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CORTICAL THICKNESS AND CORTICAL VOLUME MEASUREMENTS OF THE CINGULATE GYRUS IN SUDANESE YOUNG ADULT USING BRAINSUITE

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Abstract

Cingulate gyrus is a part of the limbic lobe. Anatomically and functionally, the cingulate gyrus is subdivided into four areas: the anterior cingulate cortex, midcingulate cortex, posterior cingulate gyrus, and the retrosplenial part. The variety of autonomic functions, such as regulating heart rate and blood pressure and having a major role in cognitive function, also has a function in emotional cognition. The present study aims to measure cortical thickness and cortical volume in apparently healthy young adult Sudanese.

A cross-sectional study was conducted among randomly selected residents of Sudan aged 20 to 40 years (30 males, 30 females) with normal magnetic resonance images of the brain. All study participants underwent magnetic resonance imaging, and measurements of the cingulate gyrus were assessed using BrainSuite software. Analysis was conducted using Statistical Package for the Social Sciences, version 28, and p-values less than 0.05 were considered significant.

For the right cingulate gyrus, the mean cortical thickness and cortical volume were 4.0 mm and 20.9 cm^3, respectively. The mean cortical thickness and volume in the left cingulate gyrus were 4.0 mm and 22.3 cm^3, respectively. The cortical volume of the left cingulate gyrus was statistically significantly larger than the right ($p=0.04$). The right and left cingulate gyrus cortical volumes of males were significantly larger than that of females ($p=0.001$), while the cortical thickness showed an insignificant difference ($p=0.3$). The cortical volume of the cingulate gyrus was not statistically related to age or body mass index.

The left cingulate gyrus's total volume was larger than that of the right cingulate gyrus. There was not significant difference in cortical thickness. Age and body mass index do not affect cortical volume and thickness.

Keywords: *cortical thickness, cortical volume, cingulate gyrus, MRI, BrainSuite.*

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INTRODUCTION

The cingulate gyrus is a part of the limbic system with the subcallosal, parahippocampal, dentate, uncus, hippocampus proper, subiculum, amygdaloid body, septal area, some nuclei of the thalamus, and hypothalamus. The cingulate gyrus lies on the medial aspect of the cerebral hemisphere and is an arch-shaped convolution situated just above the corpus callosum [*Dumas E et al., 2012; Patestas M, Gartner L, 2016*].

Anatomically and functionally, the cingulate gurus are subdivided into four areas. The anterior cingulate cortex is the frontal part of the cingulate cortex, which plays a role in a wide variety of autonomic functions, such as regulating heart rate and blood pressure and is vital to cognitive functions, such as reward anticipation, decision-making, empathy, and emotion. Neuroscientists indicate that the dorsal anterior cingulate cortex is primarily related to rational cognition, while the ventral is more related to emotional cognition. Mid cingulate cortex appears to be involved in cognitive control and decision-making. The posterior cingulate gyrus act on a topo-kinetic memory circuit with a primary function of visual-spatial orientation. Lastly, the retrosplenial cortices are responsible for spatial navigation, autobiographical memory retrieval, and imagination [*DK J et al., 2013; Patestas M, Gartner L,2016*].

In the literature, the volume of the cingulate gyrus is affected by the normal aging process, gender, and diseases (schizophrenia and Alzheimer's disease) [*Choi J et al., 2005; Calabrese D et al., 2008; Bailly M et al., 2015*]. Volumetric measurements of brain structures and cingulate gyrus volume existed in the literature previously, but until now, there were no data about cingulate gyrus volume in the Sudanese population. Therefore, this study provides a volumetric measurement of the cingulate gyrus in a healthy Sudanese young adult population and provides a starting point for new research in this field [*Joshi A et al., 2012a; Taha K et al., 2022*].

