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Exploring effects of exoskeleton control parameters on human gait features: A secondary analysis

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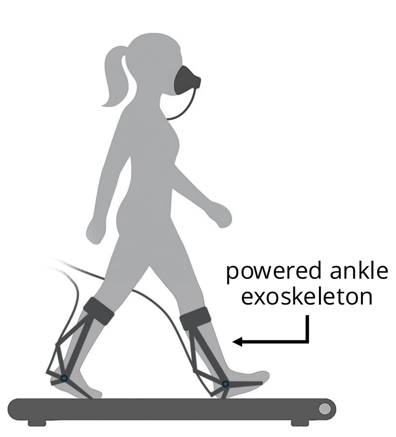
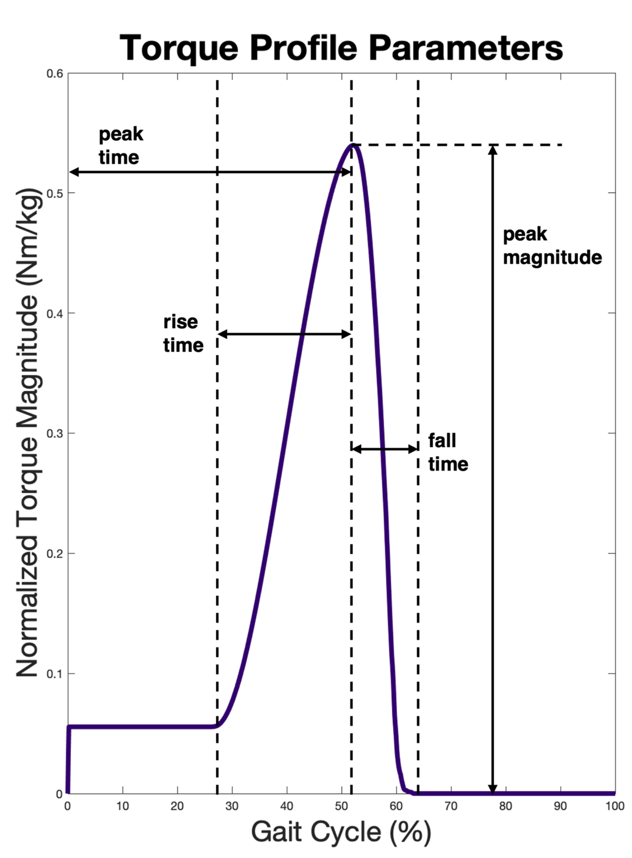
BACKGROUND

- Lower-limb exoskeletons have a wide range of applications and a similarly wide range of control strategies, each defined by a set of parameters.
- In this secondary analysis, we **modeled the relationships between exoskeleton control parameters and human gait features** to gain insight on how individual parameters affect the human response to exoskeleton assistance.
- We analyzed an open-source dataset from a previous study [1] that investigated exoskeleton assistance with a human-in-the-loop optimization algorithm.

DATASET





Participants

- 10 non-disabled participants with no prior exoskeleton experience
- Randomly assigned to one of two training groups that underwent human-in-the-loop optimization based on metabolic cost while walking with different exoskeleton torque profiles

Training groups

- **Continued optimization (C)** – started with high variation of torque profiles, converged towards optimal profile over protocol
- **Reoptimization (R)** – experienced a high variation of torque profiles throughout protocol

Protocol

- 5 training days
- 72-minute adaptation trials
- Exoskeleton torque profile changed every 2 minutes

LINEAR MIXED EFFECTS MODELS

$$y_i = (\beta_0+\mu_{0i}) + (\beta_1+\mu_{1i})x_1 + \beta_2 x_2 + \beta_3 x_1 x_2$$

Response (y_i) – model prediction specific to random element i

Fixed effects ($\beta_0, \beta_1, \beta_2$) – intercept and slope terms corresponding to predictors x_1 and x_2 (e.g. peak torque time)

Random effects (μ_{0i}, μ_{1i}) – intercept and slope terms corresponding to random element i (e.g. participant)

