Impacts of Augmented Running on Energy Expenditure and Leg Muscle Activity

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Background

- Human running is very inefficient with only around 10% of calories burned for locomotion being used to do useful work on the environment
- Previous studies have used an "exotendon" as intervention to direct more energy in human running motion towards leg swing
- Results have indicated energy savings ranging from 6% to 7% [1].
- This study investigates the applicability of an exotendon at various strengths on multiple steepness grades outdoors with indoor testing for validation

Materials & Methods

- The exotendon is a resistance band (60/120 N m^{-1}) connected by carabiners to two ankle straps (Figure 1)
- Length of the resistance band is 25% of subject leg length measured from the anterior iliac spine to the medial malleolus
- Electromyograms of 8 major muscles (gluteus maximus, iliopsoas, semitendinosus, rectus femoris, vastus lateralis, biceps femoris, soleus, and tibialis anterior) recorded

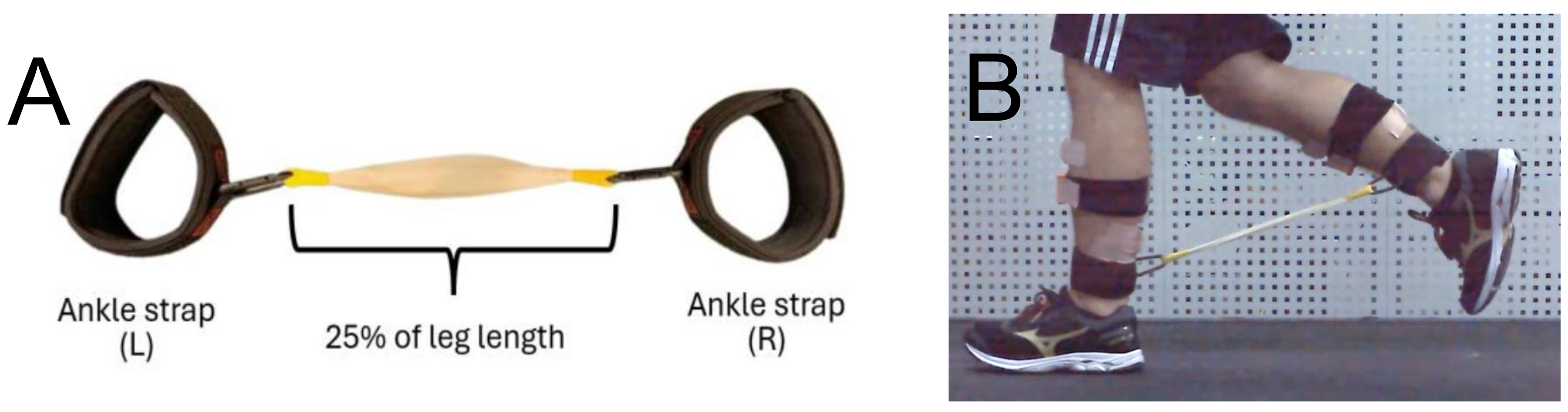

Figure 1: (A) Resistance band connected to ankle straps (B) Exotendon in use

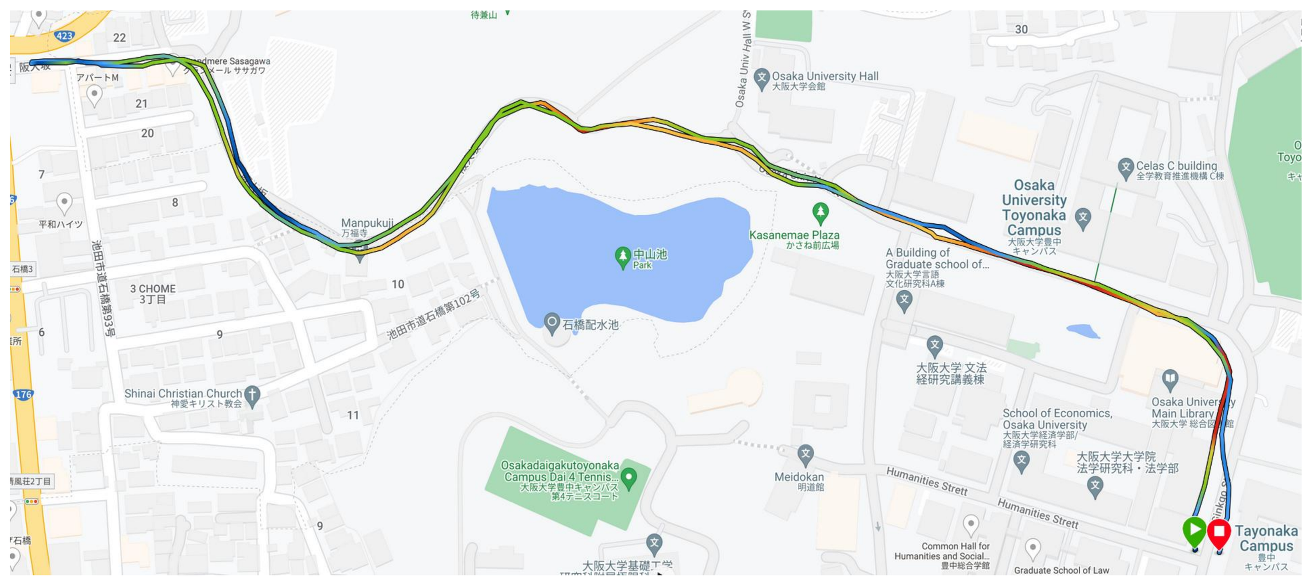

Figure 2: 2-Km path on Toyonaka campus

Study Population

5 total subjects (age: 23.4 ± 1.7; height: 175.8 ± 7.5 cm; mass: 69.4 ± 8.2 kg) participated

Outdoor Design

- 2 trials for each subject
- 1 trial is, in order, 5 minute warm-up, 2-km natural run, 2-km exotendon run (Fig. 2)
- Data recorded includes net heart rate, step cadence, and step length

Indoor Design

- 2 trials for each subject
- 1 trial is, in order, 5-minute warm up, 10-minute natural run, 10-minute exotendon run, 10-minute natural run, 10-minute exotendon run
- Data recorded includes EMG, ground reaction forces, and HR (Fig. 1B)

Results & Discussion

Outdoor Results

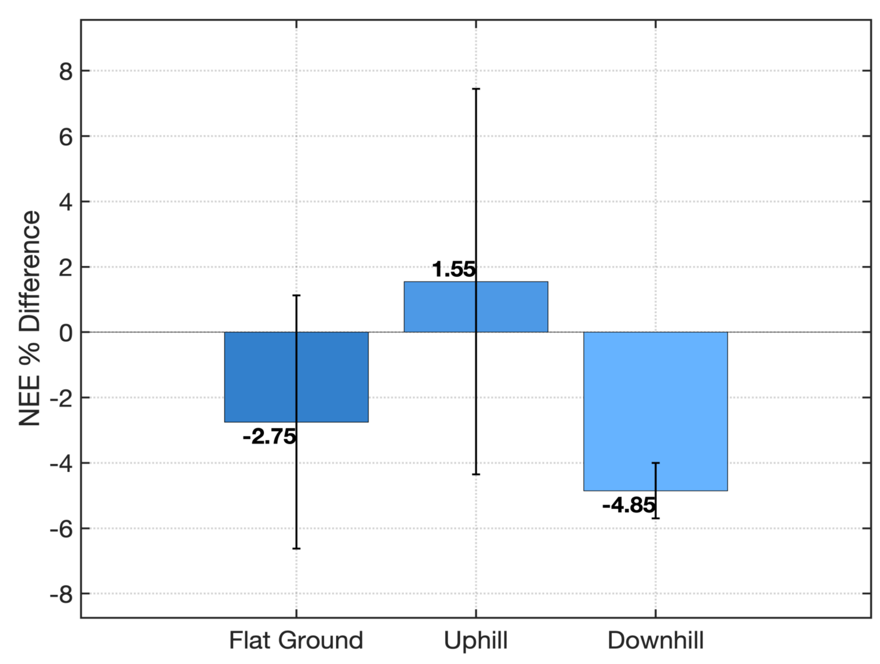

Figure 3: Net Energy Expenditure % Difference (60 N m^{-1})

