Balance deficits after mild Traumatic Brain Injury differ across timeframes of recovery

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BACKGROUND

- Recovery after mild Traumatic Brain Injury (mTBI) is complex and ongoing balance complaints are slow to resolve.
- We explored sensory and motor contributions to balance control after subacute (< 3 months) and chronic (>3 months) mTBI groups.

METHODS

Participants

Participants from 2 larger randomized controlled trials with subacute mTBI (2 – 12 weeks post injury) and chronic mTBI (> 3 months); all still reporting symptoms of imbalance

Table 1. Demographics

	HC (n=58)	Subacute mTBI (n=112)	Chronic mTBI (n=52)
Age (years, mean±SD)	36.9±12.7	34.1±11.8	38.8±11.2
Sex (% Female (N))	70% (35)	76% (85)	67% (35)
Days from injury (median)	NA	45	398
Neurobehavioral Symptom Inventory (0-88)	4.0±4.1	40.4±13.3	35.2±14.9
Injury Mechanism (%)			
Motor Vehicle Accident		30%	52%
Sport		27%	13.5%
Fall		21.5%	11.5%
Other		21.5%	21%
Blast		0%	2%

Procedures

Participants completed two Central Sensorimotor Integration (CSMI) tests that evoked center-of-mass (CoM) sway in response to pseudorandom stimuli including 1) surface tilts with eyes closed and 2) visual surround tilts with eyes open standing on a fixed surface (**Figure 1**).

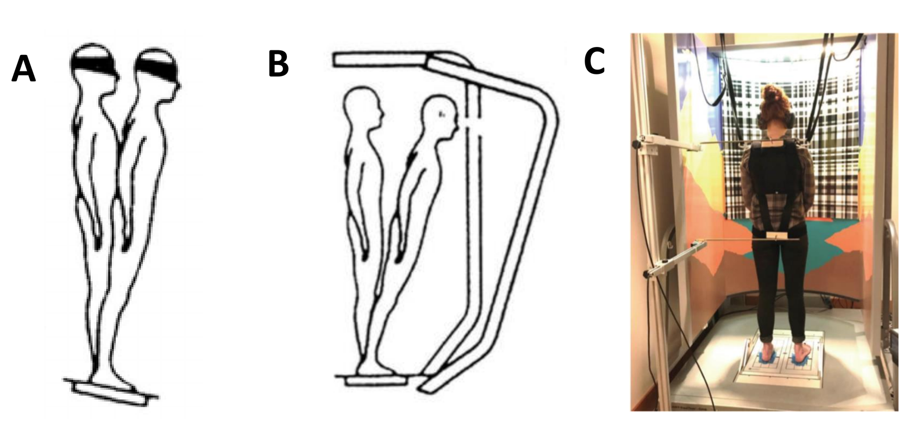

Figure 1: CSMI test conditions. (A) Eyes closed with sway evoked by stance surface rotations; (B) Eyes open stance on a fixed surface with sway evoked by visual surround rotations; (C) CSMI test performed on SMART EquiTest CRS Balance Manager System (Natus Medical Inc.).

Outcomes

- Vestibular and Visual Sensory Weights (W_{vest}, W_{vis})
- Motor Activation: Normalized Stiffness (K_p/mgh)
- System Time Delay (T_d)
- RMS value of CoM stimulus-evoked sway

