Caleb Weinman

Nyack High School

The Effects of Physical Activity and Age on White Matter Integrity

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Introduction

Since 1970, The United States population has grown about 1% annually to almost 320 million people (census.gov.) With the growing population there is also a longer average life span of 78 years (cdc.gov.) More people are living into their eighties and beyond. However, a problem arises as people begin to lose parts of brain function, namely their cognition. The average age of mild cognitive impairment is 65 years (www.ncbi.nlm.nih.gov.) Cognition is a massive part of our day-to-day lives, especially for elderly people (Ball, et al, 2002.) It is a part of everything from paying taxes to knowing where your house is. Cognitive decline is a growing problem, because as people develop it and live longer, they have it for longer, unable to live full, healthy lives. This also affects the people around them as the best care for someone with cognitive decline is a caregiver.

Much research has been done to look into halting cognitive decline, but it appears that it is an unstoppable natural process: medicines and other treatments are unable to completely halt it (Willis et al, 2006). However, there is promise in the field of cognitive research: exercise. Exercise has been shown to slow down the effects of cognitive decline significantly (Erikson, et al., 2015). Those who exercise more are less likely to develop dementias and also slow the natural deterioration of the brain (Erickson et al, 2015). We know little about exercise and its effects on the brain and its processes, so in this paper, we will explore the connection between the two.

The structure of the brain is very important in cognitive decline. Less brain matter usually equates to lesser cognitive performance. Thus, the loss of brain matter, and possible recovery of it (through brain plasticity) is a major part of the cognitive dilemma. Exercise training has been shown to boost cerebral blood flow, help connectivity in the hippocampus (Burdette, 2010.) In this study, exercise is seen to boost blood flow around the hippocampus, which is important for long term memory. Increasing blood flow and neuroconnectivity will help boost the cognitive scores of anyone.

A current problem with the study of cognitive decline is the lack of knowledge in terms of brain structure. One key part that has been recently shown to have an effect on cognition is white matter (Gomez-Beldarrain, 2016.) Gomez-Beldarrain has published many articles on cognition and dementia, including this article. Once thought to have no effect on cognition, white matter could play a huge part in brain performance. A few articles have addressed this problem there is a major lack of general knowledge. To quote Bendlin, the author of multiple journals on the topic of white matter and aging: “the relationship between white matter features and cognitive function in aging have only recently received attention and remain incompletely understood.” The lack of knowledge in the topic of white matter and cognition is a huge problem, one that this study will help address.

With physical change in the brain comes cognitive change . These changes, once thought to be permanent, are actually reversible. This is known as brain plasticity. The brain, when exposed to exercise, becomes more efficient, plastic, and adaptive (Colcombe, 2004.) In this study, Colcombe et al. tested in vivo brains to better understand plasticity. A brain's plasticity is one of its most important characteristics when facing cognitive decline, thus anything that can help this function helps the brain as a whole (Fotuhi et al, 2012.) In this study, Fotuhi et al. looked at the brain as a whole and how it is affected by changes. Other studies have gone on to show that exercise has prowess in reducing the risks of different diseases. Podewils, in 2005, stated that people who exercise are less likely to get dementia than those who are more sedentary. They also had less Apolipoprotein E, a key part of Alzheimer's Disease.

In "Cardiorespiratory fitness is associated with white matter integrity in aging" by Dr. Scott M. Hayes, et al., a similar overall result was obtained: for the most part, higher cardiovascular fitness levels were associated with superior white matter integrity. However, unlike the results in this study, Hayes's team encountered regions that were not associated by his definitions of correlation. This discrepancy could be a result of differences in experimental design. It does highlight the fact that there are differences between this experiment and others, namely the difference in specific results.

Cognition is very important in order to live a healthy life. This help comes in the form of exercise. Exercise slows the progression of cognitive decline and reduces risk of dementia. However, the relationship between different parts of the brain, exercise, and cognition is yet to be fully identified. Scientists are not fully sure of how exercise helps the mind. Not all of the mechanisms have been looked into. White matter, shown to have an effect on cognitive performance, could have an even greater effect than ever realized, thus it should be looked at in detail. What research lacks is information on specific brain elements and the effects exercise has on them. This study looked into the specific effects of exercise on white matter integrity in the aging brain. Adding to the growing research on this subject will allow scientists to move closer to finding a solution to the cognitive conundrum.