- NEE equation is accurate alternative for respiratory gas analysis
- Results are not as intense as seen in previous studies
- Applied moments due to exotendon working against gravity could result in increase during inclined grades

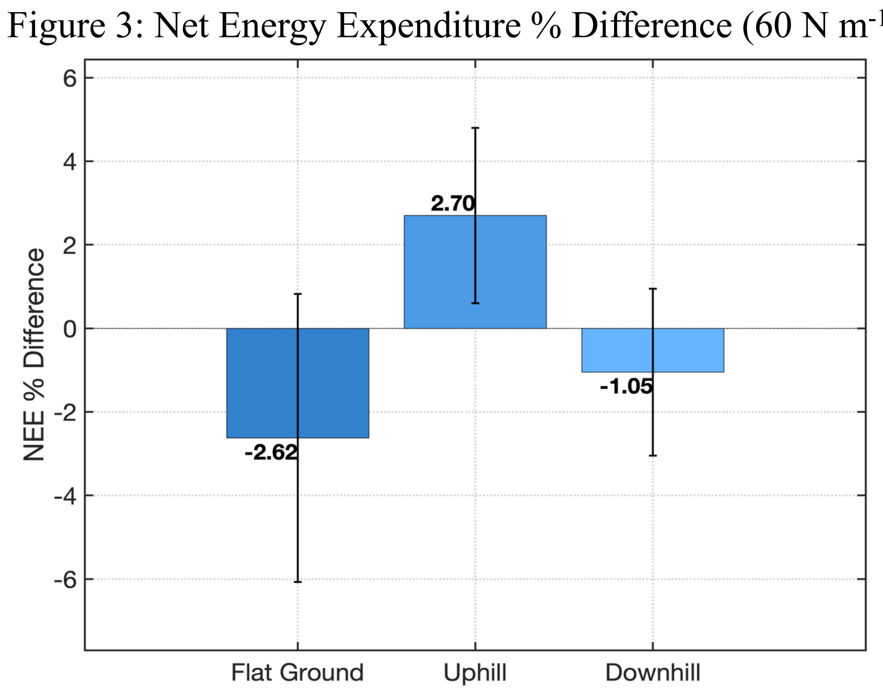

Figure 4: Net Energy Expenditure % Difference (120 N m^{-1})

- In flat portions of outdoor experiments (±0.6 grade), there is lower overall energy expenditure (kcal min^{-1})
- Declined grades (-4.6%) indicate benefits with exotendon intervention as well for both exotendon strengths (Fig. 3,4)
- Inclined grades (4.6%) saw detrimental impacts ranging from 1.55% to 2.70% on average (Fig. 3,4)

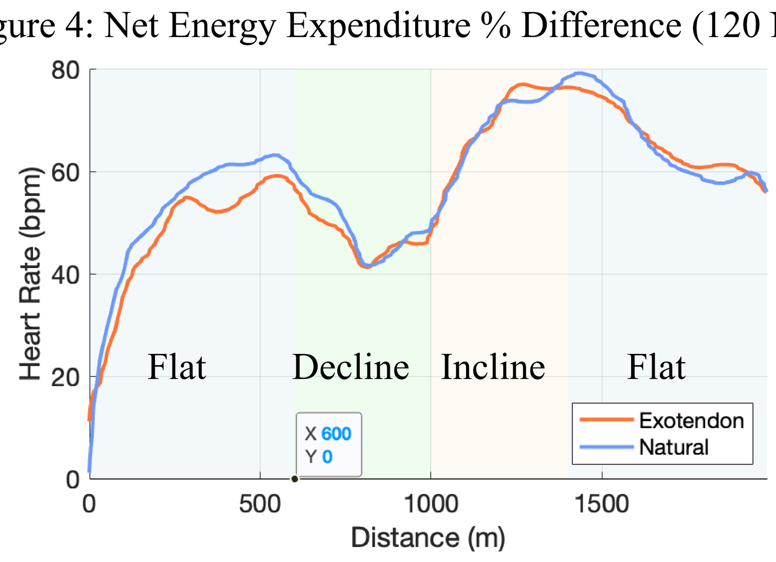

Figure 5: 60 N m^{-1} Trial Example

Net Energy Expenditure Equation [2]:

$$NEE = 1.012 - (0.0154 \times NHR) + (0.0114 \times weight) + (0.00192 \times NHR \times weight)$$

