Sub-concussive head impact affects multisensory processing for upright standing

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BACKGROUND

Sub-Concussion

- an under-recognized phenomenon resulting from low levels of head impact that has the potential to cause significant neurological damage long-term.

Visual, vestibular and proprioceptive modalities

Estimation of body position/velocity (i.e., self-motion) **is heavily dependent upon the integration of information from multiple sensory modalities.**

vestibular modality

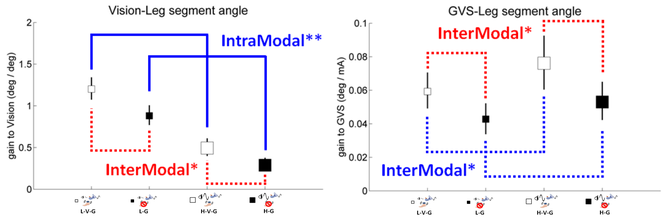
visual modality

proprioceptive modality

Sensory reweighting

Sensory reweighting is the process through which the **nervous system changes the "emphasis" of a particular sensory input** due to neurological injury or when environmental conditions change.

In our previous study, we could find **intramodal/ intermodal sensory reweighting which is the interplay between the three primary modalities for a central process** that fuses these modalities for accurate estimates of self-motion.



(Hwang et al., 2014, Dynamic Reweighting of Three Modalities for Sensor Fusion PLoS ONE 9(1): e88132)

RESEARCH PURPOSE

Q: Does sub-concussive impact affect multisensory processing for postural control of upright standing?

Q: Is there a particular sensory modality that is affected by the sub-concussive impact for control of upright standing?

We **simultaneously perturbed visual, vestibular and proprioceptive modalities** to study whether intermodal processing is affected by sub-concussive impacts.

METHODS

EXPERIMENTAL DESIGN

Pre → *After 1 week* → **Soccer heading** → *Right after* → **0 hr Post** → *After 24hrs* → **24 hr Post**

SOCCER-HEADING MODEL

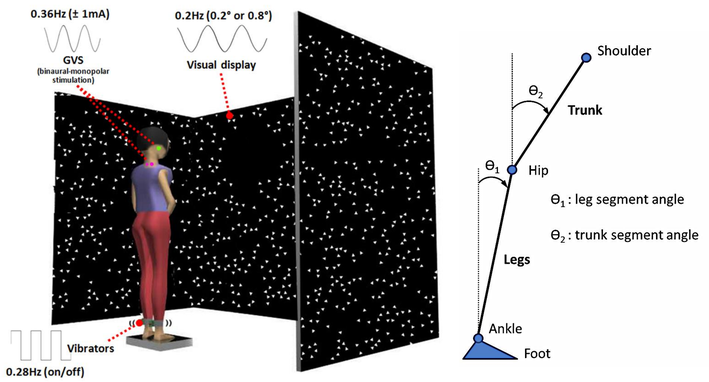
JUGs soccer machine

projected at 40 ° from horizontal at 11.2 m/s (25mph) ball speed

10 front headers in standing posture

✓ *Measured head impacts 11 - 24 g.*

SUBJECTS: 3 healthy young soccer players *(19.3 ± 2.3 years old, 182.9 ± 3.0 cm, 76.0 ± 6.8 kg)*



STIMULI

Visual stimulus

- 0.2 deg and 0.8 deg rotation (pitch) about ankle axis
- stimulus frequency : 0.2 Hz

Vibration

- 80Hz vibration at both Achilles' tendons
- on/off to approximate a square-wave periodic stimulus
- stimulus frequency : 0.28 Hz

Galvanic Vestibular Stimulation (GVS)

- ±1mA sinusoidal binaural-monopolar GVS
- stimulus frequency : 0.36 Hz

EXPERIMENT SETUP: 4 conditions, 135 sec/ trial, 3 trials in each condition

- **L-V-G** : low amplitude vision – vibration – GVS
- **L-G :** low amplitude vision – no vibration – GVS
- **H-V-G** : high amplitude vision – vibration – GVS
- **H-G :** high amplitude vision – no vibration – GVS

KINEMATICS: leg segment angle & trunk segment angle

ANALYSIS: Frequency response functions (FRFs)

