Effects of a Passive Dynamic Lower-Leg Exoskeleton during Walking

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INTRODUCTION

- The ankle produces 60% of the lower-body positive mechanical work during the stance phase of gait[1,2]
- If ankle muscles are weak, there are reductions in the ability to generate appropriate torques and powers during walking
- This leads to slower preferred walking speeds (PWS), which correlate with poor physical function, more disabilities, increased hospitalization visits and costs, and even mortality[3,4]
- Due to this, many orthotic and exoskeletal devices are being created to restore proper ankle function by promoting ankle plantar flexion[5,6]
- **Purpose:** Build a passive dynamic lower-leg exoskeleton to assist ankle plantar flexion, and assess its effects during walking
- **Hypothesis 1:** Wearing the exoskeleton will reduce the biological ankle torque contribution during stance
- **Hypothesis 2:** Wearing the exoskeleton will insignificantly affect ankle angle throughout gait
- **Hypothesis 3:** Wearing the exoskeleton will decrease the metabolic cost of walking

MATERIALS / METHODS

- Ten young, healthy participants between the ages of 19 and 35 years will walk on a level treadmill, at 10% faster than their PWS, for a variety of exoskeleton conditions (Table 1)

Table 1. Exoskeleton conditions during level treadmill walking.

Exoskeleton Walking Conditions
Normal (No Device) – [NORM]
Exoskeleton without Elastic Actuators – [NA]
Exoskeleton with Constant Actuation – [CA]
Exoskeleton with Stance-Only Actuation – [SA]

- All walking trials will be five minutes long and followed by a three minute rest
- Subjects will begin the study with a habituation period on the treadmill, involving three walking trials wearing the device with constant assistance actuators (CA Condition)
- 3D motion capture (Vicon Nexus) will measure hip, knee, and ankle motion in the sagittal plane
- An instrumented treadmill (Bertec) will measure ground reaction forces
- Using inverse dynamics, lower-body joint torques and powers will be calculated from motion and force data during walking trials

EXOSKELETON

- The lower-leg exoskeleton consists of four major components (Figure 1):
  1. Calf Cuff
  2. Passive Clutch
  3. Extension Spring (Elastic Actuator)
  4. Foot Bracket

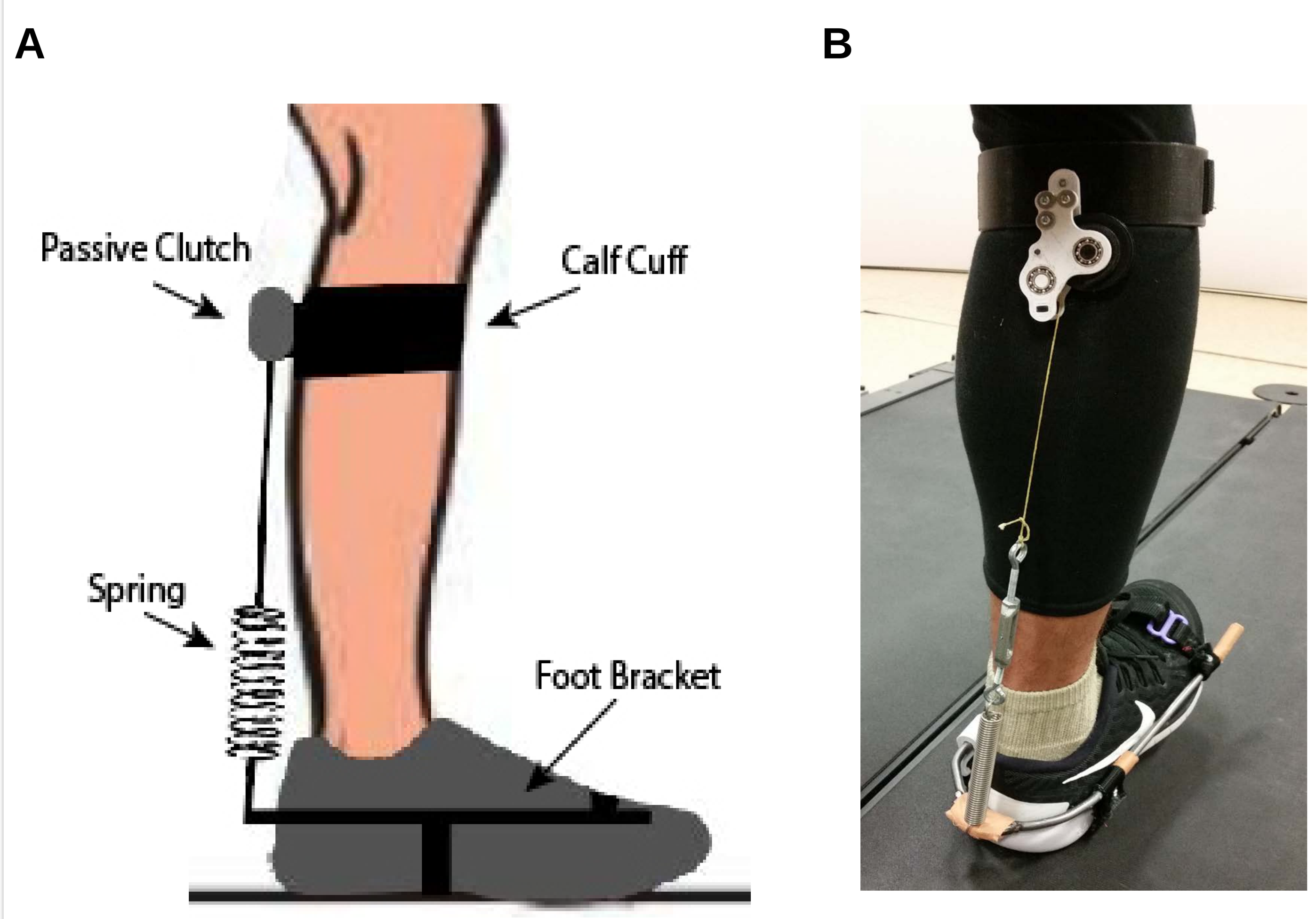

Figure 1. A) Schematic of the passive dynamic lower-leg exoskeleton with annotated components, and B) the exoskeleton being worn on the treadmill.