This study aimed to determine the cingulate gyrus volume among healthy young adult Sudanese by using magnetic resonance imaging (MRI), which provides excellent soft tissue contrast and anatomical details. Furthermore, BrainSuite is a collection of software tools that enable automatic segmentation of the brain and its gyri.

MATERIALS AND METHODS

Study population: MR images of 59 participants from different Sudanese tribes were randomly selected. All participants were right-handed, and their ages ranged from 20-40 years (mean age 37.4±6.7 years). Their mean body mass index was 24.2 ± 4.5 kg/m^2. The participants were healthy young adults without possible neurological, psychological, or congenital malformations.

Variables: Cortical volume and cortical thickness of the cingulate gyrus; age, sex, and body mass index.

Magnetic resonance image: Structural MRI was done in the radiology department, Doctor's Clinic. Magnetic resonance imaging was performed on 1.5 Tesla Philips scanners, Version: 3.2.1 (USA). T1-weighted images were obtained using three-dimensional acquisition by Magnetization Prepared Rapid Acquisition Gradient Echo (MP-RAGE) which produces clear grey/white matter contrast in the coronal section. Acquisition time is 5 *minutes* and 18 *seconds*, Slice distance is 1.0 *mm*, the field of view is 250 read,192 *mm* phase, TR =1657*ms*, TE=2.95*ms*, bandwidth 180*Hz/pixel*, flip angle 15°, ECHO spacing =7.5*ms*, phase resolution =100%, and slice resolution =50.

Magnetic resonance images analysis: MR images T1 weighted of the brain were exported, and further measurements of the cingulate gyrus were done using BrainSuite program version 16a1, which is an automatic software designed program to read and analyse the MR images of the brain, and that works in the following steps. Firstly, the

To overcome it is possible, due to the uniting the knowledge and will of all doctors in the world

brain is isolated from the surrounding tissue, and a 3D model is formulated. Following this, the skull is stripped. The diffusion constant is set to 30 (to increase the amount of smoothing), and the edge constant is set to 0.8 (to enhance skill stripping). When clicking "stage", skull stripping will be finished (Fig. 1) [*Shattuck D, Leahy R, 2002; Joshi A et al., 2004*], and the mask will contain the whole brain with a thin layer of non-brain tissue.

Moving the cerebrum to the labeling stage, the cerebrum is isolated from other brain parts (Fig. 2). Following this, the scrub mask, topology correction, and wisp removal are used to clean up the white matter mask [*Joshi S et al., 2012b*] (Fig. 3). A pial surface is then generated, and splitting together with the labeling of the hemispheres is performed (Fig. 4).

To register the cingulate gyrus volume from an isolated 3D model of the cerebral hemispheres, an image from the atlas is registered with an isolated