Data Reduction

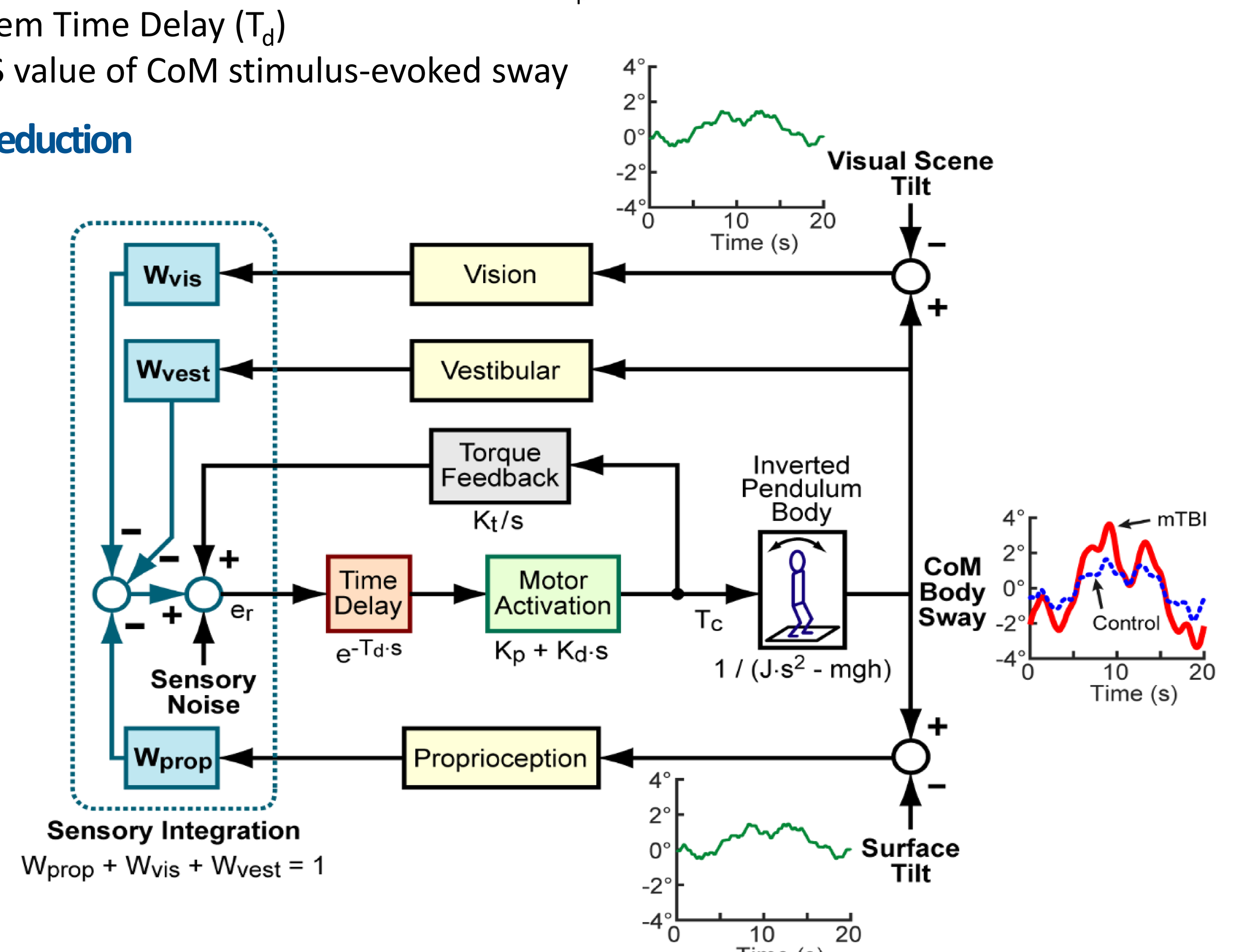

Figure 2: Feedback control model of the balance control system used in the CSMI analysis.

CSMI Model Parameter Descriptions:

Sensory Integration:

W_{vis} – Vision sensory weight indicated the relative contribution of visual orientation information for balance control.

W_{vest} – Vestibular sensory weight indicating the relative contribution of vestibular orientation information to balance control.

W_{prop} – Proprioceptive sensory weight indicating the relative contribution of ankle proprioception orientation information to balance control.

Time Delay (T_d): Total system time delay due to sensory transduction, neural transmission, central sensorimotor processing and muscle activation.

Motor Activation:

Stiffness (K_p) determines the compensatory ankle torque generated per unit of sensory-derived body sway angle.

Damping (K_d) determines the compensatory ankle torque generated per unit of sensory-derived body sway velocity.

K_p and K_d normalized by dividing by mgh (body mass x gravity constant x CoM height)

Statistical Analysis

General linear models were used to evaluate group differences while controlling for age; pair-wise comparisons were performed with tukey adjusted p-values for multiple comparisons.

RESULTS

Surface-tilt Stimulus, Eyes Closed

- Vestibular weighting was lower than HCs in subacute mTBI but was close to HC values in the chronic mTBI group (**Fig 3A**)
- Time delay was shortest in HCs and longer in both subacute and chronic mTBI groups (**Fig 3B**)
- Normalized stiffness was lowest in the chronic mTBI group (**Fig 3C**)
- RMS CoM sway was lowest in HCs and higher in both subacute and chronic mTBI groups (**Fig 3D**)

