Optimization of soft exosuit peak force with ramp and step sweep protocol

Camp Dynamic Walking 2016
University of Michigan June 4–7

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MOTIVATION

- Exoskeleton optimization has been studied with **steady-state protocols** [1-3]
- Data collection is time consuming and provides differing results when relating assistance magnitude to metabolic reduction [1-3]

➢ Continuously changing parameters could facilitate faster and individualized selection of energetically optimal assistance magnitude [4,5]

AIM & HYPOTHESIS

Aim: Compare the relationship between **metabolic response** and **peak assistance force** with a soft exosuit in continuous sweeps to the corresponding relationship in a step sweep

Hypothesis: Metabolic cost of ***ramp-up*** **>** ***step*** **>** ***ramp-down***, considering metabolic delay during incremental protocols [6]

METHODS

- Seven participants walked at 1.5 m s^{-1} wearing a multi-articular soft exosuit [7]
- Ankle suit peak force ranged from powered-off (PO) to maximum assistance (Max) defined as 75% body weight
- Change in metabolic rate was calculated relative to the PO in each of ***ramp-up***, ***ramp-down***, and ***step***
- Metabolic rate was curve fitted vs. actuation parameter using mixed model ANOVA. Differences between curve fits were evaluated at each force level using repeated measures ANOVA

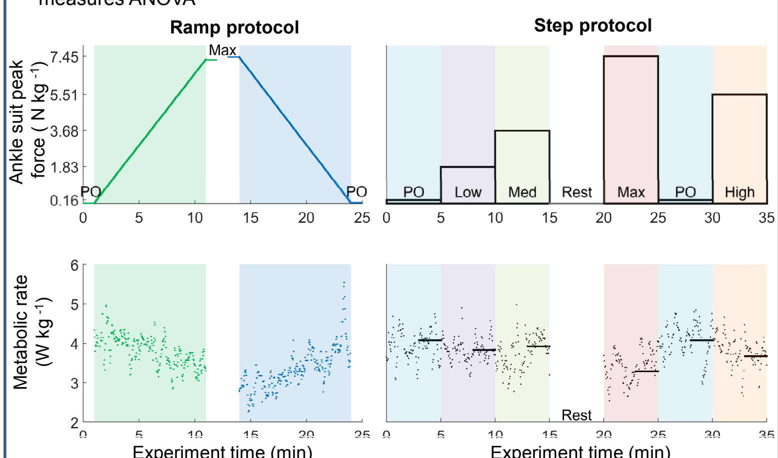

Fig 1. Protocol description: example data from one participant

RESULTS

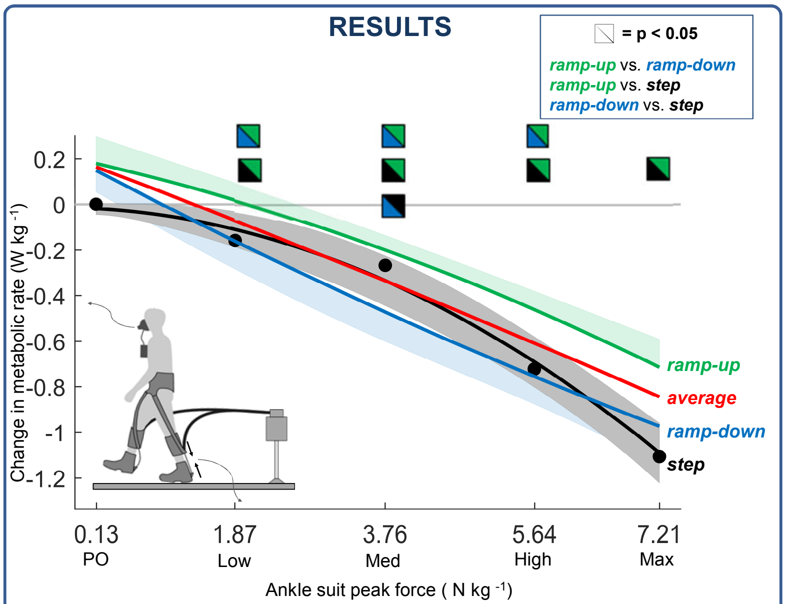

Fig 2. Change in metabolic rate vs. ankle suit peak force

DISCUSSION

- Fig 2 shows a monotonic decrease in metabolic rate from PO to Max force level
- Smaller metabolic reduction was observed in ***ramp-up*** than ***ramp-down*** due to metabolic delay
- ***Step*** condition did not match well with ***average***, suggesting that there are additional adaptation effects beyond the metabolic delay
- We were unable to find a local minimum in the tested force range
- The positive offset at PO force level in the ramp could be due to under fitting with the 2nd order polynomial
- Plotting metabolic rate vs. peak force shows that the ***step*** condition has a significant negative 2nd order coefficient, suggesting that metabolic reduction keeps reducing, which is counterintuitive
- Plotting metabolic rate vs. suit positive power (Fig 3) removes significant downward curvature of ***step*** condition, suggesting that the positive power is the underlying determinant of metabolic rate
- The ankle suit positive work rate presents a significant 2nd order relationship with ankle suit peak force, suggesting an increasing magnitude and duration of work rate with increasing peak force

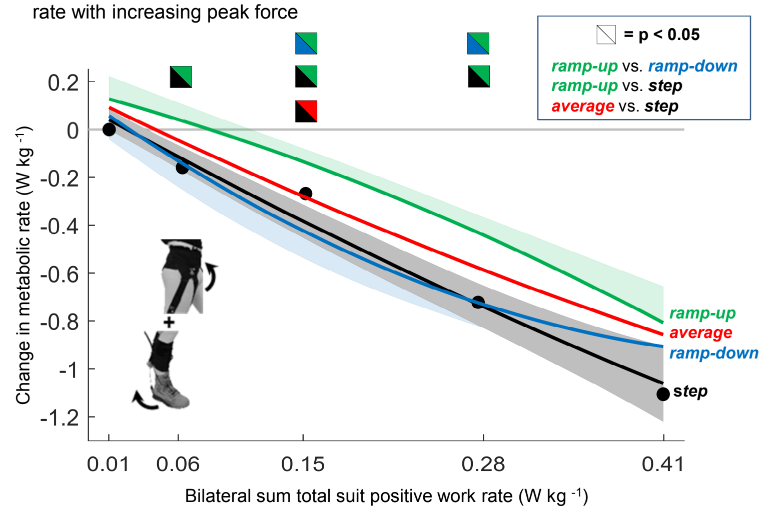

Fig 3. Change in metabolic rate vs. ankle and hip suit positive work rate

CONCLUSIONS

- Our findings confirm a delayed metabolic response in continuous sweep compared to a step sweep, but there are additional adaptation effects beyond the metabolic delay.
- Additional adjustments for delay as outlined by Selinger and Donelan [5] may be more effective at uncovering the relationship between force and metabolic rate.
- Suit positive work rate might be more important underlying determinant of metabolic reduction instead of peak force.
- This study suggests that continuous parameter sweeps may help tuning procedures for wearable robots, providing the ability to explore more parameter settings over a shorter period of time.

REFERENCES

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ACKNOWLEDGMENTS

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DARPA
FAPESP
WYSS INSTITUTE
Robert Bosch Stiftung
NSF