Multiscale Dynamics of Spontaneous Brain Activity in Sensorimotor Networks is Associated with Balance Control Performance in Chronic Ankle Instability

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Summary

To our knowledge, this is the first work to characterize the multiscale dynamics in supraspinal sensorimotor control in chronic ankle instability (CAI) by measuring the resting-state blood oxygen level-dependent (BOLD) complexity. Diminished BOLD complexity related to CAI were identified in networks related to the sensorimotor, visual and attention control, all are important contributors to balance control. More importantly, lower complexity is associated with poorer balance control performance within CAI only, highlighting that the regulation of standing balance in CAI may be particularly dependent upon the supraspinal control, which can be captured by this resting-state BOLD complexity metric.

Introduction

CAI is a consequence of lateral ankle sprains, is closely associated with diminished standing and walking performance and poor quality of life [1]. In addition to peripheral neuromuscular function, balance control depends, at least in part, on neural control in the cerebral cortex. The brain's cortical activity is influenced by dynamic interactions within networks across multiple temporal scales [2]. Therefore, the multiscale dynamics of the spontaneous (i.e., resting-state) fluctuations of neuronal activity are "complex". Still, such complexity of the resting-state fluctuations within the brain cortex in CAI and its associations to balance performance in this cohort has not been explicitly characterized.

Methods

Twenty-nine participants with CAI and 35 age-, sex-matched healthy controls (HC) completed the one-leg standing balance in eyes-open (EO) and eyes-closed (EC) condition and Y-balance test (YBT). The postural sway outcomes (e.g., sway speed) and YBT score was measured. We used multiscale entropy to quantify the complexity of resting-state BOLD signals and the BOLD complexity of each of seven functional cortical networks (i.e., visual, sensorimotor (SMN), ventral (VAN) and dorsal attention, frontoparietal, limbic, default mode network) was then obtained.

Results and Discussion

Compared to HC, participants in CAI presented lower BOLD complexity in SMN ($F = 14.83$, $p < 0.001$), visual network ($F = 6.39$, $p = 0.014$), and VAN ($F = 4.55$, $p = 0.037$). Within CAI only, but not in HC, lower BOLD complexity in SMN were significantly associated with higher sway speed in EO ($\beta = -0.38$, $p = 0.04$) and EC ($\beta = -0.42$, $p = 0.02$) conditions (i.e., greater postural sway), and lower YBT scores ($\beta = 0.54$, $p = 0.003$). Additionally, lower BOLD complexity of visual ($\beta = -0.47$, $p = 0.01$) and limbic network ($\beta = -0.44$, $p = 0.02$) was associated with greater sway speed in EO condition.

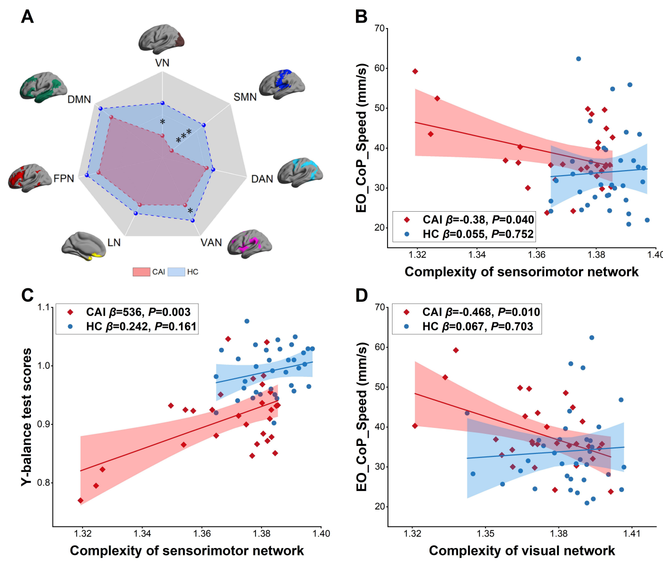

Figure 1: BOLD complexity of seven functional cortical networks and its association with balance control in CAI and HC groups.

Conclusions

This study demonstrates that CAI is associated with reduced complexity in key brain networks, including the sensorimotor, ventral attention, and visual networks. These neural alterations are closely linked to balance performance, highlighting the role of brain plasticity in mitigating functional deficits, which should be carefully considered in the management and rehabilitation of this population.

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References

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Table 1: The demographic characteristics and balance performance of the participants.

	sex	age	BMI	EO_CoP_speed, mm/s	EC_CoP_speed, mm/s	Y-balance test scores
CAI	14F/15M	20.6 ± 1.6	21.8 ± 2.6	38.2 ± 8.2	94.2 ± 13.2	0.91 ± 0.06
HC	21F/14M	21.3 ± 2.3	21.4 ± 2.6	34.0 ± 9.8	83.0 ± 29.3	0.99 ± 0.04
p-value	0.202	0.451	0.529	0.213	0.029	<0.001