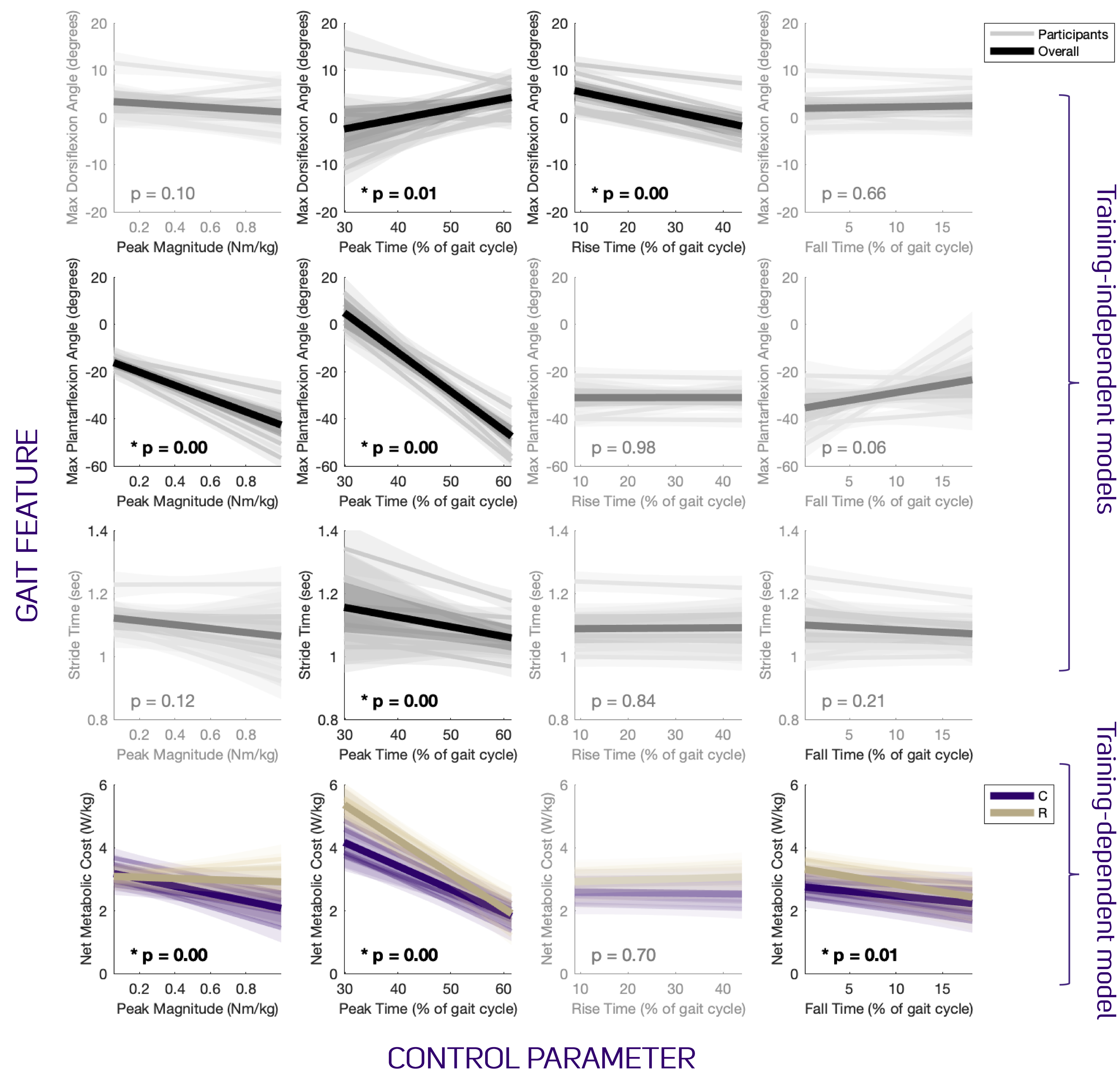
Interactions (β_3) – how one predictor (x_1) changes the effect of another predictor (x_2) on the response variable

