Effect of Aerobic Exercise on Spatial Navigation and Brain Structure as Modulated by Sex and Intracranial Volume

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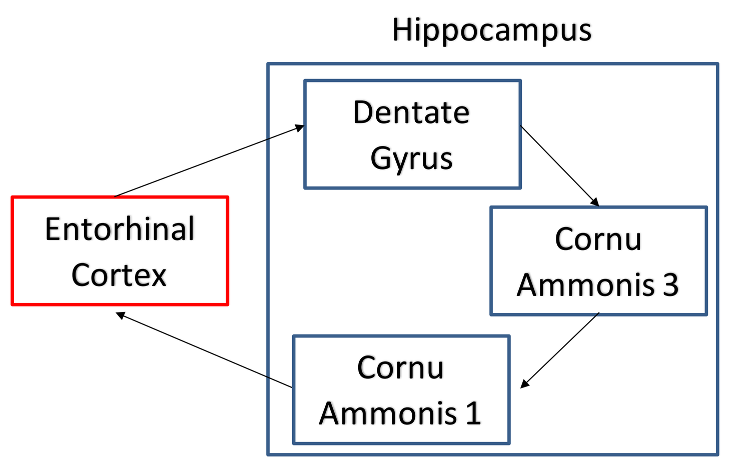
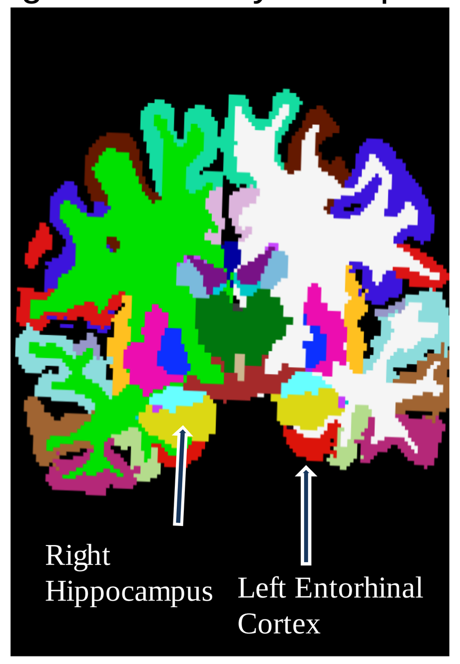
Abstract

Generally, aerobic exercise has been shown to have many cognitive benefits in regards to brain structure and brain function. Structures in the medial temporal lobe including the entorhinal cortex and hippocampus are known to be implicated in tasks of spatial learning and memory. Using secondary data recently obtained from Boston University, this research project seeks to identify an effect of aerobic exercise on morphological measures of medial temporal lobes, specifically the entorhinal cortex and hippocampus and their relationship with spatial navigation. Young healthy sedentary adults were assigned to either resistance training group or an aerobic training group for a 12-week period. Intracranial volume and sex were used as covariates. The effect of aerobic exercise versus resistance training will be analyzed using a MANCOVA, with exercise group as the independent variable, intracranial volume and sex as covariates and four dependent variables: left and right entorhinal cortex and hippocampus. Two multiple regression equations will be used to determine if structural measures can predict spatial navigation with intracranial volume and sex as covariates. This research points to the neuroprotective effects of aerobic exercise even in younger adults.

Background & Hypotheses

- Structures in the medial temporal lobe (MTL) memory system show experience-dependent neuroplasticity. Within the MTL, this plasticity has been observed in the hippocampus (HC) in both humans and animal models.
- A rodent model study found that voluntary wheel running induces neuroplasticity in the entorhinal cortex (EC) and HC.
- The work of Erikson et al. details the relationship between cardiovascular fitness and structures of the MTL, particularly the HC, in a cohort of older adults who were assigned to either a stretching group or an aerobic fitness group.
- A previous volumetric analysis in our lab showed that right EC volume, but not HC volume, was positively correlated with cardiovascular fitness (VO_2 max) in healthy young adults.
- HC and EC are critical for spatial learning and memory and spatial navigation.





Hypotheses

- **Research Question 1**: Aerobic training exercise will have an effect on medial temporal lobe structures.
- **Research Question 2**: Medial temporal lobe structures recruited in tasks of spatial navigation will be related to tasks of spatial navigation.

