Changes in Structural Brain Connectivity Following Concussion

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Purpose

To examine structural connectivity changes in concussed adolescent athletes using Graph Theoretical Analysis

Hypothesis

Concussed athletes will show structural changes in WM tracts in the frontal regions associated with executive functioning

Key Findings

Concussed athletes have altered structural connectivity in regions associated with the Default Mode Network

Background

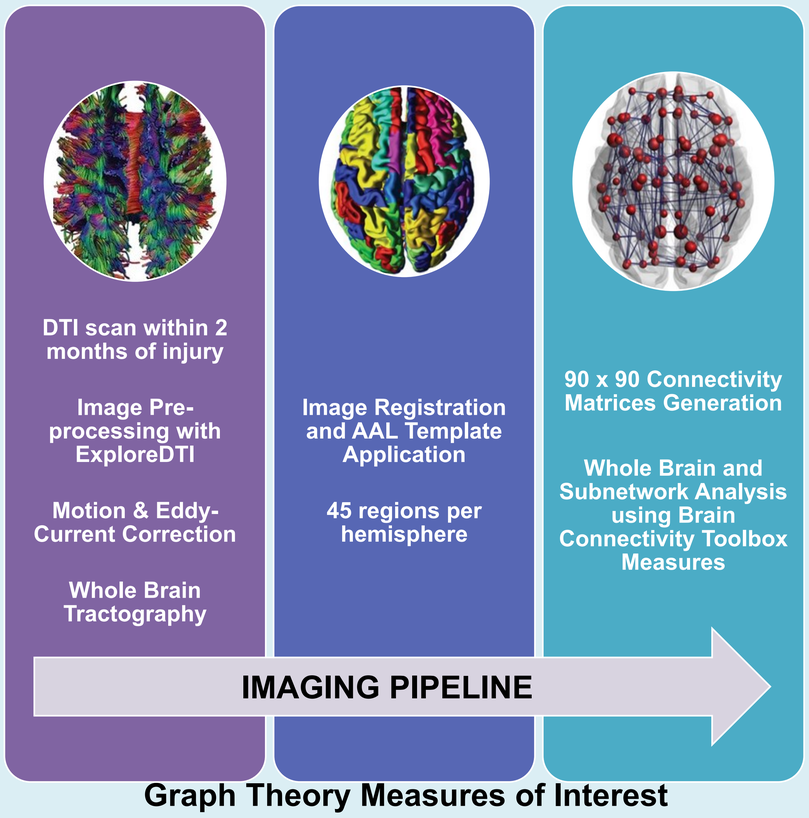
- Concussed adolescent often have long term motor and cognitive impairments which may include reaction time, movement speed, memory, and executive function.
- Concussion is known to cause traumatic axonal injury, which may result in whole brain microstructural changes affecting the integrity of white matter (WM) tracts.
- Previous fMRI findings in our lab have shown increased connectivity in the right frontal pole (executive function network) and the left frontal operculum cortex (ventral attention network) and disruptions to functional connectivity in resting state fMRI within the Default Mode Network (DMN) following sports-related concussion in adolescents.
- We sought to evaluate the corresponding structural changes in specific regions of vulnerability using Complex Network Analysis, a derivative of Graph Theory.

Methods

- Adolescent athletes who had sustained a recent (within 2 months) sports-related concussion were recruited from sports teams (hockey, rugby, baseball) in the Greater Vancouver Area.

Table 1. Patient demographics

	Concussed (n=12)	Controls (n=9)
Age (years)	15.5 ± 1.2	15.7 ± 0.9
Gender	M=10, F=2	M=8, F=1
# of Concussions	2.2 ± 1.0	n/a
Days Since Concussion	35.7 ± 15.0	n/a



Graph Theory Measures of Interest

1. **Clustering Coefficient:** likelihood of nodes in close proximity to one another
2. **Transitivity:** likelihood of sharing similar connections
3. **Local Efficiency:** ease of information flow
4. **Characteristic Path Length:** distance between nodes

Results

Default Mode Network

- AAL template regions:
  - Superior frontal gyrus - medial
  - Superior frontal gyrus - medial orbital
  - Posterior cingulate gyrus
  - Superior parietal gyrus
  - Angular gyrus
  - Precuneus
  - Middle temporal gyrus
- Concussed adolescent athletes showed significantly greater FA and decreased MD values.

