Exercise-induced increased network connectivity in the elderly: walking improves brain efficiency

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Introduction

- Literature suggests that exercise is beneficial for cognitive function in older adults
- Aerobic fitness is associated with increased hippocampal tissue and blood volumes
- We explore network connectivity changes due to an exercise intervention
- Exercise-induced changes in hippocampal blood flow are evaluated as a potential mechanism underlying the increases in network connectivity

Scanning procedure

- Post-treatment only, completed within one month after the interventions had been completed (participants in the ET group continued to exercise after completion of ET training until they were able to complete the scanning protocol)
- 1.5T GE scanner using an 8-channel head coil (GE Med Systems, Milwaukee, WI)
- Anatomic imaging (3D BRAVO), perfusion imaging (PASL Q2TIPS, TR3000, voxel size 3.75mm x 3.75mm x 8mm), and resting fMRI (EPI, TR2000, voxel size 3.75mm x 3.75mm x 5mm)

Network pipeline

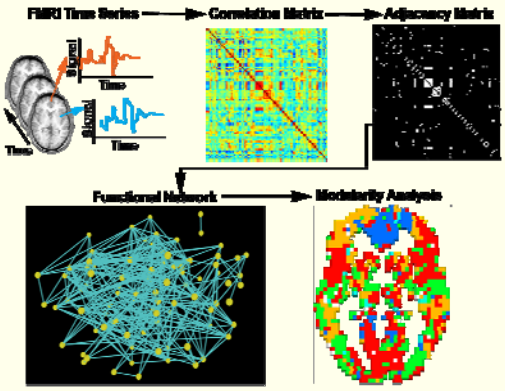


Figure 1. Processing stream for whole brain network analysis.

CBF Measurements

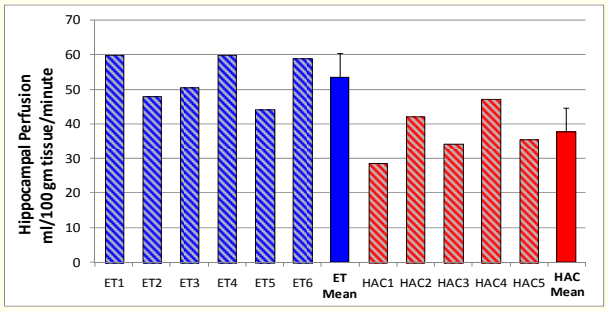


Figure 4. Hippocampal perfusion (CBF). The hatched bars are the individuals in each group, and the mean and SD for each group are the solid bars. The individuals in the ET group consistently showed elevated hippocampal perfusion compared with the HAC group.

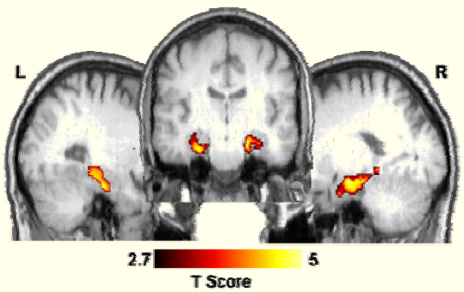


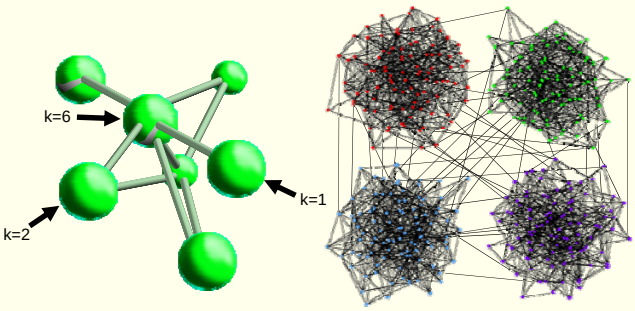
Figure 5. Statistical parametric map showing significant CBF differences between ET and HAC in the hippocampus.

Study Population

- Volunteer subgroup of sedentary older adults from larger study (SHARP-P)
- 4 month intervention
- Randomized to exercise training (ET) group (n=6) or healthy aging education control (HAC) group (n=5)
- Age_{ET} =77.6 5, Age_{HAC} =74.0 2.5

Network metrics

- Degree (k) measures the connectedness of a node
- Hubs are the most connected nodes in a network. These nodes are critical for network stability and information flow.
- Modularity (Newman 2004) identifies highly interconnected neighborhoods within an entire network. The example in the figure below shows a network with 4 distinct communities.



Figures 2 and 3. Degree and Network Modularity

Network Measurements

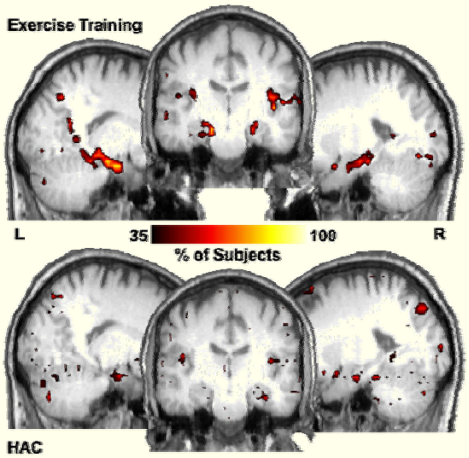


Figure 6. Hub maps show regions that have high number of connections (top 15% of all voxels) that are common across subjects in each population. The hippocampus is among the major hubs in the ET group.

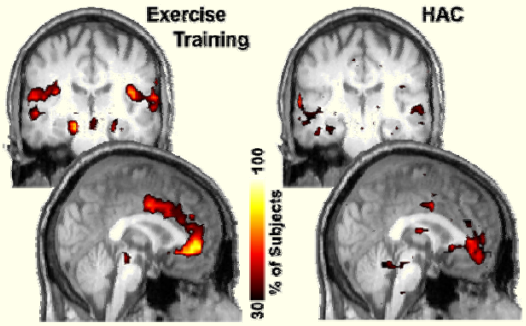


Figure 7. Consistency of community structure of the hippocampus across subjects. In the ET group the hippocampus is most notably interconnected with the anterior cingulate gyrus. In the HAC, the anterior cingulate only has minor connections with the hippocampus.

Conclusions

- Network science can be used to better understand brain function.
- Exercise may lead to higher perfusion in the hippocampus.
- The ET group showed greater connectivity within the hippocampus and ACC, and these regions were found to be within the same functional module or community.
- The exercise-associated network changes demonstrated here may be the underlying neurophysiological causes of the previously reported blood volume and brain volume changes seen with exercise in healthy older adults.
- The changes in connectivity could drive a greater demand for blood resulting in greater blood flow to the hippocampus, supporting increased neurogenesis.

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