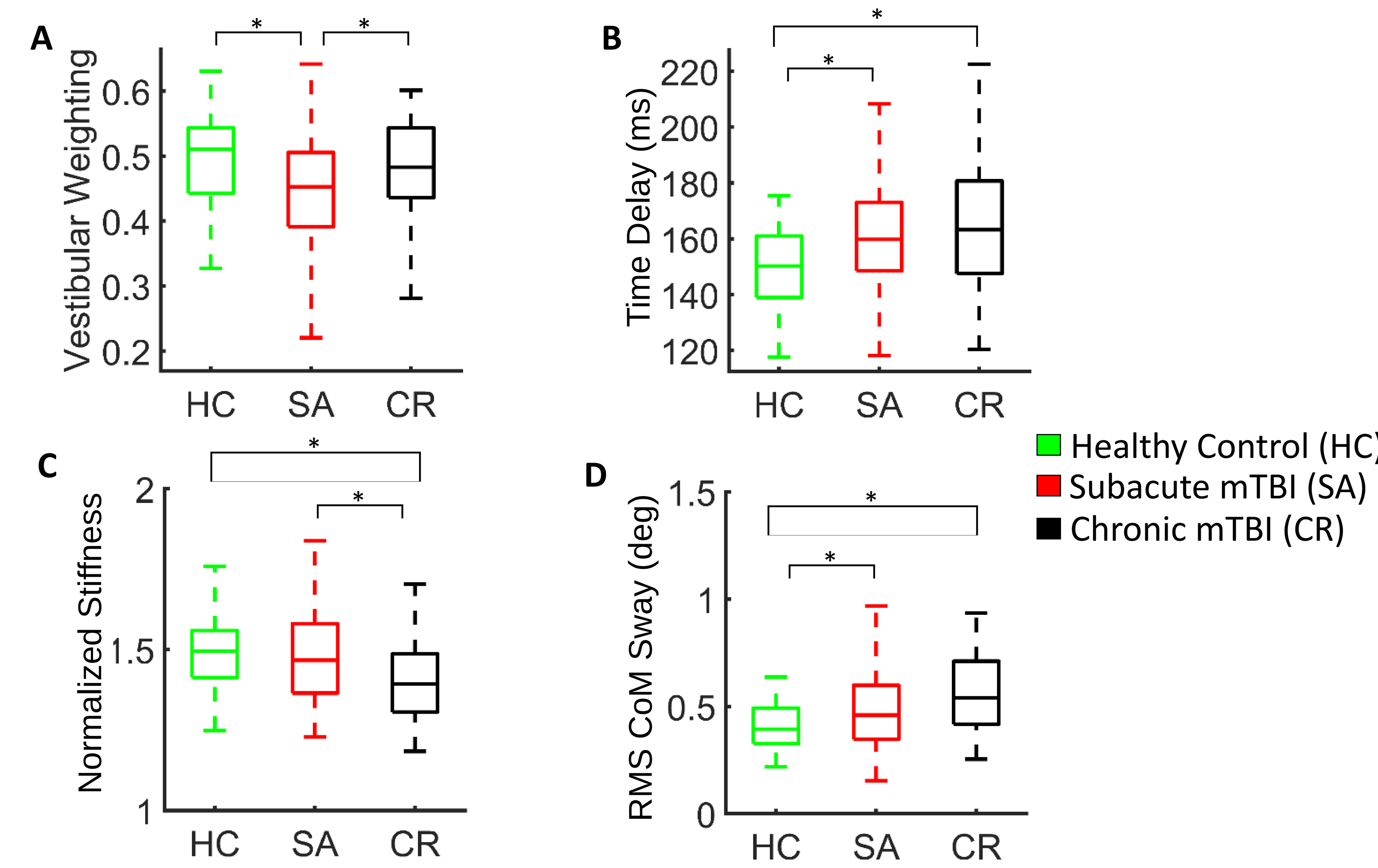

Figure 3: Box plots of CSMI outcomes for eyes closed, surface-tilt condition. (A) vestibular sensory weighting, (B) time delay, (C) normalized stiffness, and (D) stimulus-evoked CoM sway for healthy control, subacute mTBI, and chronic mTBI. * indicates significant Tukey adjusted difference ($p<0.05$)

Visual-tilt Stimulus, Fixed Surface, Eyes Open

- Visual weighting increases in chronic mTBI group (**Fig 4A**)
- Stiffness decreases with in both subacute and chronic mTBI groups (**Fig 4B**)
- Time delay increases in both subacute and chronic mTBI groups (**Fig 4C**)
- RMS Sway increases in both subacute and chronic mTBI groups (**Fig 4D**)

