Effect of Haptic Feedback on Static Standing Sway

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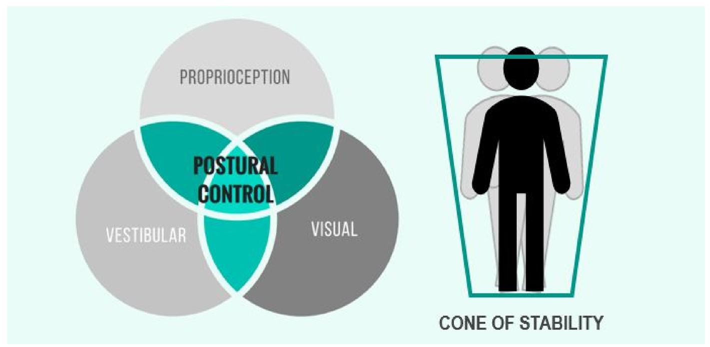
Background

- **Postural control** is a complex system that allows an individual to maintain balance within a "cone of stability," leading to maintenance of an upright posture, improved balance, and decreased risk for sustaining a fall.



- **Proprioceptive feedback** is utilized by an individual to gain understanding of surrounding environments; a common example of this is demonstrated by maintaining contact with walls or other objects to improve one's balance.
- According to the CDC: Deficits in static or dynamic balance are major contributing factors for falling, and consequently contribute to a loss of independence.
- Previous studies demonstrate successful use of light tactile feedback, such as light finger touch, rather than mechanical support to reduce uncontrolled postural sway.

Figure 1. [Above] Visual of haptic device and anatomical markers required for motion data analysis.

Study Goal

- To explore the use of proprioceptive input as a means of attenuating postural sway through the development and implementation of a hands-free device, with the ultimate goal of providing sway-reference haptic input located at the upper trunk and shoulders to determine:

Q: Does sway-referenced haptic input improve static standing stability?

*Stability measured as attenuation of COM excursion.

Methods and Experimental Setup

- **Haptic device description:**
  - Six haptic tactors were created using a 3D printer, run by DC motors, and an arduino board, attached by straps to the upper trunk and shoulders located at left and right proximal humerus, posterior scapula, and subclavicular regions (Fig. 2). Parameters were set to 3-5 degrees of sway constraint.
- **Research conditions:**
  - Seven subjects went through a battery of tests (Table 1) to compare conditions simulating a cane, proprioceptive touching of the surrounding, diminishing visual inputs, and a cognitive load.
- **Motion data acquisition and analysis:**
  - Motion data was captured using Qualisys 3D Motion Capture System comprised of 12 high speed cameras with capabilities to interpret 2D marker sets in real time, generating a working model. (Fig. 3)
  - AMTI Force Plates were synced with the motion system to accurately measure center of mass (COM) excursion at the same time, as demonstrated in Graph 1.

	Eyes Open	Eyes Closed + Pole	Eyes Closed + Touch	Eyes Closed	Eyes Open + Haptic	Eyes Closed + Haptic
Quiet Standing	-	4	6	8	-	17
Foam	10	11	12	13	19	20
Cognitive Load *(spelling)*	1 *Alignment Lavender*	5 *Technique Camouflage*	7 *Philosopher Foliage*	9 *Sculptor Diaphragm*	15 *Hysterical Maneuver*	18 *Lightning Algorithm*
Visual Conflict	2	-	-	-	16	-
Strobe	3	-	-	-	-	-
Cognitive Load + Foam	-	-	-	14 *Corruptible Nucleus*	-	21 *Thermometer Zucchini*

Table 1. [Above] Subjects' balance was systematically tested with conditions of increasing difficulty, as described above in a chronological order. Results were analyzed to compare effectiveness of haptic device vs. current techniques, such as assistive devices or proprioceptive touching, for the respective abilities to attenuate COM deviations and thus balance deficits.

Figure 2. [Below] Experimental setup of haptic device, 3D marker set, and AMTI Force Plates. The subject demonstrates the experimental setup for "Eyes Opened-Haptic Device-with Foam" condition.

Hypotheses

#1 The device improves sway

→ The device will significantly improve all mechanical measures of uncontrolled postural sway in participants with the **greatest stabilizing benefits** observed during visual and proprioceptive challenge conditions.