Materials & Methods

Design

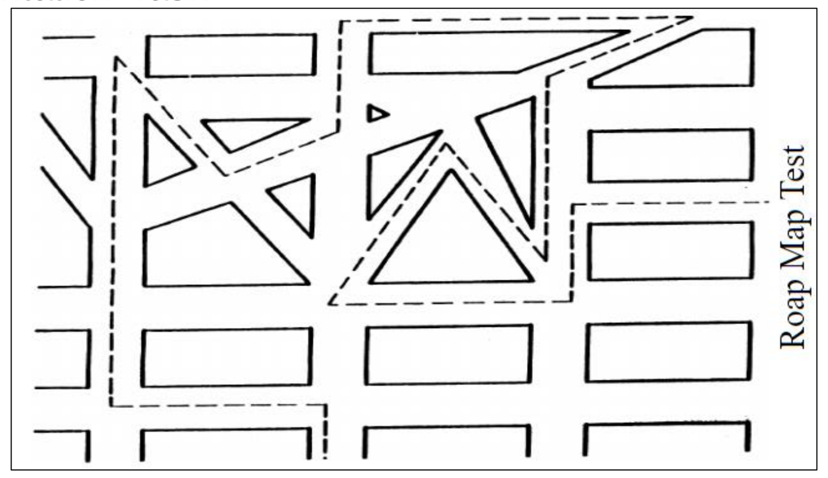
- **RQ 1**: Experimental Study - MANOVA
- Independent variables:
  - Exercise group and time
- Dependent variables:
  - Morphometric measures – Entorhinal Cortex
- Covariates:
  - Sex and intracranial volume
- **RQ 2**: Correlational Study – Multiple Regression
- Predictor variables:
  - Left and right EC thickness
- Outcome variables:
  - Performance on tasks of spatial cognition
- Covariates:
  - Sex and intracranial volume

Participants

- Cross-sectional healthy adult cohort (N = 29, M_{age} = 25.4, SD_{age} = 3.3)
- 76% female; 62% assigned to Resistance Training Group

Instruments

- 3T Phillips Achieva MRI Scanner at BUMC
- Freesurfer analysis of high-resolution T1-weighted images
- Road Map Test and Perspective Taking/Spatial Orientation Task

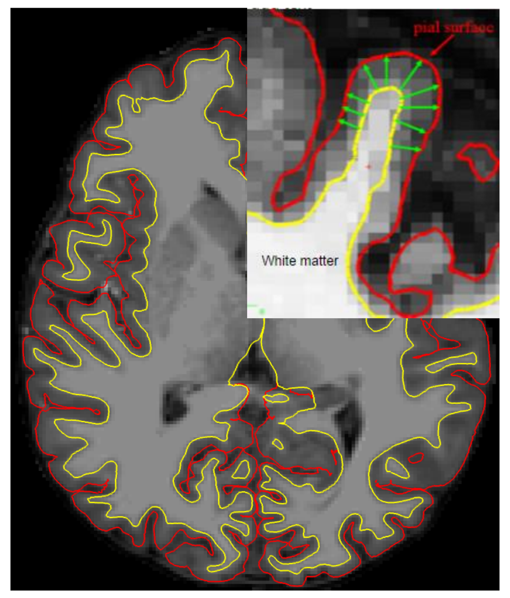


Procedure

- Participants were recruited from the greater Boston area and underwent:
- Assessment of VO_2 max as measure of cardiovascular thickness
- Whole-brain T1-weighted structural scan (Voxel size: 1 mm^3)
- Tests of spatial cognition following neuroimaging
- Randomly assigned to:
  - Aerobic Training Group: walking
  - Resistance Training Group: strength training

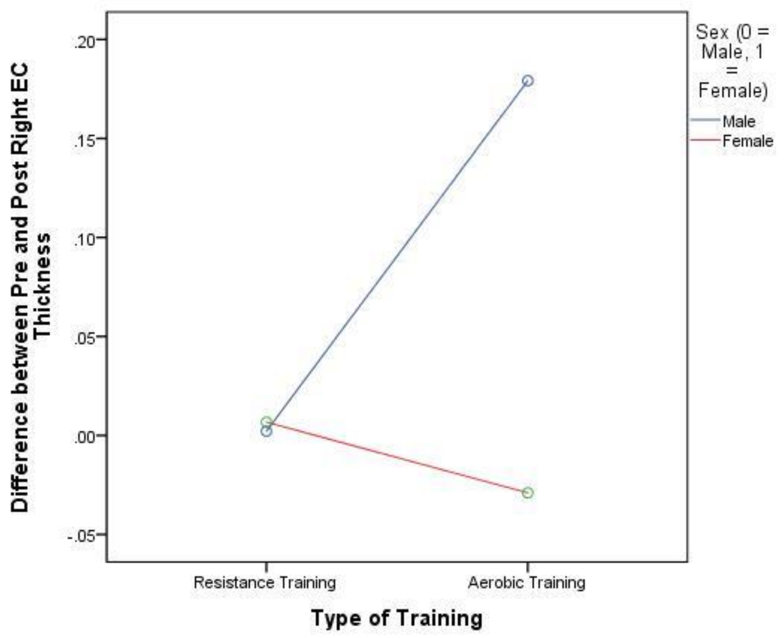
MRI Analysis

Freesurfer (5.3.0) MRI analytic software was used to calculate cortical thickness and cortical and subcortical volume.

