Brain Structure-Function Coupling in Female Roller Derby Athletes

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UNCG Female BRAIN Project

This is your aging brain on contact & collision sports

Contact & collision sports ↑ risk of concussion
Mechanical loading of the head accelerates brain aging independent of concussion

Neuroimaging studies characterize the natural history of concussion in collegiate athletes

Neuroimaging studies of (sub)concussion do not include female athletes

The Human Brain is a Complex Network

White matter pathways can be inferred from water diffusion

Brain Structure
Brain Function

Blood Oxygen Level Dependent (BOLD) Signal is a surrogate measure of neuronal activity.

Structure-Function Coupling

Functional connectivity is only partially supported and constrained by the underlying white matter structure. Structure-function coupling may be more sensitive to effects of aging than constituent parts. 

Sex-specific trajectories

Blue indicates ↑ structure-function coupling in females
Red indicates ↑ structure-function coupling in males

Participants

Roller derby (RD) athletes 
n = 19
23-45 y.o. (M = 32.1 y.o.)
No mTBI during brain imaging

Control Participants 
n = 14
20-49 y.o. (M = 24.6 y.o.)
Not currently engaged in contact or collision sports
No mTBI in previous 3 yrs

Gu (2020). Regional structural-functional connectome coupling is inheritable and associated with age, sex and cognition in adults. bioRxiv.
Methods: Graph Signal Processing

Consider each grey ball as a Twitter user

‘Followers’ are designated by a blue line

Consider their signal (+/-) as a tweet in favor of or against

Taco Tuesday as a National Holiday

Research Questions

1. Are there patterns of structure coupling/decoupling that predict age differently between RD & controls?

2. What are the brain areas (& networks) that contribute to these patterns?

Partial Least Squares Correlation

Non-parametric: Permutations & bootstrap resampling

Like Principal Component Analysis or Canonical Correlation

Results: Latent Variable I ($p < .0001$)
Results: Latent Variable I

- Greatest coupling in visual, sensory processing, and motor areas
- Greatest decoupling in brain areas implicated in higher-order cognition

Results: Latent Variable II (p=.0006)

RD = ↑ Structural Coupling in FPN & DMN
Controls = ↑ Structural Decoupling in FPN & DMN
Increased Structure Coupling in the FPN & DMN

Structural Coupling in FPN & DMN: RD > Controls

Decreased BOLD variability related to declining cognition (n = 422, 43-89 y.o.) Millar 2020, Cerebral Cortex

Desegregation of brain networks is common in aging XXX

Structural Decoupling in FPN & DMN: RD ~ Controls (LV1)

LV1 = aCC, mOFC, SgCC, and DLPFC appear throughout the exercise literature

LV2 = iPC and IOFC exhibit faster rates of thinning in those with a history of mTBI Santhanam 2019 Brain & Behavior

Questions?

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Methods: PLS-Correlation

Structure-Function Coupling in Each Brain Area (66 x 360 Matrix)

Age (66 x 1 Vector)

Brain x Age Correlation (2 x 360 Matrix)

SVD decomposes this matrix to latent variables

Treated as a different 'Task' or a Repeated Measure Data permuted within task across groups
"Resting-State' Brain Function

Most of the brain's energy consumption is used at rest.

Spatiotemporal patterns in spontaneous fluctuations of the BOLD signal can be decomposed into networks.

These networks represent the brain's functional organization.

Finger Tapping

Rest (20% of EE)

There are s/g behavior differences

Can we find areas/circuits that are different to explain behavioral differences?

Total brain volume is different between males and females (Cohen's d = .80) and most structural/functional differences do not survive correction for TBV.

"If 'real', then they like sex differences in gene-phenotype interactions: very small, thus only revealed through studies of large samples, and explaining very little variance"