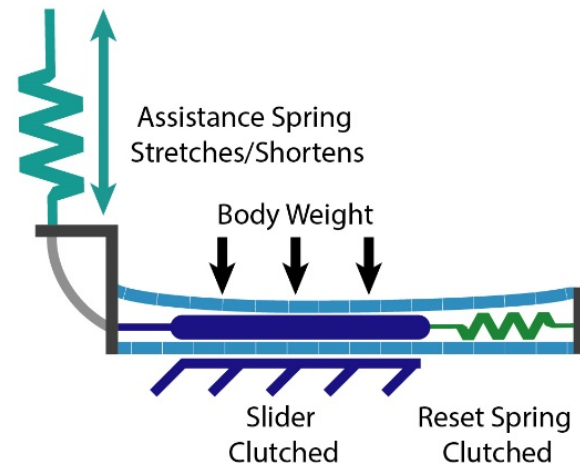
Unmotorized clutch under foot: automatically on in stance, off in swing



A. Unclutched



B. Clutched



Unmotorized clutch under foot: automatically on in stance, off in swing



SOCIETAL & INDUSTRIAL APPLICATIONS

Augment strength, offload calf muscles or reduce fatigue



create