Indoor Results

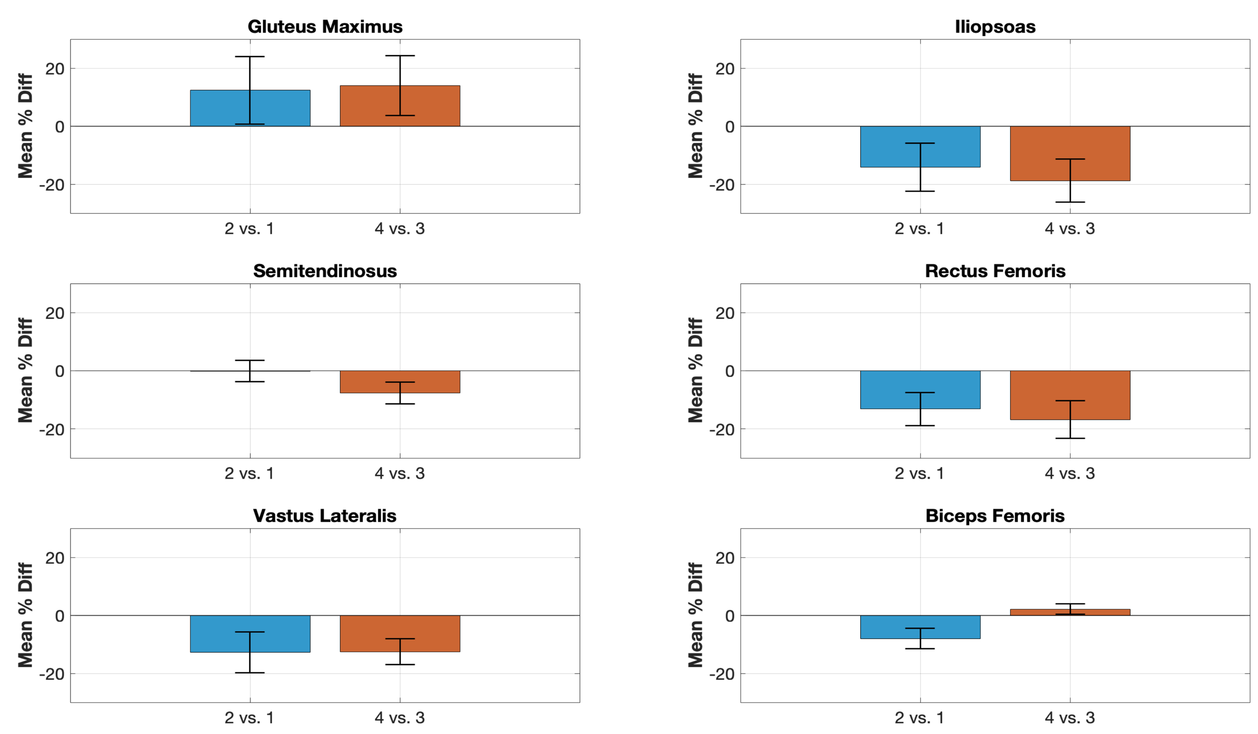

Figure 6: EMG Running Cycle % Difference Per Muscle (60 N m^{-1})

- Major muscles are grouped into Hip, Quad, and Hamstring. Lower leg results were insignificant.
- 60 N m^{-1} saw greater impact in quadricep muscles (vastus lateralis and rectus femoris)
- Gluteus maximus and iliopsoas reacted oppositely to moderate exotendon (Fig. 6)

