Sex-based Comparison of Subcortical Regions in the Human Brain

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Abstract

The purpose of this project is to identify, through digitally rendered MR images of the human brain, significant differences in the volume of individual subcortical regions between female and male brains. Differences in region volume separate from overall volume or brain size demonstrates the need for future sex-specific models and templates of the brain. These findings have implications for industry standard brain modeling and their applications. The significant differences identified through this analysis indicate the many implications the relative size of subregions may have on future biomechanical tests or designs.

Background

The subcortical regions of the brain are located within the cerebral cortex, and contain centers involved in both cognitive and emotional function. Sex based differences in the volumes of these regions have been overlooked in the past and can lead to disparities in the outcomes of traumatic brain injuries.

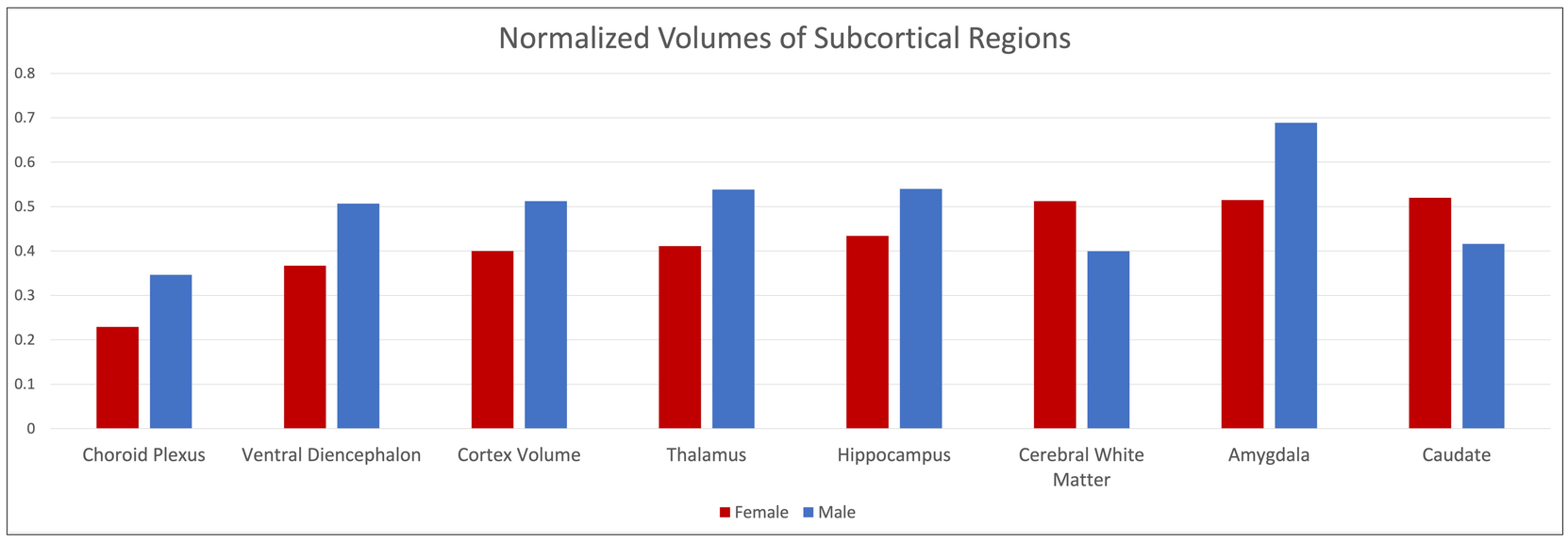
Methodology

Data included in this study is from 94 healthy subjects between the ages of 18 and 22 (47 male and 47 female.)