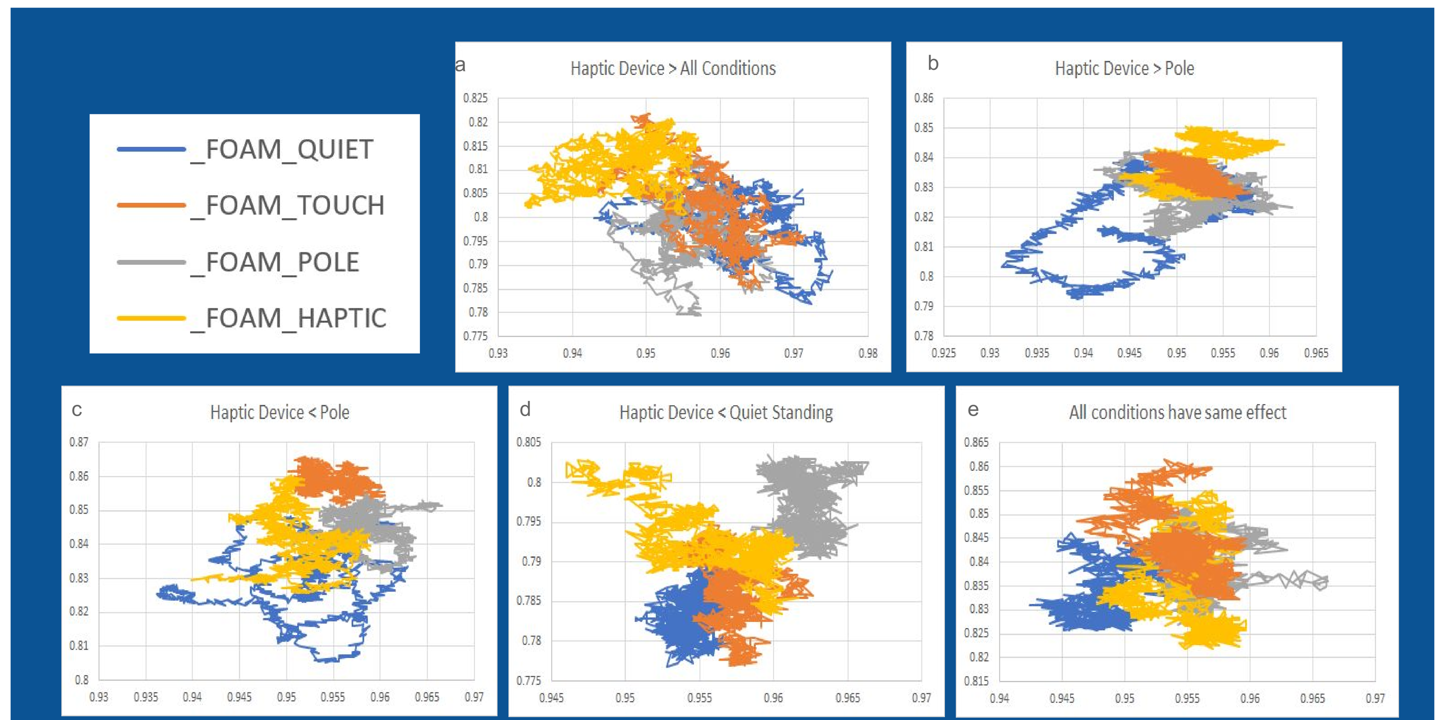
#2 Better than pole/touch

→ The device will provide **greater improvement** in all mechanical measures of uncontrolled postural sway in patients **as compared to** the stability provided by a **pole and/or finger touch contact**.

#3 In a way that subjects notice/prefer

→ Participants will subjectively **rate the device as better** at improving overall postural stability as compared to a pole and finger touch contact.

Results



Graph 1. [Above] Graphs demonstrate COM displacement with eyes closed in four experimental conditions. A range of responses were noted amongst subjects with benefit only being demonstrated in 1 of 7 subjects (Graph 1a).

#1 Rejected

→ Device **did not consistently** improve **all** mechanical measures of postural sway.

#2 Rejected

→ **No significant, consistent** difference found in attenuation of sway between stability provided by device, pole, or finger touch contact.

#3 Rejected

→ **50%** of participants **preferred the pole**, 33% preferred the haptic device, 17% preferred the finger touch contact.

Discussion and Conclusion

Although all 3 hypotheses were rejected - interesting observations were discovered leading to further studies:

[*Current research successfully demonstrates the ability of a haptic device to **shift the cone of stability**; however, future efforts should act to compare effects of varied haptic input types and parameters within the **same subject** to **reduce postural sway**. These adjustments may ultimately allow for successful implementation of a hands-free device to decrease a person's risk of falling.*]

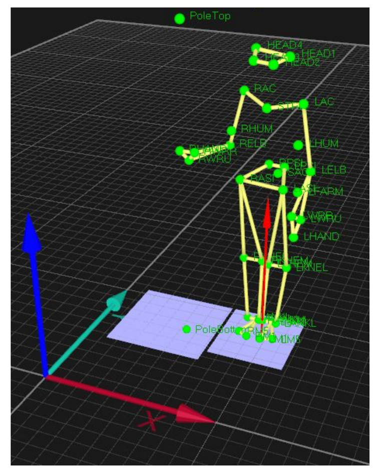


Figure 3: [Above] Visual of Qualisys biomechanical model formulated from anatomical markers.

- Haptic input demonstrates the ability to **change the shape and/or location** of the COM sway.
- **One of seven subjects** demonstrated a greater attenuation of sway with implementation of the haptic device when compared to finger touch or pole with eyes closed, pointing to **potential benefit** of the device in situations of diminished vision (e.g. low light, vision deficits). (Graph 1a)
- Multiple subjects showed **no attenuation** of sway across conditions with implementation of the haptic device when compared to finger touch or pole. (Graph 1c-e)
- There was **no benefit** with using the device during **cognitive tasks** during any conditions. Potential causes may be due to the increased challenge of dual tasking.

Conclusion:

>> Haptic device is **better than quiet standing**, but not as effective as finger touch at attenuating sway, and demonstrates an **equivalent** ability to diminish sway when compared to pole with eyes closed. (Graph 1)

Further Study Considerations

?

- Motional analysis and force plate data suggest the haptic device has potential to shift the shape/location of COM sway and may benefit postural control for **a subset of individuals** – particularly those who have **sustained multiple concussions**.
- Improve compressive nature of garment to maintain uniform tactor position and improve skin-to-tactor contact throughout course of experiment.
- Is reduced COM excursion the only valid measure of clinically meaningful stability?
  - Is the haptic device able to shift the cone of sway to another region (i.e. from L/R, from anterior/posterior) and have a functional impact to reduce risk of fall?

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