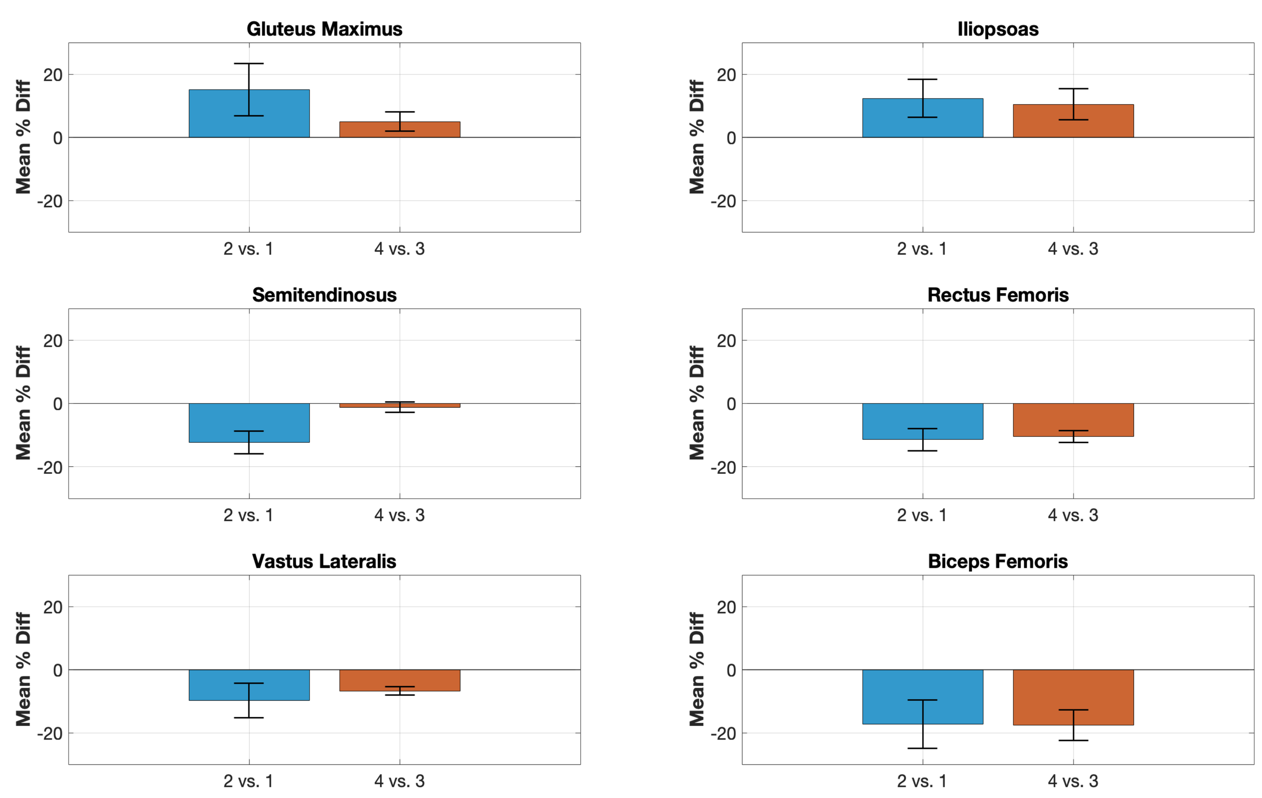

Figure 7: EMG Running Cycle % Difference Per Muscle (120 N m^{-1})

- 120 N m^{-1} iterations saw a large detrimental impact (Fig. 7) on both hip muscles
- Improvements in both quadricep and hamstring groups however
- Lower leg muscles resulted in insignificant change with exotendon application
- 60 N m^{-1} looks to have greater benefits while limiting detrimental effects

	60 N/m	120 N/m
Hip	0.37%	12.30%
Quadriceps	-12.06%	-7.80%
Hamstrings	-1.48%	-10.30%

Figure 8: Major Muscle Group % Difference Including Cadence Evaluation

- Including step cadence increase allows for more accurate view of exotendon effect on muscle activity
- Step cadence averaged from outdoor analysis to be 2% increase
- Ground reaction force analysis resulted in negligible change in the direction of work

Conclusions

- Results indicate that <u>exotendon benefits apply only to flat and declined steepness grades while remaining detrimental to inclined grades</u>
- The 60 N m^{-1} resistance strength seems to reduce major muscle activity the most while minimizing negative impacts
- Increased sample sizes for both outdoor and indoor experiments is necessary to improve accuracy of results

References

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2. Hiilloskorpi, H. K., M. E. Pasanen, M. G. Fogelholm, R. M. Laukkanen, A. T. Mänttäri, "Use of heart rate to predict energy expenditure from low to high activity levels." *International Journal of Sports Medicine* 24.05 (2003): 332-336.