Methodology

Diffusion tensor imaging and $V0_2$max data was taken from a larger study based at Columbia University Medical Center. The study has been going on for multiple years and still continues. Participants were volunteers. There is a large mix of ages, with data ranging from twenty-year-olds to seventy-year-olds and above. Race and gender will not be taken into consideration when drawing conclusions. All data taken is anonymous.

Subjects are split into different groups based on on age (G2 = twenty-year-olds, etc.) Each corresponding DTI set is attached to both the subject ID and their group. Voxel-based analyses of each image is done using the software Freesurfer. This information and the images are then connected with the corresponding $V0_2$max values for a statistical analysis. Also, the creation of skeletonised diffusion tensor images using the software TBSS will be done for future research.

The DTI and $V0_2$ max data was assessed by Openmx. No interventions of any type will be given to participants after their data is taken within this study, as this is baseline assessment.

The effects of age and amount of physical activity on the integrity of white matter within the living human brain is assessed at a non-intervention level.

Results

ClusterIndex	Voxels	MAX	MAX X (mm)	MAX Y (mm)	MAX Z (mm)
6	4436	0.992	-10	41	-17
5	1758	0.991	-11	-12	-14
4	768	0.991	17	-40	7
3	603	0.991	10	-8	-12
2	530	0.991	-11	-40	21
1	56	0.99	-25	-31	-3

Cluster #6
Anterior thalamic radiation L:0.546889
Anterior thalamic radiation R:0.564472
Cingulum (cingulate gyrus) L:1.16975
Cingulum (cingulate gyrus) R:0.0750676
Forceps minor:25.1803
Inferior fronto-occipital fasciculus L:0.944995
Inferior fronto-occipital fasciculus R:0.711452
Superior longitudinal fasciculus L:0.00608656
Superior longitudinal fasciculus R:0.00135257
Uncinate fasciculus L:0.831605
Uncinate fasciculus R:0.701984
Superior longitudinal fasciculus (temporal part) L:0.0365194
Superior longitudinal fasciculus (temporal part) R:0.00135257

Cluster #5 Anterior thalamic radiation L:16.5068 Corticospinal tract L:2.59841 Forceps minor:0.0682594 Inferior fronto-occipital fasciculus L:4.33675 Inferior longitudinal fasciculus L:0.225825 Superior longitudinal fasciculus L:0.987486 Uncinate fasciculus L:1.61889 Superior longitudinal fasciculus (temporal part) L:0.140501 Superior longitudinal fasciculus (temporal part) R:0.00511945
Cluster #4 Anterior thalamic radiation L:0.136719 Anterior thalamic radiation R:0.322917 Cingulum (cingulate gyrus) R:0.0390625 Cingulum (hippocampus) R:0.39974 Forceps major:4.50391 Inferior fronto-occipital fasciculus R:0.311198 Inferior longitudinal fasciculus R:0.165365 Superior longitudinal fasciculus R:0.00390625 Superior longitudinal fasciculus (temporal part) R:0.015625
Cluster #3 Anterior thalamic radiation R:18.5556 Corticospinal tract L:0.109453 Corticospinal tract R:5.16252 Cingulum (cingulate gyrus) R:0.0248756 Forceps minor:0.228856 Inferior fronto-occipital fasciculus R:0.00497512 Superior longitudinal fasciculus R:0.0199005
Cluster #2 Anterior thalamic radiation L:0.3 Anterior thalamic radiation R:0.164151 Cingulum (cingulate gyrus) L:0.209434 Forceps major:5.30189 Superior longitudinal fasciculus L:0.0169811