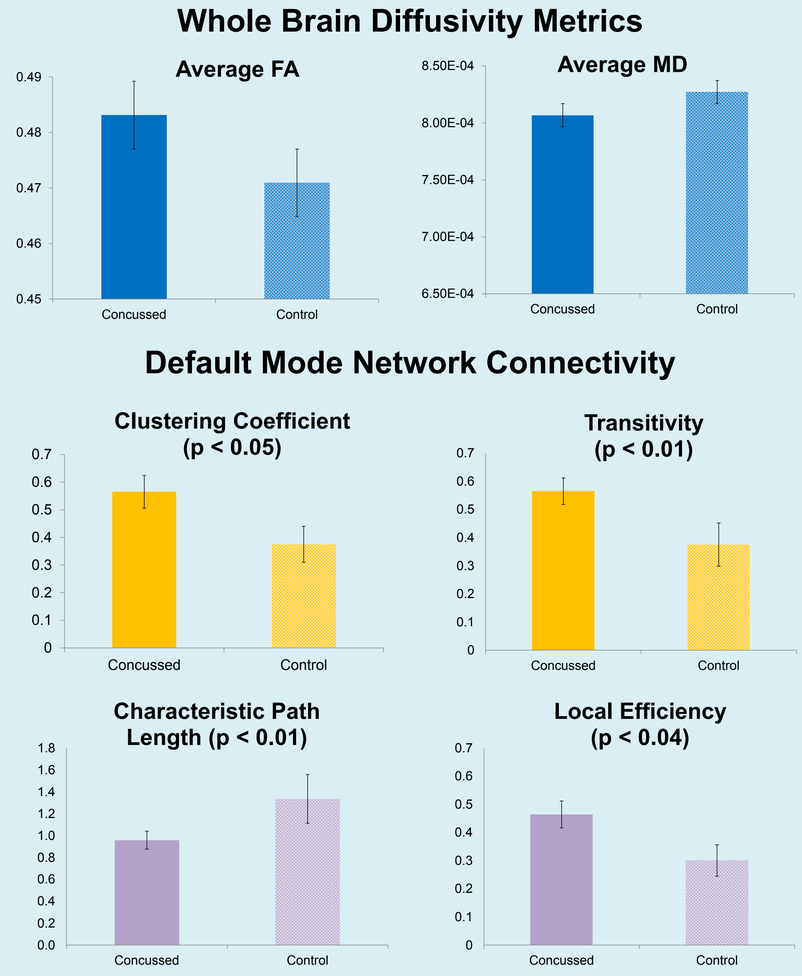


Figure 1. DMN connectivity in concussed adolescent athletes showed increases in clustering coefficient, transitivity, and local efficiency across both FA and MD metrics. A decrease in characteristic path length was also noted.

- In concussed subjects, structural alterations in connectivity were evident using the FA, MD, and number of tracts for evaluations.

Discussion

- Complex Network Analysis (CNA) may help identify areas of significant damage as well as regions where greatest recovery may occur.
- CNA suggests new pathways are concentrated areas within composite DMN neighbourhoods. These changes in the DMN suggest greater local segregation.
- This disordered state may reflect a shift towards the increased importance or establishment of 'hubs' within the network and pose increased risk for 'hub failure'.
- The literature has shown that structural changes are dynamic, and may represent recovery or compensatory mechanisms.
- Despite altered structural connectivity in the DMN, frontal, attention & executive networks were preserved.
- Future studies may use CNA to evaluate persistent structural changes in Post Concussive Syndrome.

Conclusion

The structural underpinnings of the DMN are disrupted in adolescent athletes following a concussion. These changes are still evident up to two months after injury.

Key References

1. Borich M, et al. Alterations in resting-state brain networks in concussed adolescent athletes. J Neurotrauma. 2015 Feb 15;32(4):265-71. doi: 10.1089/neu.2013.3269. Epub 2014 Nov 25.
2. Virji-Babul et al. Changes in functional brain networks following sports-related concussion. J Neurotrauma. 2014 Dec 1;31(23):1914-9. doi: 10.1089/neu.2014.3450. Epub 2014 Oct 10.
3. Virji-Babul et al. Diffusion tensor imaging of sports-related concussion. Pediatr Neurol. 2013 Jan;48(1):24-9. doi: 10.1016/j.pediatrneurol.2012.09.005.