The Impact of a Soft Back Exosuit on Various Movement Tasks: Standing with Perturbation

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Introduction

- In the year 2020 the World Health Organization reported that an estimated 619 million people globally suffered from lower back pain. [1]
- It is estimated that in the US, lower back pain costs anywhere from \$50 to \$100 billion annually. [2]
- Risk factors for lower back pain include: old age, lack of exercise, excess weight, disease, improper lifting, and poor lifestyle choices. [3]
- Injury of the lower back occurs as a result of high trunk stress.
  - Evidence suggests a trunk angle of 60° for more than 5% of total work time, or 30° for more than 10% of total work time results in higher risk of lower back injury. [4]
- Current solutions include braces and exoskeletons/exosuits.
  - Braces provide passive support for injury prevention and recovery but fall short of exoskeleton support. [5]
  - Exoskeletons typically provide specialized (active) support at the cost of comfort and high power requirements. [6]
- In light of these needs, ASU's NMCHR lab developed an initial prototype of a soft back exosuit to support movement.
  - This study highlights a design validation experiment for the initial prototype of the device.
- Margin of stability (MoS) was used as a metric of stability.

HYPOTHESIS: MoS during standing perturbations will increase when subjects wear the device and increase further when double jamming is active since the device will provide a higher force.

About the Device

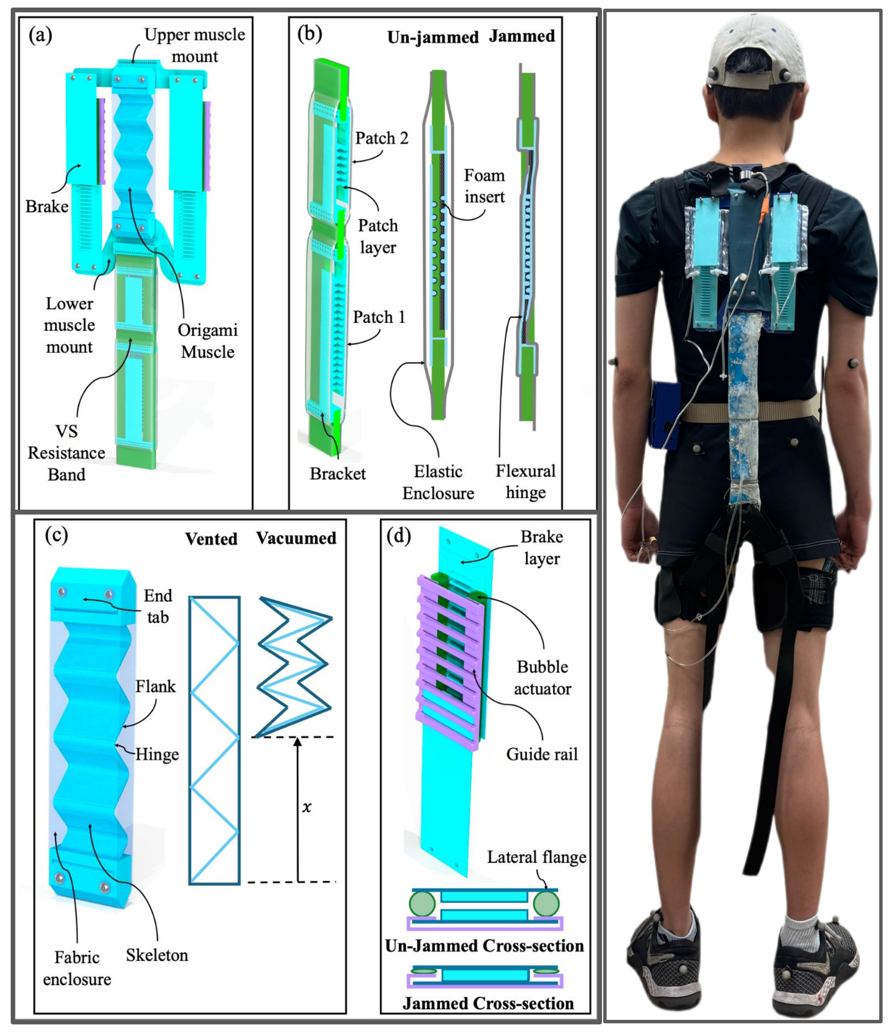

Figure 1: Overview of key device components (left) and image of a subject wearing the device (right)