- **The FRF, $H_{xy}(f)$, is the CSD divided by the PSD of the input.**
- **PSD** – power spectral density; **CSD** – cross spectral density
- **Gain** : the absolute value of the FRF, $H_{xy}(f)$
- **Phase** : the argument of the FRF, $H_{xy}(f)$, converted to degrees

RESULTS

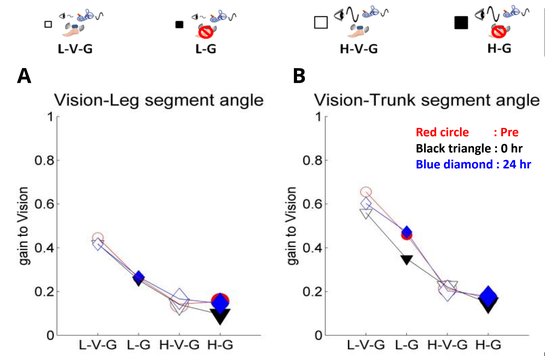


Figure 1. Gain of segment angles relative to vision

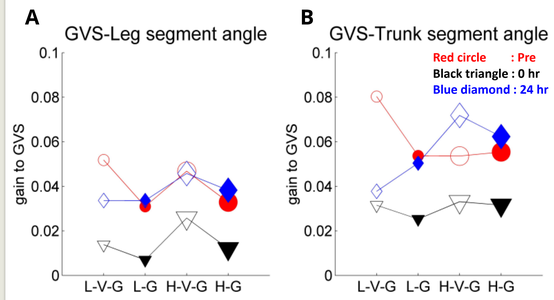


Figure 2. Gain of segment angles relative to GVS

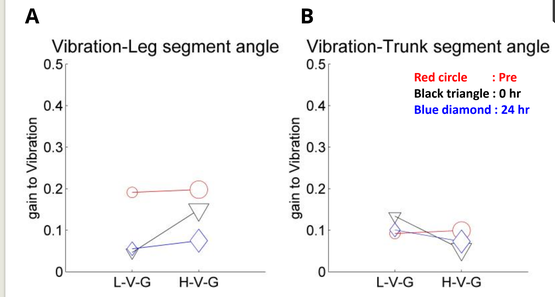


Figure 3. Gain of segment angles relative to vibration

GAIN RESPONSES: Vision low to high amplitude

Conditions: **L-V-G to H-V-G** or **L-G to H-G**

IntraModal Visual Downweighting in Pre, 0 hr and 24 hr *(Fig 1A-B)*

➡ **decrease leg/trunk gain relative to vision**

InterModal Vestibular Upweighting in 0 hr and 24 hr *(Fig 2A)*

➡ **increase leg gain relative to GVS**

InterModal Proprioceptive Upweighting in 0 hr *(Fig 3A)*

➡ **increase leg gain relative to vibration**

GAIN RESPONSES: Vibration off to on

Conditions: **L-G to L-V-G** or **H-G to H-V-G**

InterModal Visual Upweighting in Pre, 0 hr and 24 hr *(Fig 1A-B)*

➡ **increase leg/trunk gain relative to vision**

InterModal Vestibular Upweighting in Pre and 0 hr *(Fig 2A)*

➡ **increase leg gain relative to GVS**

These intermodal effects suggest …

vibration disrupts proprioceptive information at the foot/ankle, forcing the nervous system to compensate by upweighting vision and vestibular information.

GAIN RESPONSES: Sub-concussive head impact

Visual gain response *(Fig 1A-B)*

: no differences before/after sub-concussive head impact

Vestibular gain response *(Fig 2A)*

: gain to GVS decreased after sub-concussive head impact (0 hr), and recovered back to pre-heading level after 24 hours (24 hr).

Proprioceptive gain response *(Fig 3A)*

: Proprioceptive upweighting indicated at 0 hr rather than Pre and 24 hr.

CONCLUSION

Pilot results indicate **a trend of a decrease in GVS gain in 0 hr post session compared to the pre- and 24 hr post-session**.

Gains relative to vision did not change between test sessions.

These results suggest that **mild mechanical insults affect vestibular system processing rather than visual processing**, indicating that even mild (sub-concussive) head impact may have detrimental consequences with long-term repetitive exposure.