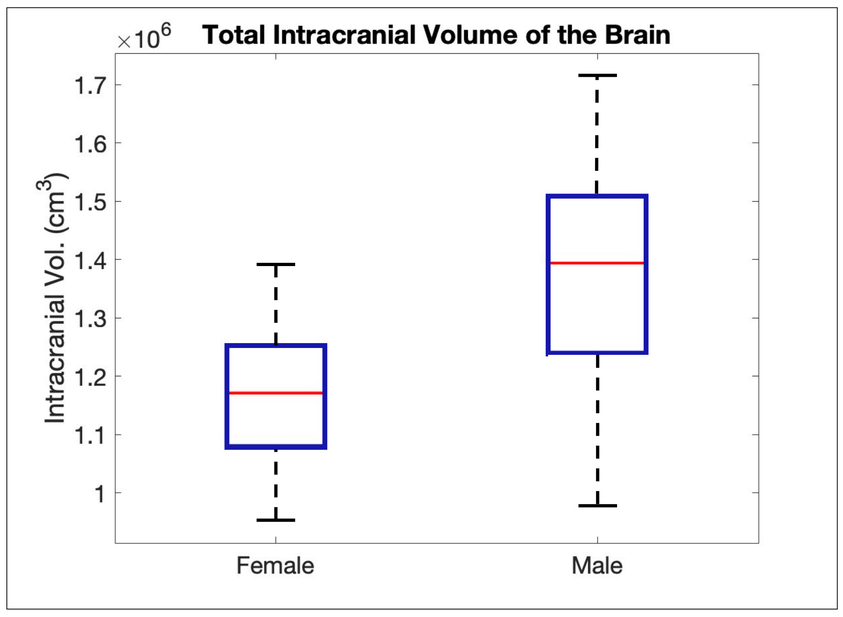
Information about the subcortical region volumes was obtained using FreeSurfer Automatic Segmentation, which automatically identifies 65 regions and other areas of interest. Select regions or classifications were omitted from these 65 due to relevance to future studies, as well as the analysis at hand.

Region data for each individual brain was exported and organized by sex on MATLAB. For 19 regions, data exists for both right and left hemisphere regions. These data were combined and subsequently normalized to understand the overall volume of the various regions. Basic data normalization to account for an overall difference in size between the sexes was performed, and paired t-tests determined regions with statistically significant difference, as compared to a normalized dataset

Figures



Results



The figure above shows the drastically different spreads that subcortical regions of the brain can have between the sexes. The intracranial volume, displayed above, represents the total brain volume including the ventricles and cerebral spinal fluid as well, both of which are known to be a measurement with significant disparity between males and females. The median ICV volumes are seen to differ by around 222400 cm3, and though the minimum values are nearly identical, the range and IQR for the male subjects is much greater than the female.

The figure to the left indicates 8 of the statistically significant regions. Of these 8, only 2, the caudate, and the cerebral white matter, are seen to be greater in females than in males. The data to the left has been normalized within each grouping to account for the overall average volumes within each sex . White matter findings are consistent with preexisting literature supporting a greater mass of white matter in females than in males.

Discussion

The above results and relevant analysis lead to a few significant conclusions. Previous research has demonstrated well-documented sex-based differences in overall brain volume

First, this research focused specifically on subcortical regions, to back up and enhance with previous findings. Two areas of the brain, white matter and caudate, were seen to be significantly greater in females. This may provide supporting evidence for the distribution of white and gray matter in males and females--suggesting gray matter, which is not included in FreeSurfer's automatic segmentation, would appear significant with an inverse trend. The caudate is an internal brain structure, involved in cognition and memory, and is highlighted against the amygdala, which has also previously been found to have a greater volume in males than in females.

Volume differences in these regions could change the metrics for clinical work related to traumatic brain injury, from diagnostic methods to prognosis estimates and treatments.

Conclusion

The statistical differences between male and female subcortical regions indicate the need for attention to be paid regarding sex-specific differences, and for these differences to be appropriately incorporated into future templates and models. An increase in the subject size, broadening of the age continuum, and consideration of other physiological factors should be accounted for as this work continues.

Future work will be completed with the same methodology on subjects over the age of 80, to examine how age may act as a factor in volume differences.

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