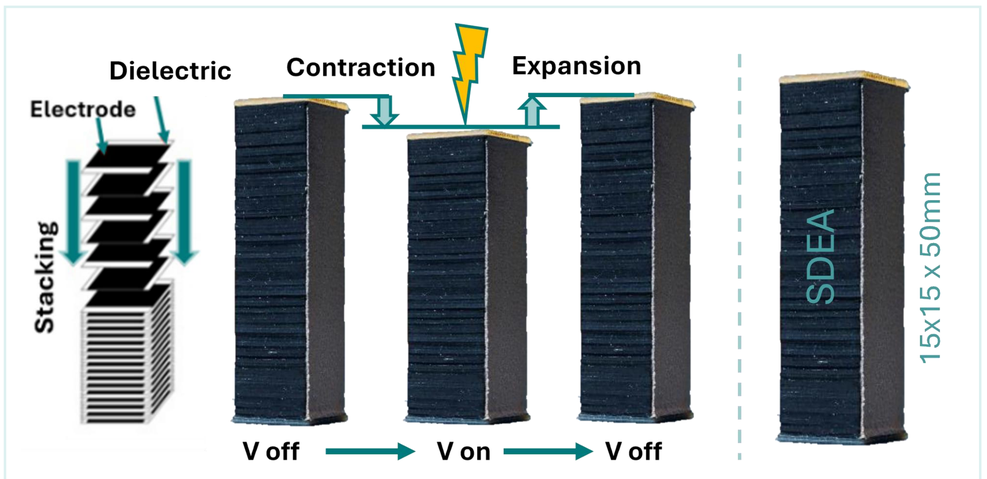
Theoretical Evaluation of DE-AFO: a Comfortable Robotic Ankle Exoskeleton for Children with Cerebral Palsy Powered by Advanced Stacked Dielectric Elastomer Actuators

Mobina Masaei[1] & Ahad Behboodi[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE
mmasaeikoroyeh@unomaha.edu

INTRODUCTION

- Although current powered AFOs have active propulsion assistance, they have **rigid** structures with **heavy** and **noisy** actuators.
- DE-AFO, a type of powered AFO, utilizes **"Artificial muscles"** to produce force in the sagittal plane.
- Artificial muscle: A type of soft electroactive polymer → Stacked Dielectric Elastomer Actuator (**SDEA**).
  - **Noiseless**, **lightweight**, **flexible**, **muscle-like properties**.



Aim: Evaluating the DE-AFO's ability to compensate for dorsiflexion (DF) and plantarflexion (PF) force deficits.

Study Design

- Three children with cerebral palsy (CP) (12-13 yrs).
- Seven typically developing (TD) peers (10-16 yrs).
- Calculated DF and PF forces using the measured ankle moment ($\boldsymbol{\tau}$) values.
- Assessed DE-AFO torque ($\boldsymbol{\tau}$) generation in the sagittal plane.
- Compared force deficits (f_{Diff}) with the maximum actuator DF and PF forces.

$$\boldsymbol{\tau_{Diff}} = \boldsymbol{\tau_{TD}} - \boldsymbol{\tau_{CP}}$$

DE-AFO

- A biomimetic (powered by SDEA) AFO assisting ankle movement in the sagittal plane.
- Two dorsiflexor fibers → **51.7 N** of force
- Four plantarflexor fibers → **103.5 N** of force
- Gait phase detection controller → Synchronizes the actuator function with the user's natural gait cycle.
- 3D printed structure enables more adjustability.
- Lightweight, compact, and silent design.