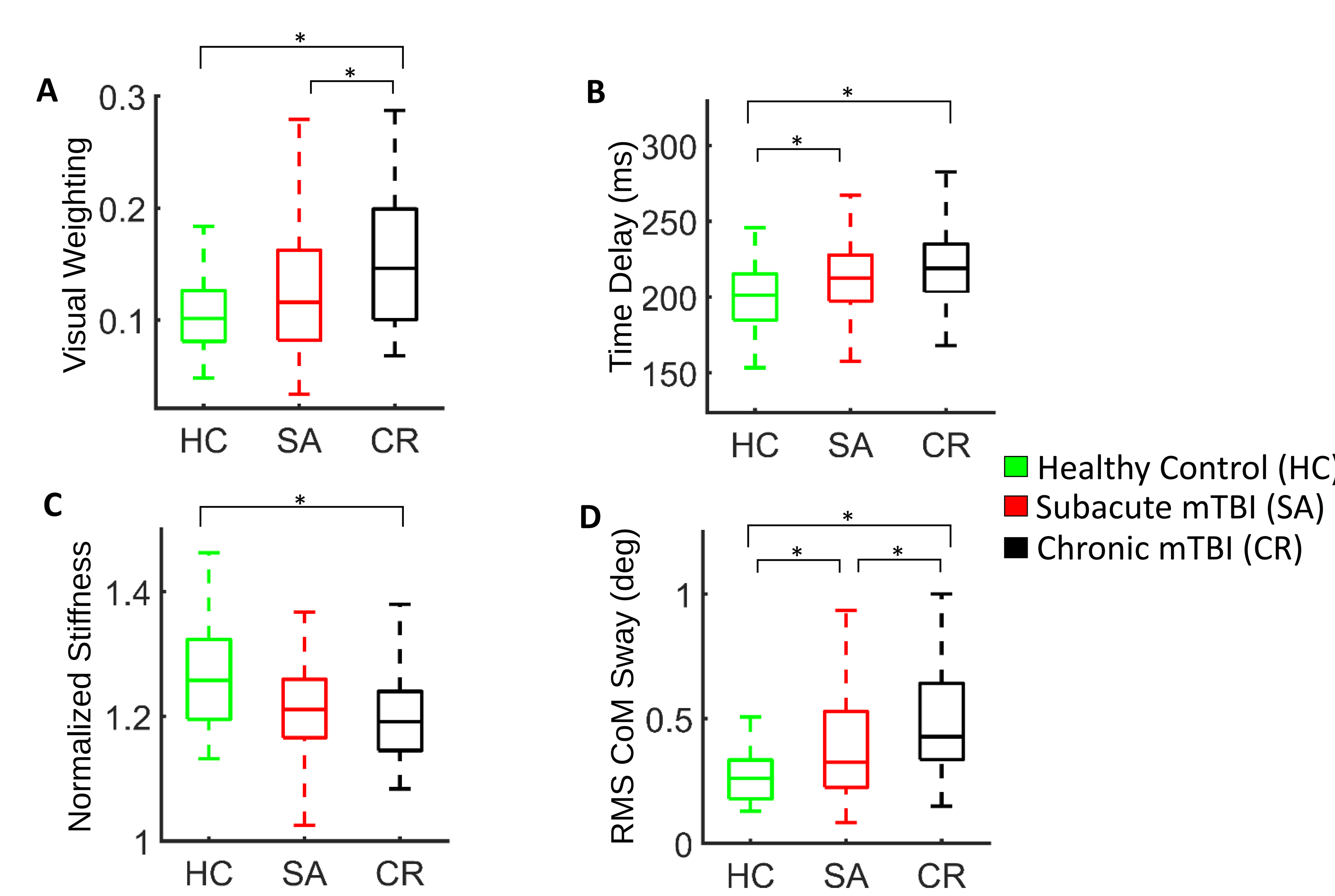

Figure 4: Box plots of CSMI outcomes or visual-tilt, fixed surface condition. (A) visual sensory weighting, (B) time delay, (C) normalized stiffness, and (D) stimulus-evoked CoM sway for healthy control, subacute mTBI, and chronic mTBI. * indicates significant Tukey adjusted difference ($p<0.05$)

CONCLUSIONS

- Vestibular weighting was reduced in subacute mTBI but had resolved in the chronic mTBI group.
- The greater reliance on vision (increased visual weighting) in the chronic mTBI group compared to both the HC and subacute groups may represent a maladaptive strategy.
- Both mTBI groups had longer time delays and increased RMS sway under both CSMI test conditions.
- Stiffness was similar in the HC and subacute mTBI groups suggesting that it was initially unaffected by injury but later was reduced in the chronic mTBI group with both CSMI conditions. Stiffness reduction may be a compensation for lengthened time delays.

CLINICAL RELEVANCE

- Depending on time since injury, different rehabilitation approaches may be needed with a focus on vestibular and visual reweighting in subacute and on motor activation in chronic mTBI.

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