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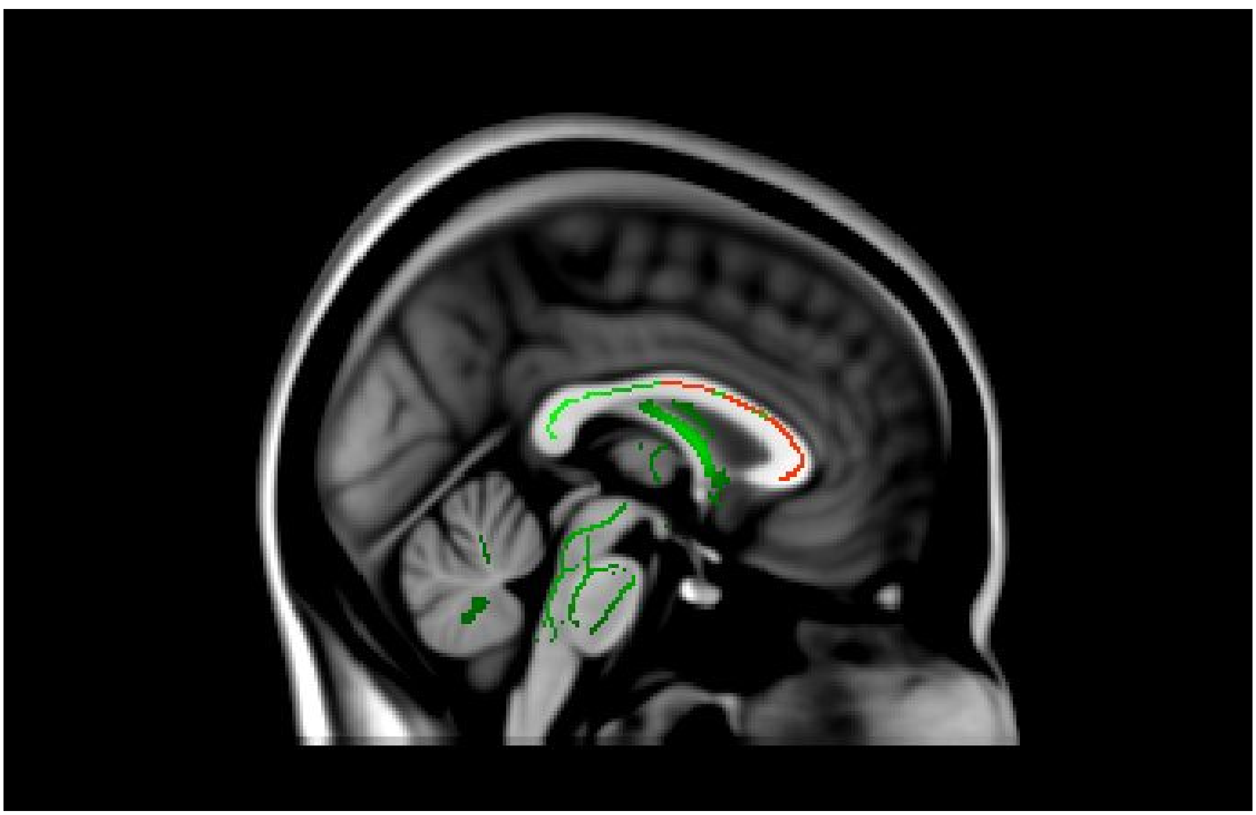
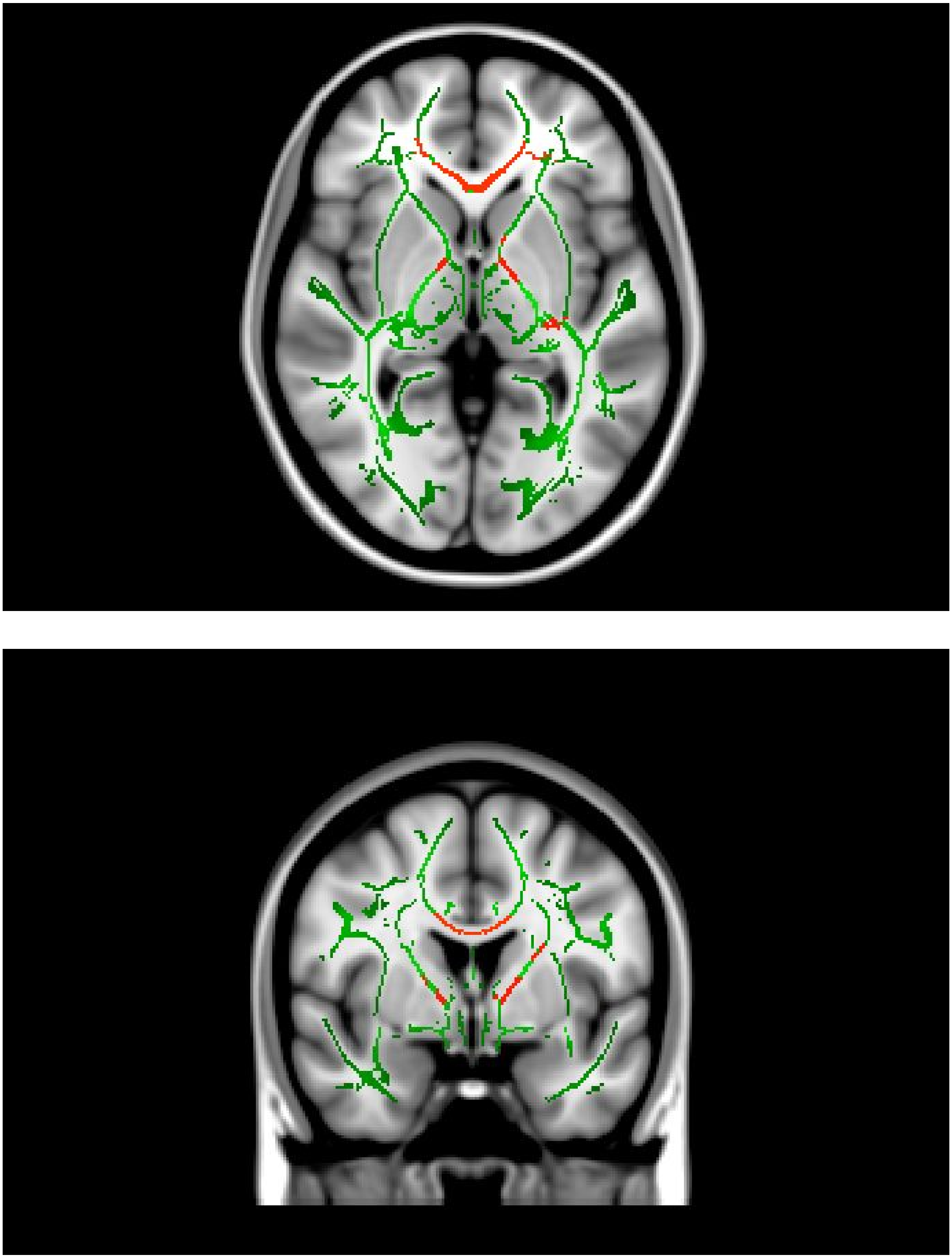
Anterior thalamic radiation L:0.3
Anterior thalamic radiation R:0.164151
Cingulum (cingulate gyrus) L:0.209434
Forceps major:5.30189
Superior longitudinal fasciculus L:0.0169811

