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HUMAN REHABILITAION GROUP

Texas A&M University

Interactive Balance Rehabilitation Tool with Wearable Skin Stretch Device

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Outline

- Background & Introduction
  - Balance Rehabilitation program
  - Wearable haptics
- Wearable Skin Stretch System
  - Wrist-worn Device Design
  - Control Algorithm
- Experiments
  - Protocol
  - Interactive Program
  - Results
- Conclusion & Future Works

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Background

- A good physical balance training program should be
  – Thorough and effective
  – Entertaining
- Game-based approach has been introduced in balance training programs for the past few years
  – Nintendo Wii Fit balance board
  – Virtual Reality

→ **Wearable haptics**

Augmented haptic feedback

- Wearable "actuator"

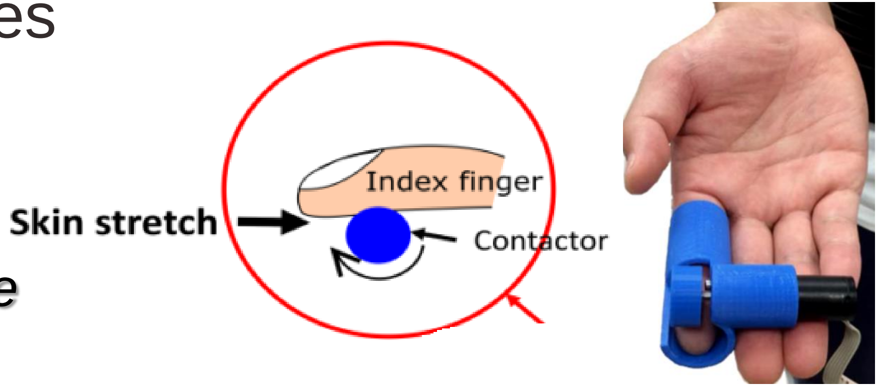
Fitbit®

Apple Watch

Wearable sensor

Augmented haptic feedback

- Wearable "actuator"
- Light touch at fingertip improves standing balance [1]



We propose a ***wrist-worn haptic device*** that can deliver **directional cues** in response to individual's postural sway

[1] Y. T. Pan, H. U. Yoon, and P. Hur, "*A Portable Sensory Augmentation Device for Balance Rehabilitation Using Fingertip Skin Stretch Feedback*," *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 25, no. 1, pp28-36, 2017

Objective: to determine the feasibility of the proposed system in improving dynamic stability for healthy subjects

