Alterations in structural and functional connectivity in female high school athletes after a competitive soccer season

A graph theoretical analysis of brain network integrity and the ameliorating effect of a neck collar device

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OBJECTIVES

- Repetitive sub-concussive impacts (SCI) experienced during contact sports may result in cumulative detrimental effects in brain networks
  - A1: Quantify network alterations in functional and structural connectivity in female high school soccer athletes after experiencing a full season of repetitive, sports-related head impacts using Magnetic Resonance Imaging (MRI)
- There are limited strategies that effectively protect female athletes from sports-related head impacts
  - A2: Evaluate the efficacy of a jugular vein compression neck collar device designed to reduce brain injury during contact sport participation

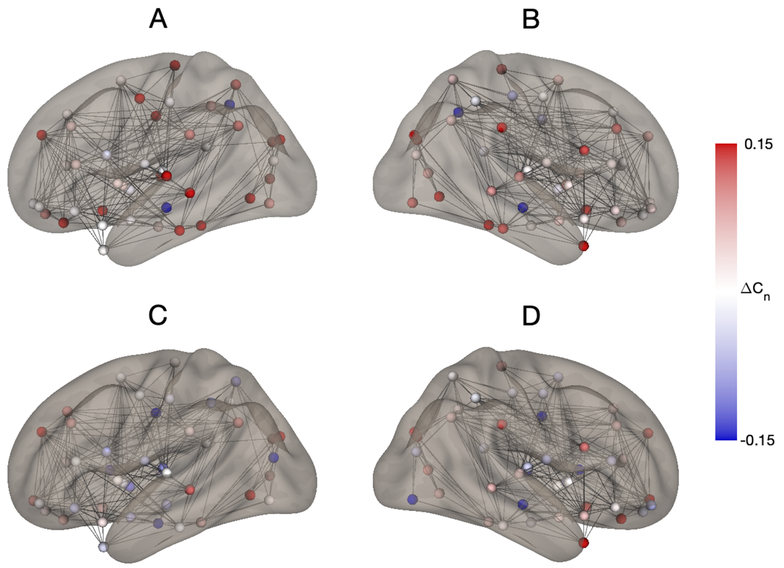


Figure 1: Lateral views of the right (A,C) and left (B,D) hemispheres showing longitudinal changes in AUC of clustering coefficient at the nodal level (C_n) for non-collar (A, B) and collar (C, D) groups. Spheres represent nodes and are positioned at the center of mass of their respective ROI. Lines are representative of network edges at a density level of 0.2; cross-hemispheric connections are hidden to improve readability.

METHODS

- 204 high school female soccer athletes, recruited from eight area high school varsity teams
  - Prospectively assigned to the collar or non-collar group based on team membership
  - Excluded for MRI contraindication (N=40), failure to complete athletic season (N=31), or diagnosis of concussion during season N=12)
- MRI data were collected at pre-season and post-season
  - Diffusion Tensor Imaging (DTI) for structural connectivity (N_{collar}=72, $N_{non\text{-}collar}$=56)
  - Resting state functional MRI (rs-fMRI) for functional connectivity (N_{collar}=70, $N_{non\text{-}collar}$=55)
  - Standard imaging data processing was used, and graph theoretical analyses were applied to quantify the structural connectivity based on DTI/tractography and the functional connectivity using rs-fMRI data. Network connectivity measures, included: global clustering coefficient (C_g), characteristic path length (L), modularity (Q), normalized clustering coefficient (λ), normalized characteristic path length (γ), and small-worldness (σ).

RESULTS

Functional Connectome: the non-collar group had significant pre- to post-season increases in C_g (4/5 network density levels), L (1/5 network density levels), and Q (2/5 network density levels). The collar group did not show any significant changes for any measure at any network density level. Between-group differences showed that changes were significantly greater in the non-collar group compared to the collar group for C_g (3/5 network density levels) and γ (1/5 network density levels)

Structural Connectome: The non-collar group had significant pre- to post-season increases in Q at 4/8 network density levels. The collar group did not show any significant changes for any measure at any network density level. Between-group differences showed that changes in Q were significantly greater in the non-collar group compared to the collar group at network densities of 0.18, 0.19, 0.21, and 0.23

DISCUSSION & CONCLUSION

- Findings from this work indicate brain network reorganization is occurring
  - JVC collar appears to mitigate this effect.
  - This study does not conclusively suggest any specific mechanism, but a reasonable supposition is that axonal injury plays a role based on other DTI studies of SCI and similarities to findings in traumatic brain injury
- Clinical impact of the current results is not clear; future work is needed to determine whether and to what extent SCI-associated altered connectivity relates to adverse neurobehavioral outcomes

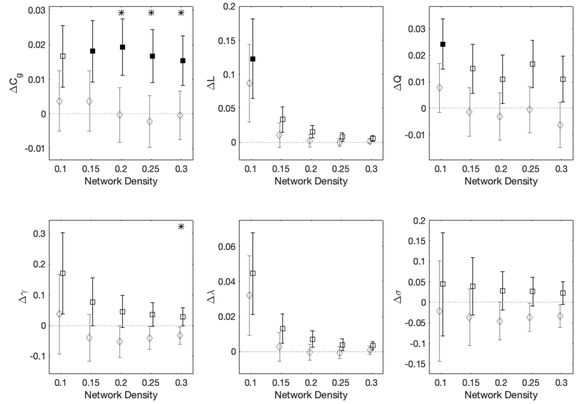
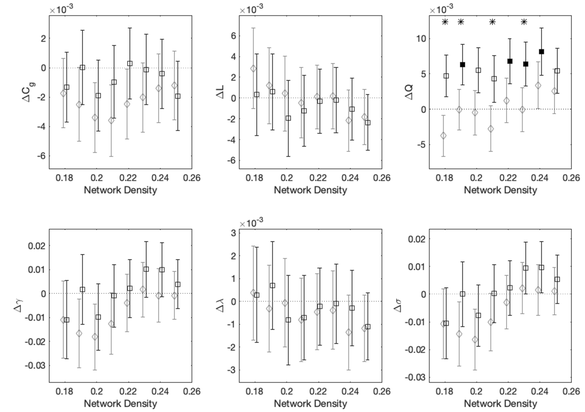


Figure 2: Mean longitudinal changes in graph measures of the functional (above) and structural (below) connectomes for collar (gray diamonds) and non-collar (black squares) groups computed at different network density levels. Error bars show standard error; filled symbols indicate significant ($p<0.05$) within-group changes while asterisks indicate significant ($p<0.05$) between-group differences. Data are offset on the x-axis by group to improve readability.



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