Local Dynamic Stability in Single and Dual-Task Concussed Gait: Preliminary Results

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Most signs and symptoms resolve within 7-10 days after a standard sports concussion.
Complex gait tasks appear hypersensitive to concussions

**Decreased gait velocity**
Martini et al. (2011) *Arch Phys Med Rehab*

**Increased mediolateral sway**
Catena et al. (2009) *J NeuroEng & Rehab*

**Increased joint-coordination variability**
Chiu et al. (2013) *Gait & Posture*
Persistent, complexity-dependent gait changes may represent altered motor control.

Suitability for high-demand situations? (e.g., competitive athletics)

Ability to respond to local and global perturbations?
Local dynamic stability can quantify the response to local perturbations

Traditional variability measures quantify perturbation magnitude

LDS quantifies neuromuscular response and attenuation

May indicate system’s response to global perturbations

Lockhart and Liu (2008) *Ergonomics*
Hypothesis: Recently concussed athletes exhibit persistent decreased LDS post-concussion

\[ n = 9 \text{ VT varsity athletes} \]

(5 concussed, 4 matched controls)

Tested weekly for 6 weeks post-concussion*

* Not all athletes tested for all 6 weeks

Controls tested same days as match

14 bouts of straight gait under single and dual-task conditions

(serial 7 subtraction)
Trunk mounted IMUs collected tri-axial accelerations during gait

TEMPO platform developed by University of Virginia

Accelerations used to estimate LDS using Lyapunov exponents $\lambda_s$

13 bouts of 8 strides
Time-normalized strides
Normalized to gait speed

$\lambda_s$ compared using GEE

Main effects = Group, Week, Task
Interaction effects = Group*Task, Week*Task
Covariance Structure = Compound Symmetric
Significance level = 0.05
Groups showed similar LDS during single-task gait

20 healthy young adults
Van Schooten et al. (2014)
*Gait & Posture*
Dual-task affected concussed group more than controls

**Significant group*task interaction (p < 0.01)**

\[ DTC = \frac{\lambda_{DT} - \lambda_{ST}}{\lambda_{ST}} \times 100 \]

\( n = 2 \)  \( n = 5 \)  \( n = 4 \)  \( n = 5 \)  \( n = 4 \)  \( n = 4 \)  \( n = 3 \)

DTC of galvanic vestibular stimulation

Sloot et al. (2014) ABME
Recently concussed, asymptomatic athletes may be vulnerable during dual-task gait / cognitive loads

High cognitive loads during competition

Decreased performance?

Factor in higher musculoskeletal injury rates post-concussion?

Improve concussion rehab

Translate deficits to on-field risks
Conclusion: Recently concussed, asymptomatic, medically cleared athletes have lingering motor control abnormalities that persist after returning to play

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Maximum Lyapunov exponents $\lambda_S$ estimated the LDS

$\lambda_S$ estimates the divergence of nearby state space trajectories

Needs defined attractor in state space
Maximum Lyapunov exponents $\lambda_S$ estimated the LDS

$+\lambda_S = \text{Diverge}$

$-\lambda_S = \text{Converge}$