Here are X,Y, and Z views of the mean images produced. A green colour represents a slight correlation between exercise and WMI, and a red colour represents a heavier correlation.





What we see in these results is a consistent correlation between superior Vo2max values and white matter integrity. MAX values closer to 1 indicate a closer correlation. Overall, correlations were convincingly high.

Also contained in the results are particularly notable correlation values for the different clusters (groups that the analysis program put certain brains into based on characteristics.) Some parts of the brain in certain clusters had a much higher correlation than others. The analysis program noted differences in the right and left sides.

The final piece of the results comes in the form of "average" images. These images were comprised from all of the analyzed DTI images. This created a mean image of the X,Y, and Z views of the slices. Green streaks indicate where Vo2max and white matter integrity were correlated slightly, the red streaks indicate a higher correlation value.

Discussion/Conclusion

Due to the fact that the age analysis did not come out with any correlations, the project as a whole has to be a assessed. Age should have had an effect on the overall integrity if not in specific regions.

In order to investigate the effects of fitness exercise on cerebral white matter integrity in older adults, Heo et al. examined a one-year long aerobic training program and determined longitudinal differences in FA values in 70 older adults. They found that improved aerobic fitness is associated with superior white matter integrity specifically in the prefrontal and parietal brain regions. In our paper, while we observed no different specific region effects. This is interesting, as many papers that do this see changes in specific brain regions.

This study had different results than others around it. First, the correlation coefficient of WMI to exercise was around 0.991, making the connection much more significant than in other studies. Secondly, all WM tracts were found to have some sort of correlation to exercise, whilst in other studies there are some choice tracts that show no connection.

Gender was not taken into consideration for this project. In many studies, gender differences are present. The prefrontal cortex seems to have the most amount of differences. Overall cranial volumes were present in other studies. Sex might have been an important variable to take into account.

Since individual plasticity is different between subjects, splitting the participants by decade may have skewed the data. A difference of one year makes no significant difference (for example: a 29 year old in G2 is not very different than a 30 year old in G3).

In conclusion, age has no significance when higher V02 max levels are present. Higher V02max levels are correlated with superior white matter integrity across all age levels.

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