- Design focused on comfort
  - Attaches at the shoulder and thigh
  - Light weight
  - Minimalistic design
- Designed to provide passive support
  - Structure uses several elastic components
- Includes a pneumatic jamming system for active support

Methods

- Five healthy subjects were selected on a voluntary basis to participate in this study (5 male, 0 female)
- Subjects were asked to stand straight on a treadmill and exposed to brief perturbations (belt acceleration).
  - Perturbation strength was calibrated to cause an induced trunk angle of 35°± 3°.
- Subjects completed a total of 20 trials under no device, device on, and device on with active double jamming (60 total trials).
- Vicon motion capture technology was used to gather MoS and trunk angle data.
- A linear mixed-effects model (LMM) was used to analyze group data.

Marker Name	Position	Marker Name	Position
LFH	Left front head	RFH	Right front head
LBH	Left back head	RBH	Right back head
LSHO	Left shoulder	RSHO	Left wristbone
LELB	Left elbow	RELB	Right elbow
LWRB	Left wristbone	RWRB	Right wristbone
LPSI	Left posterior pelvis	RPSI	Right posterior pelvis
LASI	Left anterior pelvis	RASI	Right anterior pelvis
LKNE	Left knee	RKNE	Right knee
LANK	Left ankle	RANK	Right ankle
LHEE	Left heel	RHEE	Right heel
LTOE	Left toe	RTOE	Right toe

Table 1: Table showing the marker configuration utilized to obtain all motion capture data.

Equations:

$$(1)\ MoS = BoS - XCOM$$

$$(2)\ XCOM = P_{COM} + \frac{V_{COM}}{\sqrt{\frac{g}{l}}}$$

$$(3)\ MoS_{ij} = \mu + \beta_{condition(j)} + b_{subject(i)} + \varepsilon_{ij}$$

