Novel method for setting population-specific joint torque assistance requirements with applications to exoskeleton design

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Introduction

- Accurately identifying assistance requirements is essential in the development of wearable assistive devices
- Traditional approaches arbitrarily choose a constant assistance level across joint angles and joint velocities
- We propose to calculate assistance requirements based on torque deficits of the specific target population
- We demonstrate the method for unimpaired older adults.

Methods

Determination of torque deficits through a mathematical model [1] that finds **maximum voluntary joint torques** as a function of **joint angle** and **joint velocity**. We used the dataset from [1] to demonstrate the method.

$$T_{Active}(\theta,\dot{\theta}) = C_1 \cos(C_2(\theta - C_3))\zeta(\dot{\theta}) \qquad \dot{\theta} \geq 0$$

$$T_{Active}(\theta,\dot{\theta}) = C_1 \cos(C_2(\theta - C_3))\zeta(\dot{\theta})(1 - C_6\dot{\theta}) \qquad \dot{\theta} < 0$$

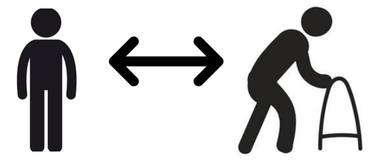
with $$\zeta(\dot{\theta}) = \frac{2C_4C_5 + |\dot{\theta}|(C_5 - 3C_4)}{2C_4C_5 + |\dot{\theta}|(2C_5 - 4C_4)}$$



Population

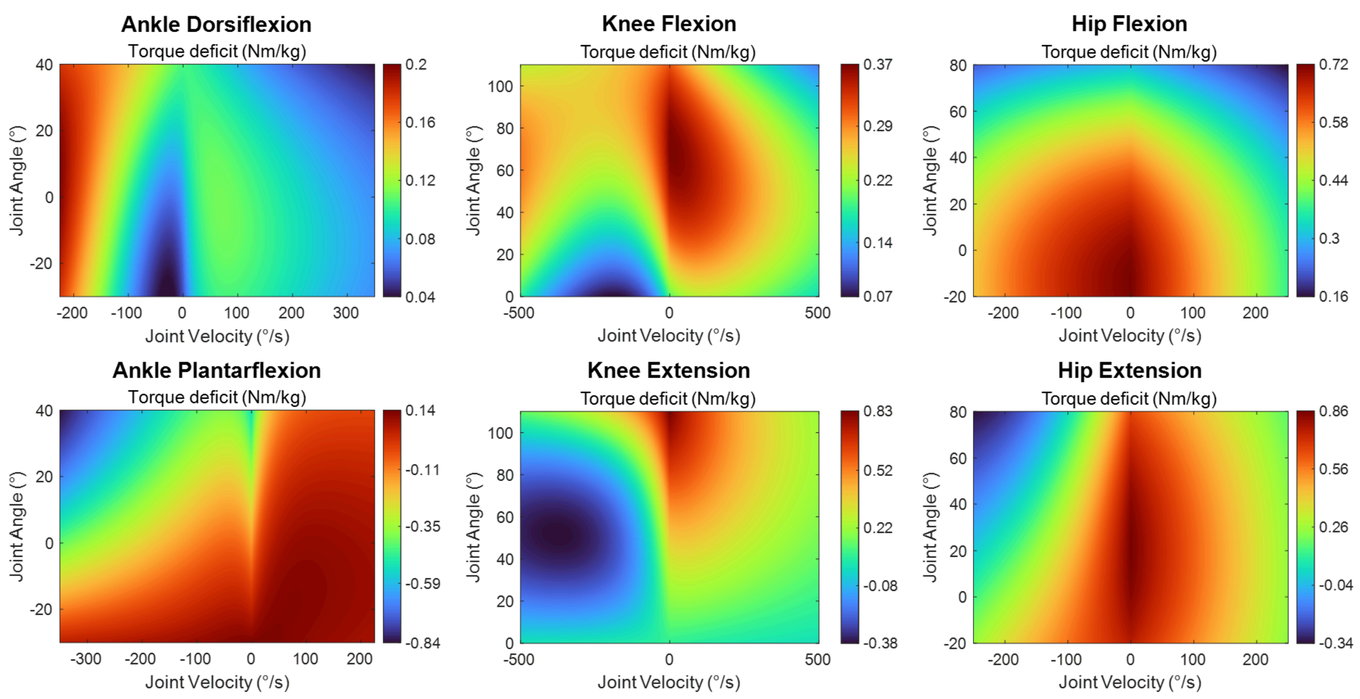
	Reference population: Young adults (n∼14) (18-25)		Target population: Older adults (n∼6) (65+)	
	M	F	M	F
Age (years)	19.6 +/- 1.1	19.6 +/- 1.3	71.7 +/- 2.3	68.3 +/- 2.5
Mass (kg)	72.8 +/- 7.2	62.1 +/- 6.3	86.2 +/- 11.4	64.5 +/- 2.9
Height (cm)	174.8 +/- 5.2	160.6 +/- 5.0	174.3 +/- 8.6	161.7 +/- 4.7

In this method, the **target group** is the exoskeleton user. The exoskeleton designer chooses the **reference group** that the target group should match in ability.



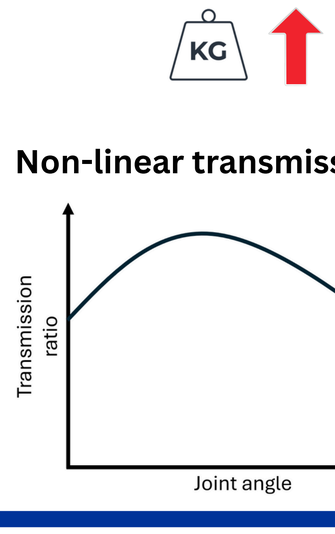
Results

- Older adults' **torque deficits vary across joint angles and velocities** and can be matched to motor characteristics.
- **Power deficits** sometimes show **different** trends than **torque deficits**.
- Our **results** give **similar peak torque deficits** compared to **other methods** (e.g., [2]), but with **added information** (joint angle and velocity)



Discussion

- Traditional approaches often overestimate assistance requirements, leading to an over-dimensioned (and larger/heavier) actuation system
- We developed **a method that finds torque deficit as a function of joint angle and joint velocity** that can be used to correctly dimension actuators for assistive wearable robotic devices
- Our results allow **design of non-linear transmissions** based on torque and power deficit given as function of joint angle
- Future work: apply method to sarcopenia and stroke populations



References
[1]: Anderson et. al., DOI: 10.1016/j.jbiomech.2007.03.022.
[2]: Böhme et. al., DOI: 10.1017/wtc.2022.1