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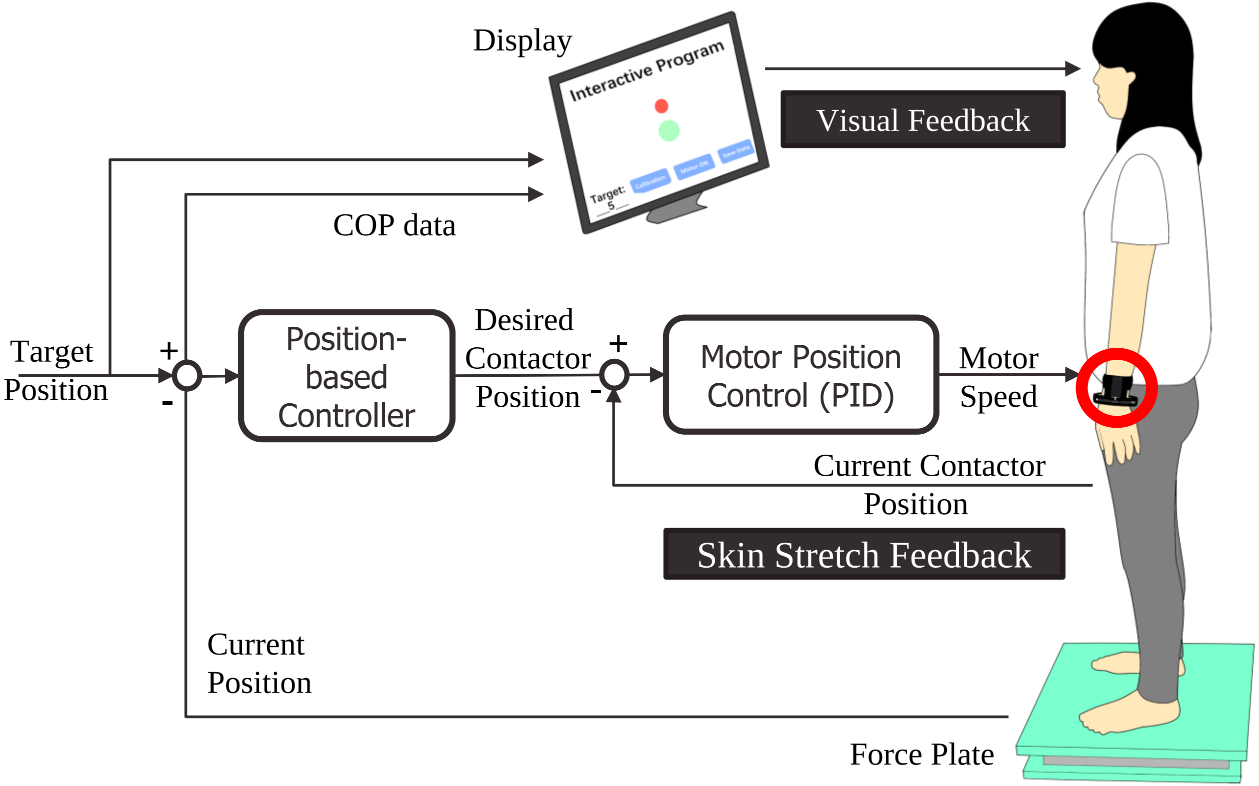
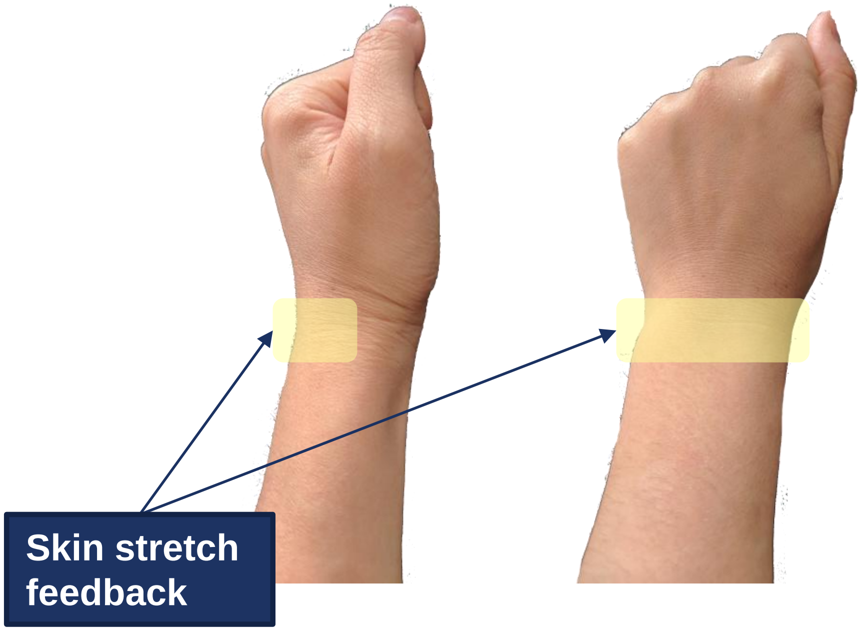
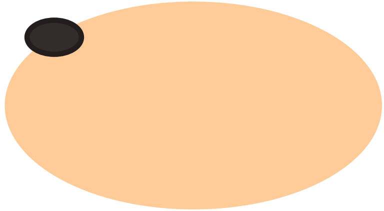
System Overview