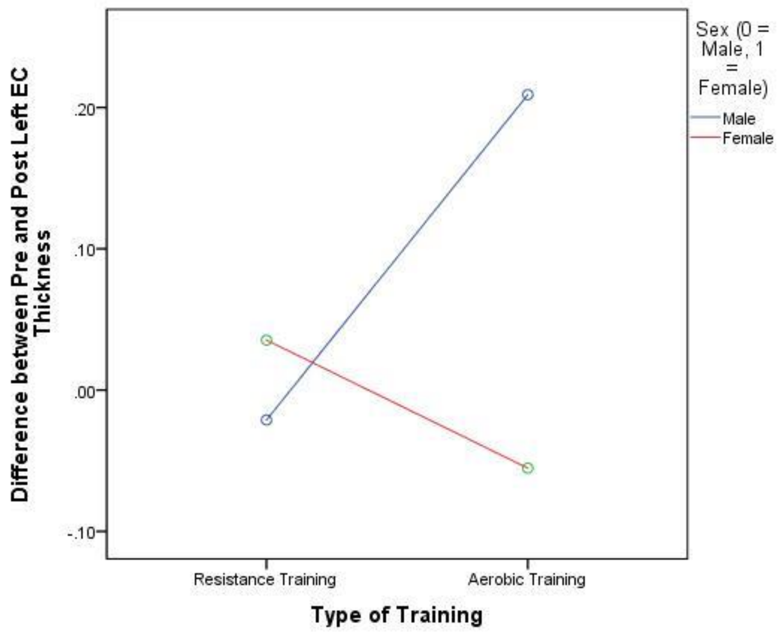


Results

RQ1: Males had a small but significantly greater thickness growth for both left and right entorhinal cortical thickness (F(1,28) = 4.532, p = .016 , η^2 = .159; F(1,28) = 6.718, p = .044, η^2 = .219). There were also significant interactions between sex and group. Both sexes had the same growth during resistance training but males showed a greater increase in cortical thickness growth after aerobic training, but females on average declined.



A sex by group interaction for right entorhinal cortical thickness was found (F(1,28) = 4.908, p = 0.36, η^2 = .170)



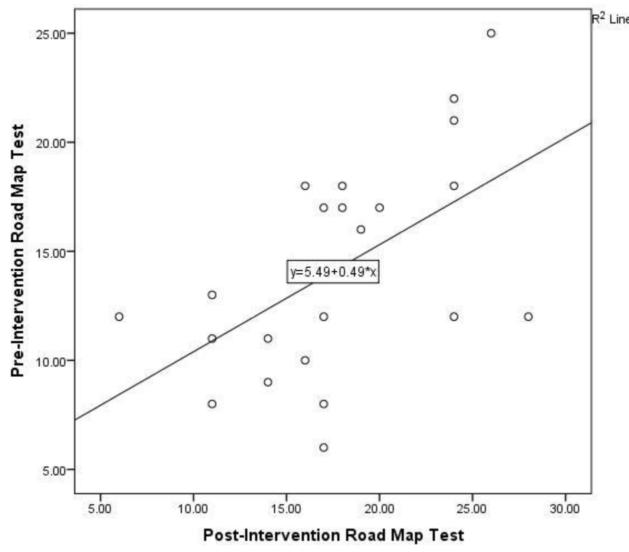
A sex by group interaction for left entorhinal cortical thickness was found (F(1,28) = 15.903, p = .001, η^2 = .399)

RQ2: The multiple regression model was significant with a medium strength(F(3, 19) = 4.08, p = .023, R^2 = .291). The only significant single predictor was Pre-Intervention Road Map Test Score.

Predicted Post-Road Map Test Score = 11.305 + .488(Pre-Road Map Test Score) + 20.247(Left EC Thickness Growth) + 14.122(Right EC Thickness Growth)

Table 1: Correlation coefficient (p < 0.05, ** p < .01)*

	Post RMT	Pre RMT	Left EC Thickness Growth
Pre RMT	**.546****		
Left EC Thickness Growth	.333	.152	
Right EC Thickness Growth	**.395***	.403*	.175



Summary & Conclusion

- Although we had significant findings, they were not as predicted. We failed to reject the null hypothesis that aerobic exercise would produce greater growth in EC thickness than resistance training group.
- The interaction of group by sex on entorhinal cortical thickness was unexpected and deserves further research.
- For the second research question the null hypothesis was rejected for the Road Map Test only. Almost 1/3 of the variance in the post-intervention Road Map Test was predicted by prior performance as well as morphometric bilateral measures of the entorhinal cortex.
- Growth thickness did not predict post-intervention Perspective Taking Spatial Orientation scores.

Limitations

- Poor generalizability due to small sample.
- Majority of the participants were female.
- Although the participants claimed to be sedentary some had high pre-intervention fitness levels.

Future Work

- Compare cognitive and brain changes after a 12-week exercise intervention to baseline in cohort of healthy, sedentary older adults.
- Compare healthy young adults and healthy older adults undergoing the same 12-week exercise training program.

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