Results

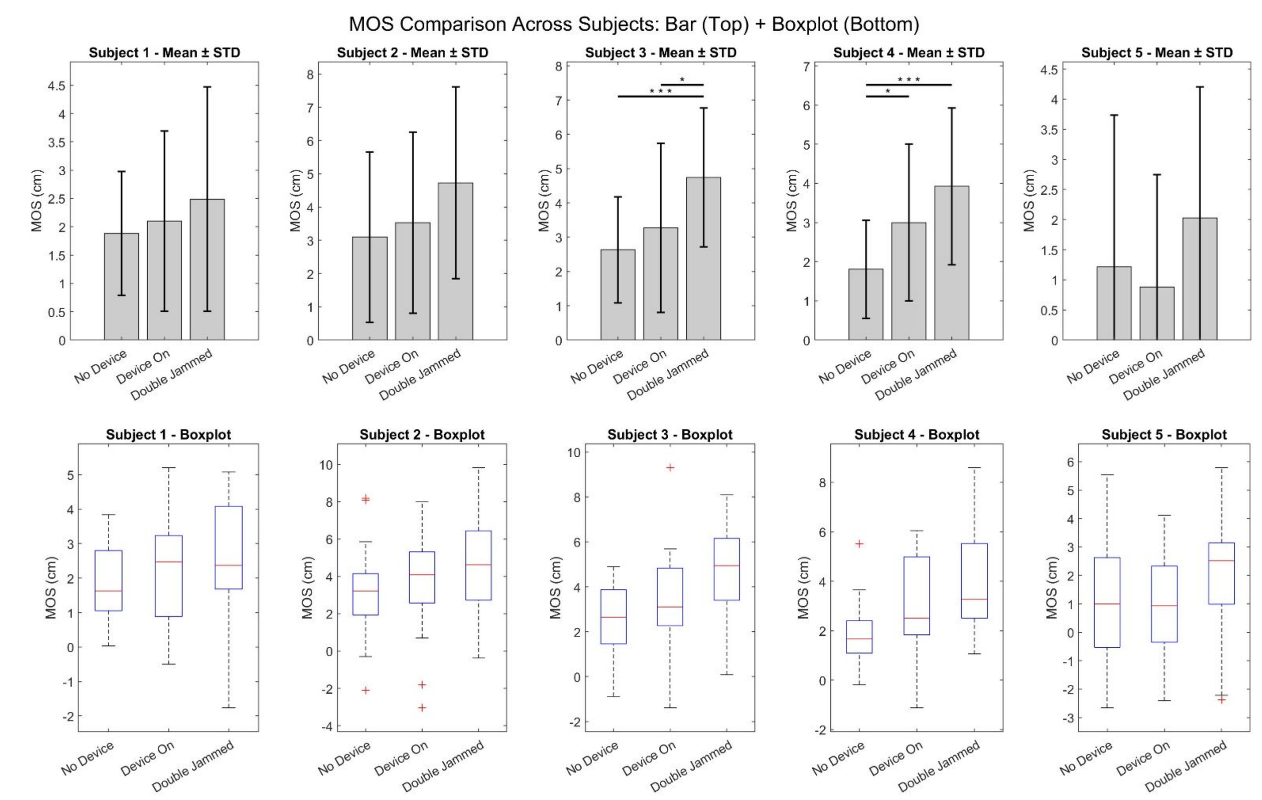

Figure 2: MoS mean values by experimental group (top). Respective subject box plots included on bottom. Statistical significance indicated as "" (α = .05), "**" (α = .01), and "***" (α = .001).*

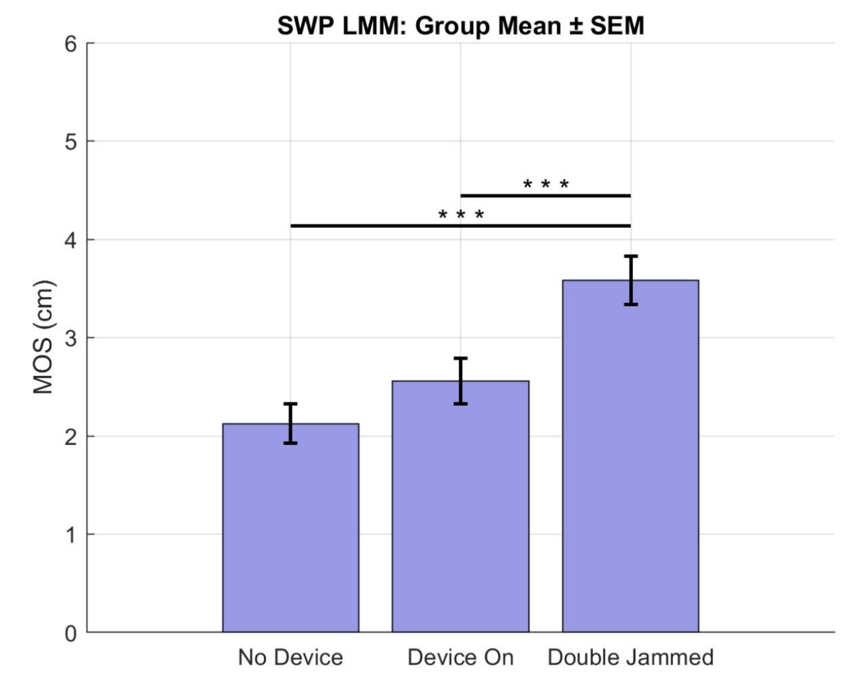

*Figure 3: MoS results compared between subjects after application of a LMM (3). Statistical significance annotated by "***" lines (α = .001).*

Analysis & Discussion

- Trunk angle remained consistent for all documented subjects.
- Individual MoS results show minimal relationships between the three experimental conditions.
  - Individual data mostly shows a positive trend but lacks statistical significance.
  - Stability (MoS) appears to improve from no device → device → device double jammed conditions.
- Group data (LMM applied) shows a significant increase in MoS for the double jamming condition.
- Error may have resulted from marker capture difficulties, device repairs, and/or hardware and software limitations.

Conclusion

Results from this experiment only partially supported the hypothesis. While individual MoS trends appear promising, few statistically significant relationships were found. Group results partially supported the hypothesis, suggesting that the double jamming condition provides increased support in comparison to the other two conditions.

Future Work

- Results of this study will be used to enhance future iterations of the exosuit device.
  - Current iteration shows promising results.
- The protocol for this study will be used to test future device iterations; results of this study may be used for comparison.
  - Small modifications may be made as required.

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