Exoskeleton-Assisted Walking Increases Muscle Volume in People with Spinal Cord Injury (SCI)

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INTRODUCTION

- Spinal cord injuries (SCI) affect 28-55 million people in the United States [1].
- Following a SCI, rapid muscle atrophy leads to decreased metabolic rate, increased fat storage, and increased risk of obesity-related illnesses such as cardiovascular disease [2].
- In radiographs, adipose tissue has very low radio-density.
- American Spinal Injury Association (ASIA) classifies the level of injury based on an impairment scale:
    - Class A (Complete) through E (Normal)
- Robotic exoskeletons are becoming increasingly available in clinical settings. However, little is known about the musculoskeletal benefits of using an exoskeleton.
- Robotic exoskeletons rely on motors at the hip and knee, a computerized control system, and rechargeable batteries to allow for assisted walking and rehabilitation [4].
- Exoskeleton-assisted gait training can be used to deliver controlled repetitive training and reduce physical burden on physical therapists [3].

Objective: (1) To develop standardized methods to measure muscle radio-density and volume in CT scans. (2) To compare CT data between time points in an ongoing clinical trial.

METHODS

Subjects

- 27 subjects with class A-C SCI (age: 33.7± 8.8 years, height: 177.8 ± 10.2 cm, weight: 74.8 ± 14.1 kgs.) were enrolled in a 12 month clinical trial
- Subjects were randomly assigned to two groups:
    - Immediate gait training: subjects participated in exoskeleton assisted gait training for study months 0 to 6
    - Delayed gait training: subjects participated in exoskeleton assisted gait training for study months 6 to 12
- Gait training lasted for 1 hour, 3 days a week for 26 weeks

Figure 1. Indego Exoskeleton

METHODS CONT.

Quantitative Image Analysis

- Mimics v. 18.0 (Materialise, Leuven, Belgium) was used to quantitatively analyze CT scans
- 15% regions of the thigh and 15% of the calf were cropped into individual sections on each leg, calculated based on subject height

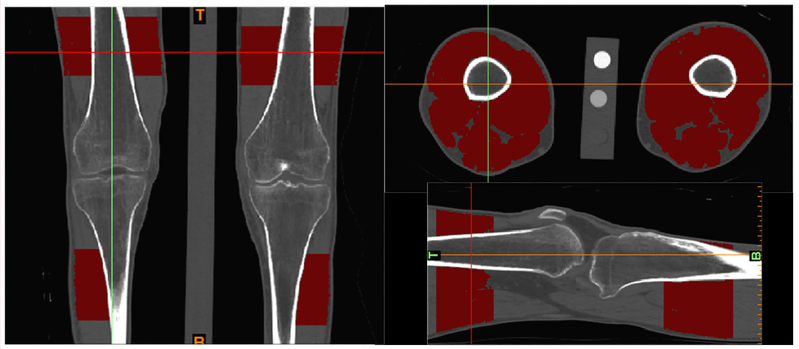

Figure 2. 25-40% of the upper leg and 15-30% of the lower leg were cropped into individual sections. Analyzed regions in all three planes are shown in red.

- Muscles were isolated from skin, blood vessels, etc. using region growing, thresholding and morphology tools.
- A threshold of -49 to 169 Hounsfield units (HU) was used to delineate muscle tissue. Less radio-dense tissue (lower average HU) indicates fattier/lower quality muscle.

Statistical Analysis

- Pearson correlations were calculated for demographics and baseline values of muscle volume and radio-density
- Precision (%CV) calculated for all metrics
- Paired t-tests were used to compare pre/post measures of muscle volume, radio-density and volume*radio-density

RESULTS

Baseline muscle volume was significantly correlated with body mass and height (r=0.409 to 0.495, p<0.035; Figure 3)

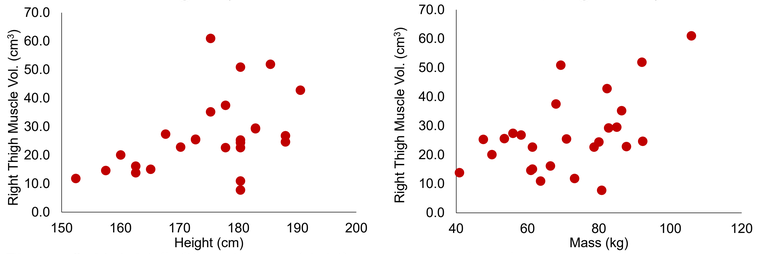

Figure 3. Height (left) and mass (right) versus muscle volume.

RESULTS

- Precision for muscle volume and radio-density was 1.3-1.4%.
- Gait training was associated with significant increases in muscle radio-density*volume (16% increase; p=0.035)
- These increases were primarily due to changes in volume (15% increase; p=0.02), and not radio-density (3% increase; p=0.346)

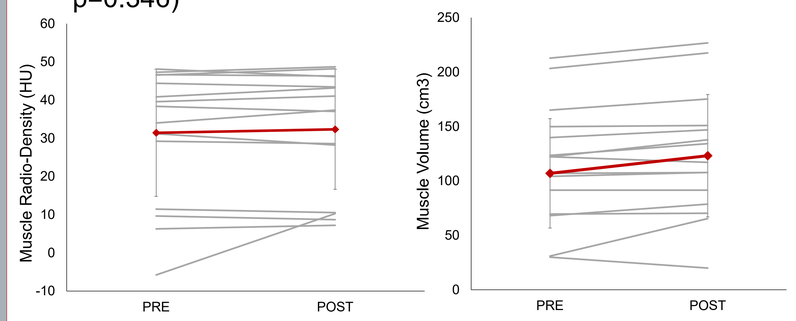

Figure 4. Pre and post muscle radio-density (left) and volume (right). Left figure shows that muscle density did not significantly change during gait training, but right figure shows that muscle volume increased significantly by 15% (p=0.02). Red bars show the group average at each timepoint. Error bars represent standard deviation.

DISCUSSION

- This research demonstrates that passive motion generated during exoskeleton-assisted walking could improve muscle quantity in people with SCI.
- Muscle mass is linked to improved cardiovascular fitness
- These results could be used to develop and evaluate improved rehabilitation interventions

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