Model selection process

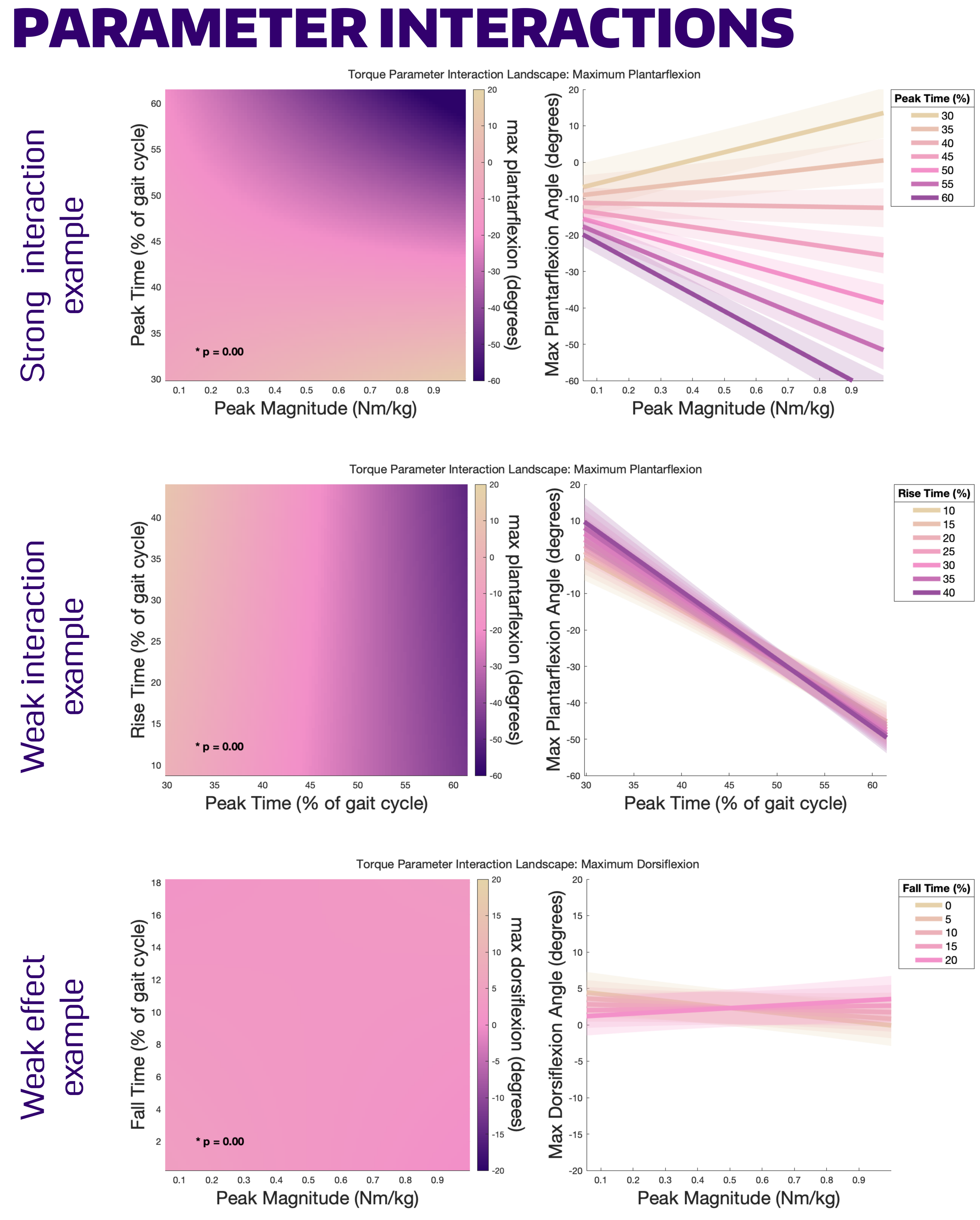
1. Ran models with varying fixed effects, random effects, and interaction structures
2. Compared model performance using Akaike Information Criterion (AIC) scores and likelihood ratio tests (LRTs)

Response variable	Optimal model structure		
	Fixed effects	Random effects	Interactions
Maximum dorsiflexion	Torque parameters	Participant, Training day	Parameter:Parameter
Maximum plantarflexion			
Stride time			
Net metabolic cost	Torque parameters, Group	Participant, Training day	Parameter:Parameter, Group:Parameter

CONTROL PARAMETER EFFECTS



PARAMETER INTERACTIONS



INSIGHTS

1. Peak torque timing had significant effects on all gait features
2. Between-parameter interactions can affect parameter-gait relationships
3. Only the net metabolic cost model improved with training group as a predictor
4. Accounting for individual differences (participant) and time spent walking in the exoskeleton (training day) improved all models

ORIGINAL STUDY

[1] K. L. Poggensee, S. H. Collins, How adaptation, training, and customization contribute to benefits from exoskeleton assistance. Sci.Robot.6,eabf1078(2021).

ACKNOWLEDGEMENT

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