- The exoskeleton assists plantar flexion at the end of the stance phase of gait, facilitating forward propulsion
- As the ankle angle changes throughout the gait cycle, there is a resulting change in the length between the clutch and the heel of the foot bracket
- During the stance phase, this stretches the spring as the heel is in contact with the ground
- As toe-off begins, the clutch releases the spring, applying a plantar flexion torque about the ankle and assisting forward propulsion

PILOT RESULTS

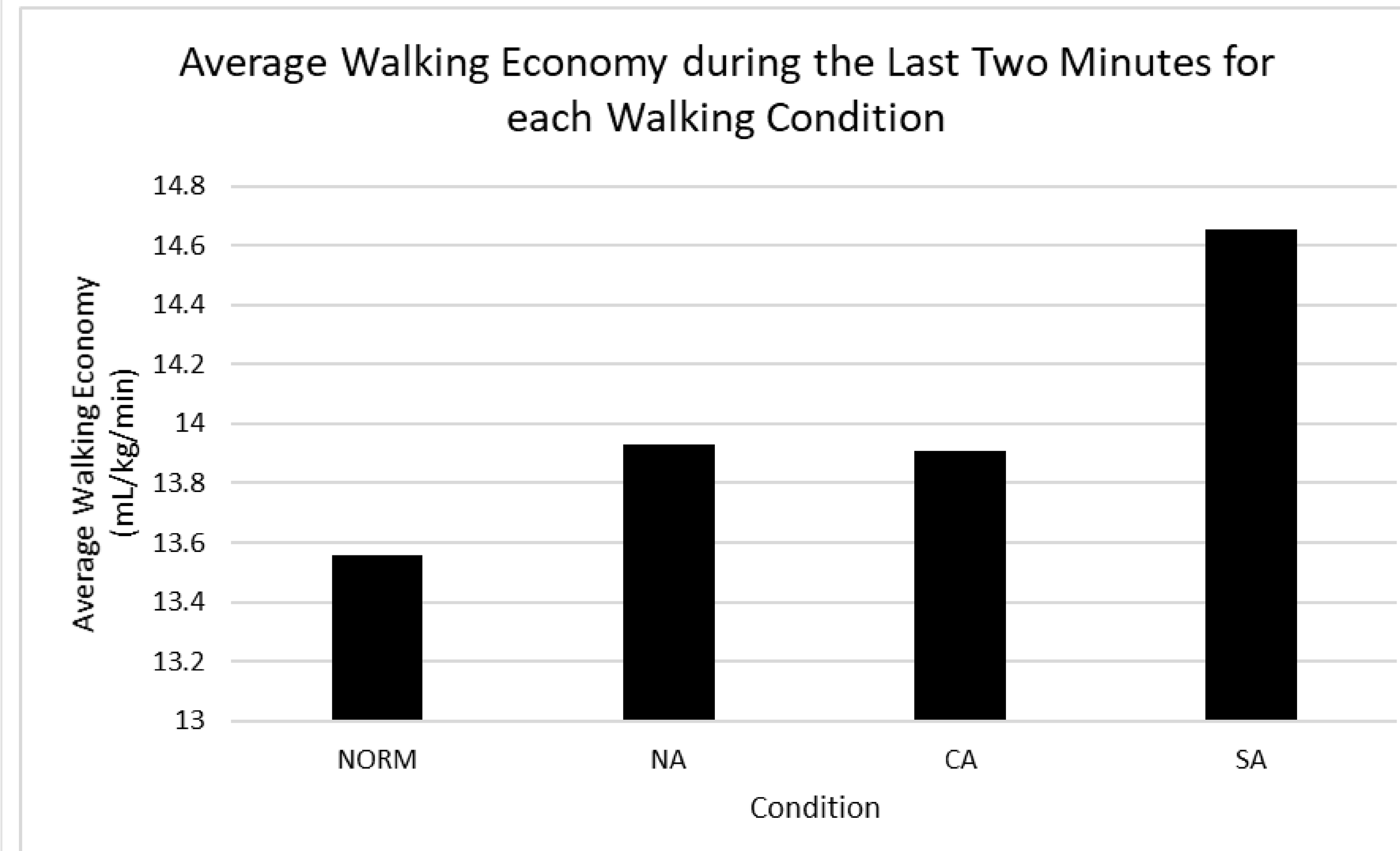

Figure 2. Pilot data of one subject's average walking economy for the last two minutes during each walking condition.

- The average walking economy for the last two minutes increased from 13.559 mL/kg/min to 14.656 mL/kg/min between the NORM and SA conditions (8.09% increase)

DISCUSSION

- Results of this study hope to determine normative effects of the lower-leg exoskeleton on lower-limb joint angles, torques, and the metabolic cost of walking
- If the exoskeleton is able to decrease the metabolic cost of walking, or the required biological torque contribution across subjects, the device may be beneficial to pathological population who exhibit ankle weakness or reduced forward propulsion

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