Human Wrist

- A natural anatomical anchor point

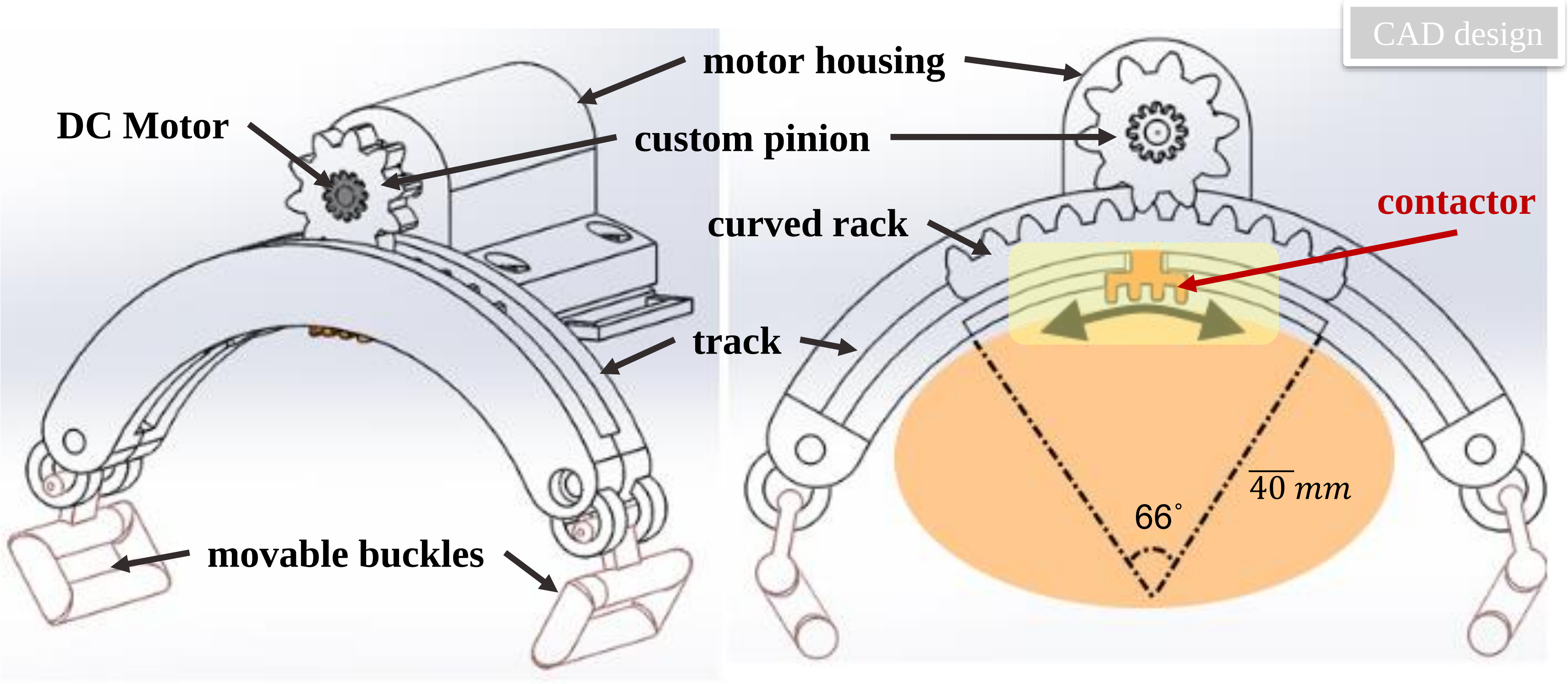




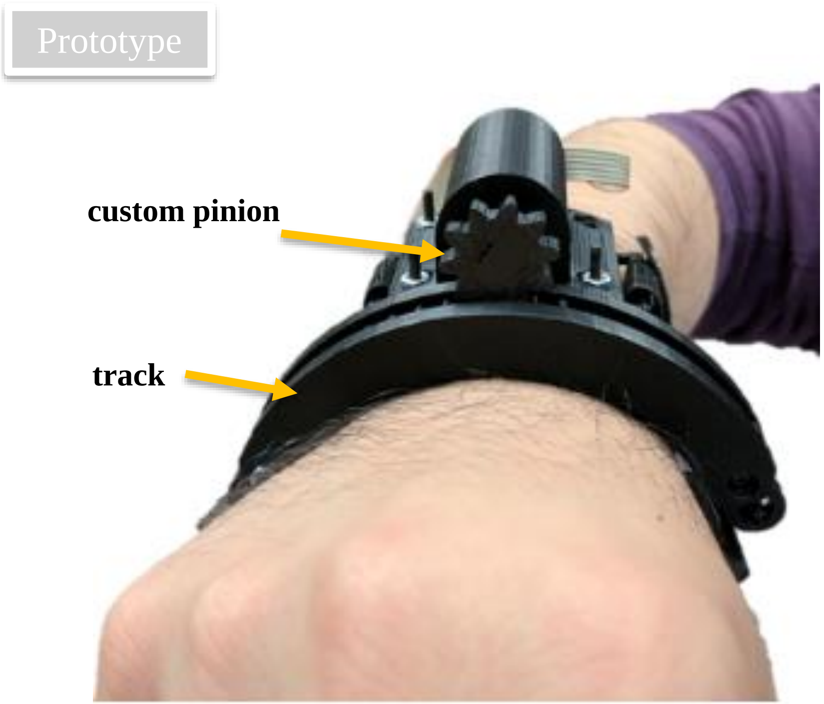
Cross-section:
oval shape

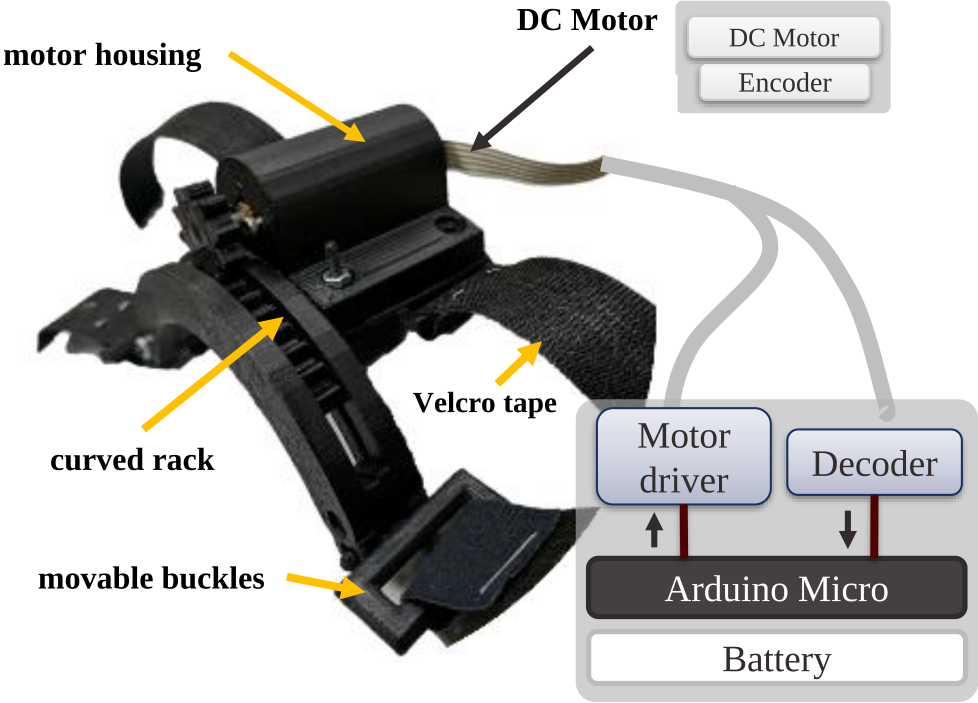
Wrist-worn Device Design

- Rack and pinion mechanism

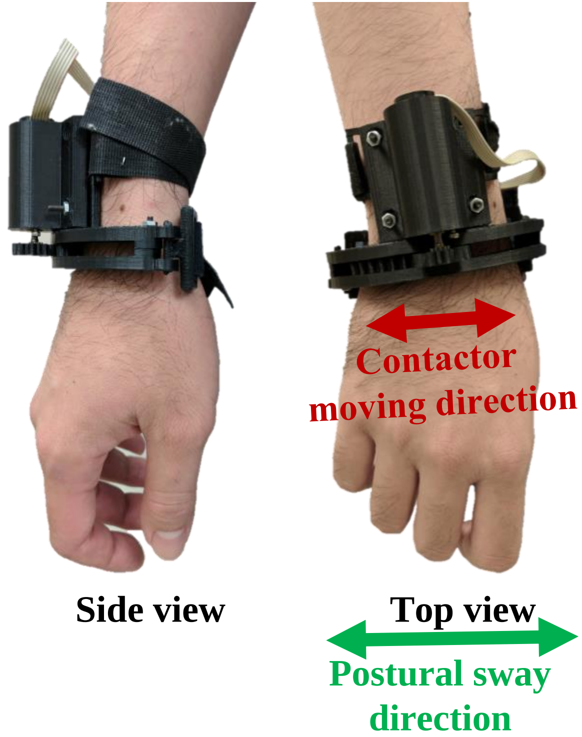


Wrist-worn Device Design





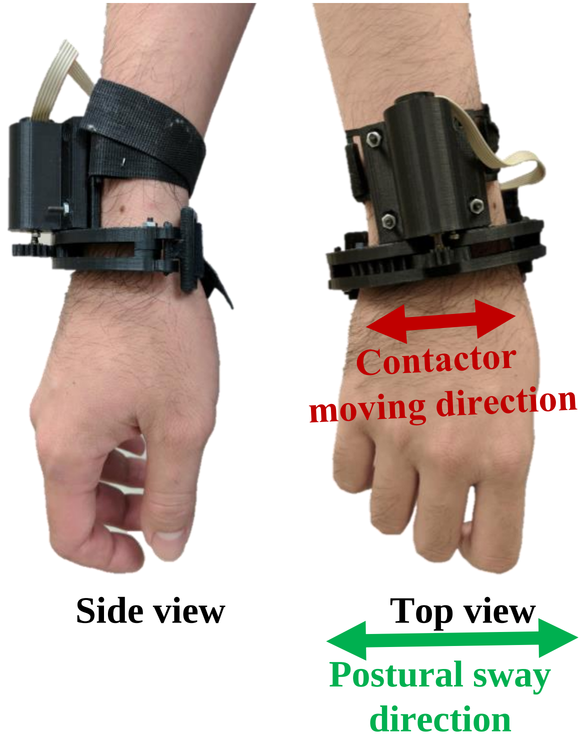
Control Algorithm



$$\theta_C = \theta_L \cdot \chi_{COP} / \chi_{FL}, \text{ if } \chi_{COP} \geq 0$$
$$\theta_C = \theta_L \cdot \chi_{COP} / \chi_{BL}, \text{ if } \chi_{COP} < 0$$

θ_C : contactor location
θ_L : limit of the pinion angle, 150°
χ_{COP}: current COP
$\chi_{FL/BL}$: absolute value of COP limits at front/back

Control Algorithm



$$\theta_C = \theta_L \cdot \Delta\chi / \chi_{FL}, \text{ if } \chi_{COP} \geq 0$$
$$\theta_C = \theta_L \cdot \Delta\chi / \chi_{BL}, \text{ if } \chi_{COP} < 0$$

$\Delta\chi$: $x_{COP} - x_T$ and x_T is the pre-defined target position
θ_C : contactor location
θ_L : limit of the pinion angle, 150°
χ_{COP}: current COP
$\chi_{FL/BL}$: absolute value of COP limits at front/back

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Experimental Protocol

- 5 healthy young subjects (age ± s.d.: 25.2 ± 2.9, 2 females)
- Weight shifting tasks in sagittal plane