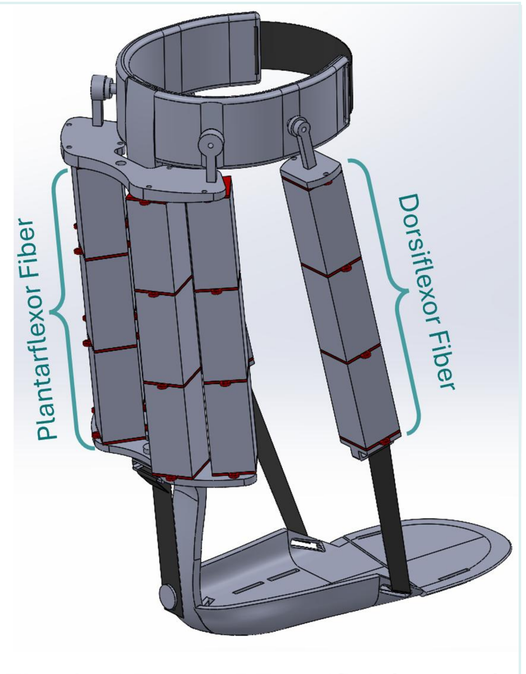
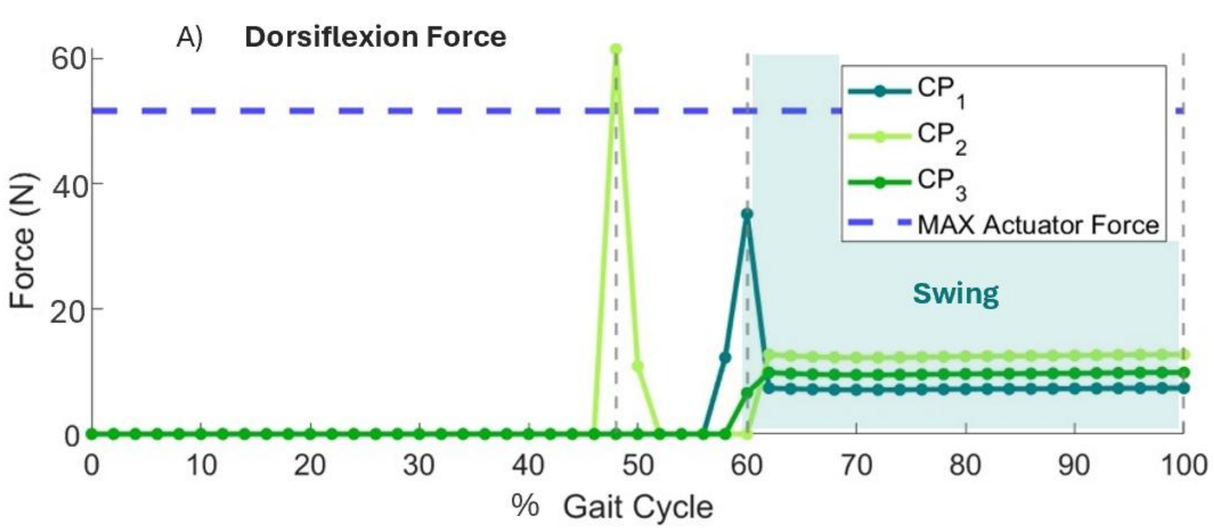


Fig 1. DF and PF artificial muscle fibers are shown, each generating 25.84 N of force.

RESULTS

DE-AFO successfully compensated for approximately 100% of dorsiflexion deficits during the swing phase and was capable of generating 75% of the desired plantarflexion force during pre-swing, highlighting its potential to enhance gait function in individuals with CP.



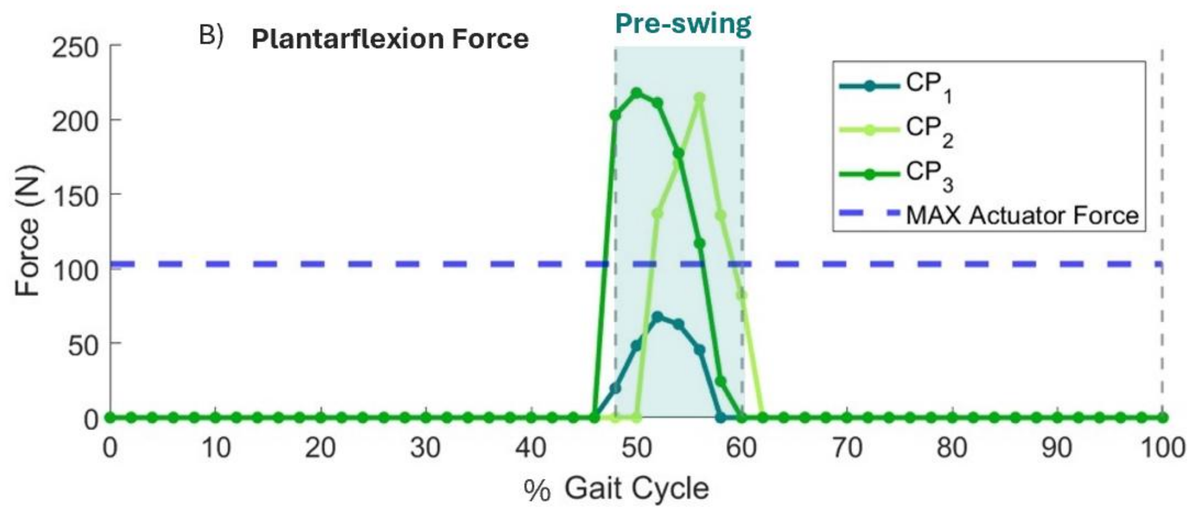


Fig 2. A) DF and B) PF force deficits for each child with CP, with each child represented by a different color. The dashed line indicates the maximum actuator force.

- DE-AFO was capable of generating a DF force of **51.7 N**.
- The highest DF deficit in **pre-swing** phase → CP02 → **61.5 N**
- DE-AFO **completely** compensated DF deficit in **swing phase**.
- DE-AFO was capable of generating a PF force of **103.5 N**.
- The highest PF deficit in **pre-swing** phase → CP03 → **218 N**
- DE-AFO compensated for **75%** of the averaged PF deficit.

REFERENCES

[1] Patel DR, et al. Transl Pediatr, 9(1):S125–35, 2020.
[2] A. Aboutorabi, et al. Ann. Phys. Rehabil. Med, 60(6), 393–402, 2017.
[3] V. Mohammadi, et al. Sensors, 24(12), 3787, 2024.