Visual feedback only

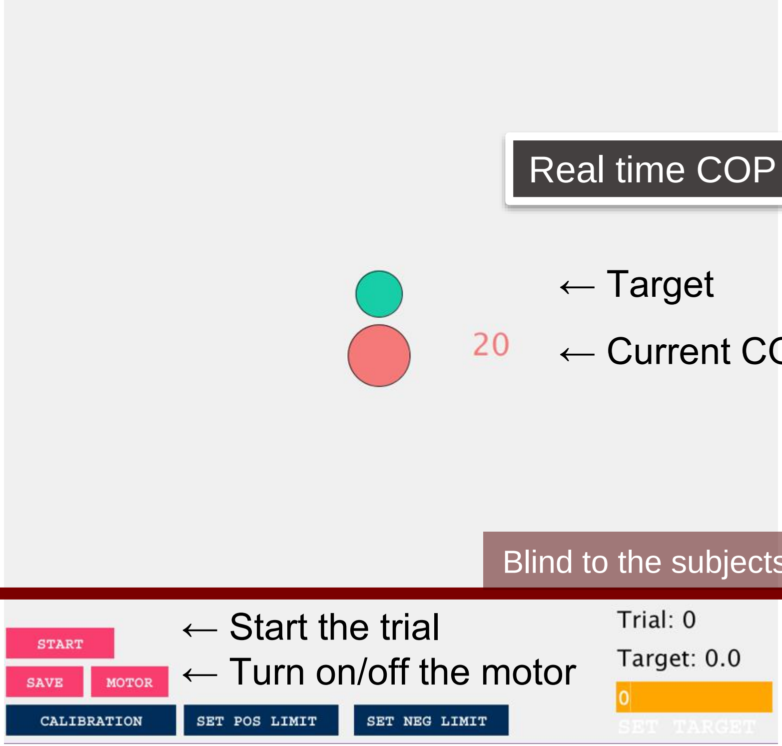
Visual feedback + skin stretch feedback

Skin stretch feedback only

Calibration phase:
1) Posture equilibrium
2) Front/back limit

Instruction:
Hit the target and stay for 1 sec

Interactive Program



Real time COP tracking

← Target

← Current COP

Blind to the subjects

← Start the trial

← Turn on/off the motor

COP movement recording

Calibration phase

Trial info

Set target

Experimental Protocol

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Visual feedback only

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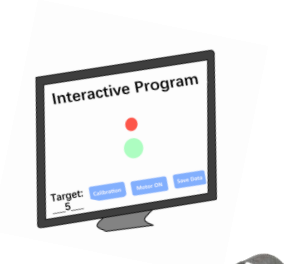
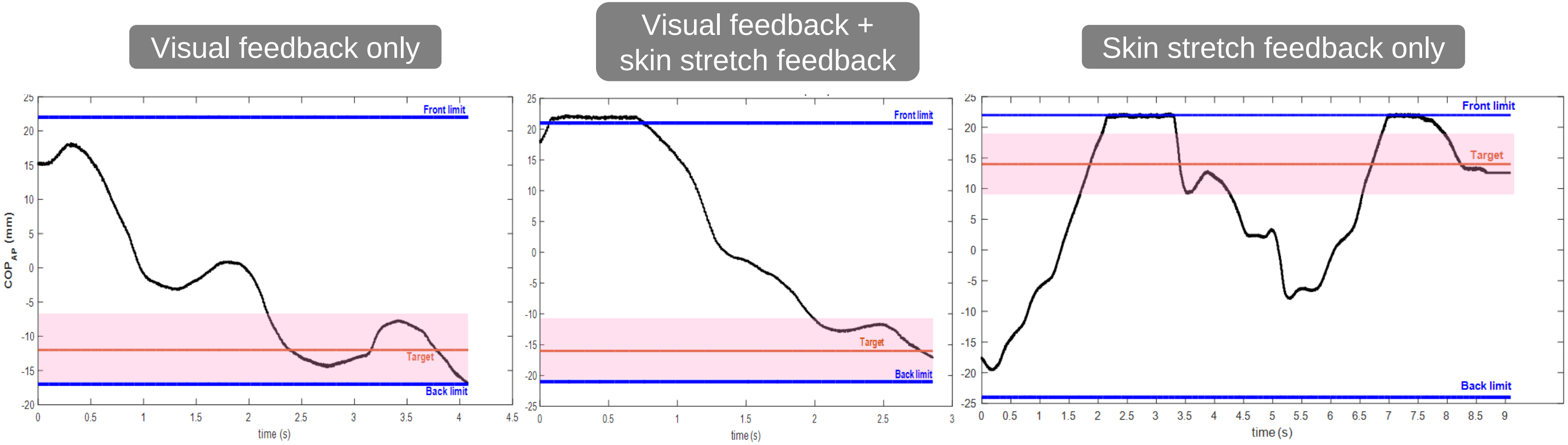


Calibration phase:
1) Posture equilibrium
2) Front/back limit

Instruction:
Move the contactor back to the center of the wrist

- Total 6 tasks
- Trial fails if reaching time > 3 mins

Results



▲ COP_{AP} trajectories from subject No. 2

	V	V+S	S*
Time to target (s)	5.94 ± 0.34	5.38 ± 0.65	11.45 ± 2.62**
Speed (mm/s)	61.07 ± 22.34	63.13 ± 19.77	62.82 ± 18.88

*one trial failed; ** p<0.05

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Conclusion

- Interactive framework for balance rehabilitation incorporating both visual and skin stretch feedbacks was developed
- All subjects could easily map their positions with the directional cues provided by the wrist-worn skin stretch device
- Additional tactile feedback might help regulate postural stability, though no significant difference was found between V and V+S tasks
- All subjects could complete the motor tasks using the skin stretch cues only
- Potential use for the long-term rehabilitation program

Future Works

- Wearable wrist device design improvement
  - Easy to wear, accommodate difference shapes of human wrist
  - Better localization of the contactor
- Include complex postural control tasks
- Increase sample size and recruit wider age groups and people with neurological impairment

Q&A

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  - www.hurgroup.net (Lab)