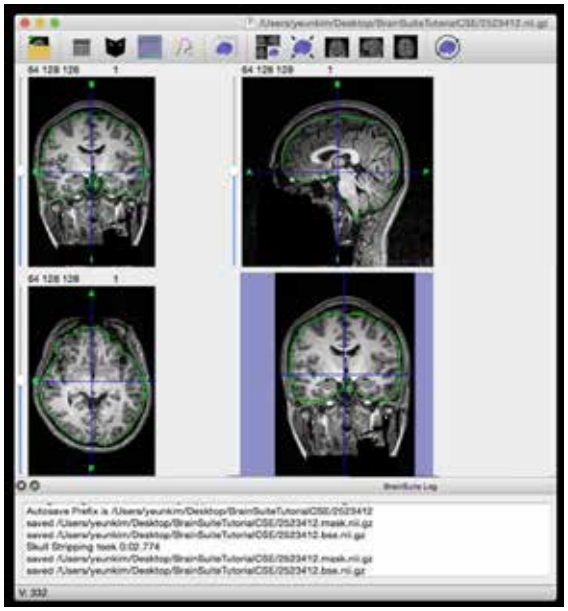

FIGURE 1. *Cortical surface extraction [Shattuck D, Leahy R, 2002].*

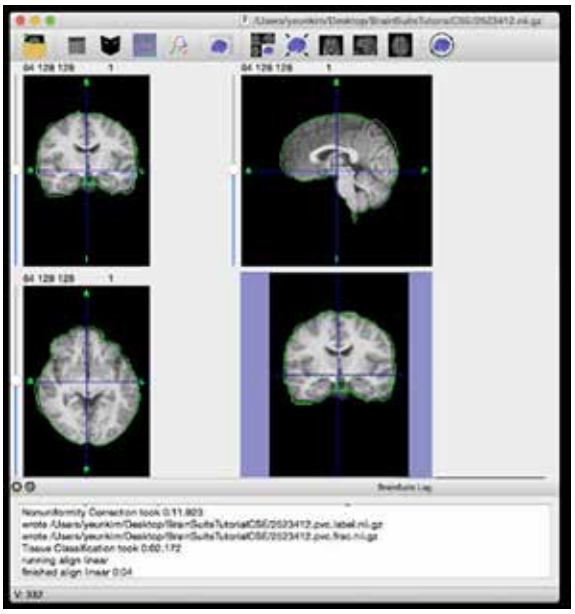

FIGURE 2. *Labeling of the cerebrum, cerebellum, and brain stem [Shattuck D, Leahy R, 2002].*

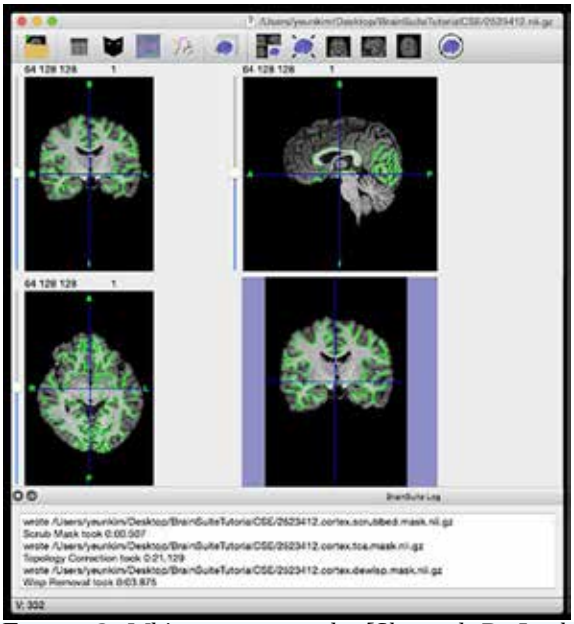

FIGURE 3. *White matter masks [Shattuck D, Leahy R, 2002].*

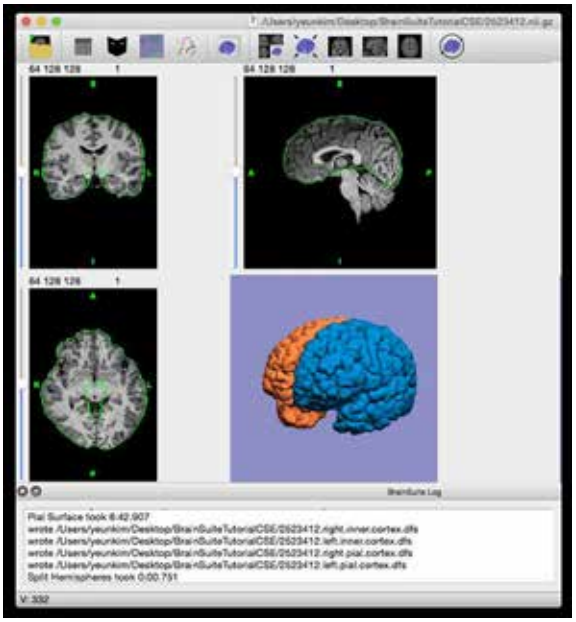

FIGURE 4. *Creation of the pial surface [Shattuck D, Leahy R, 2002].*

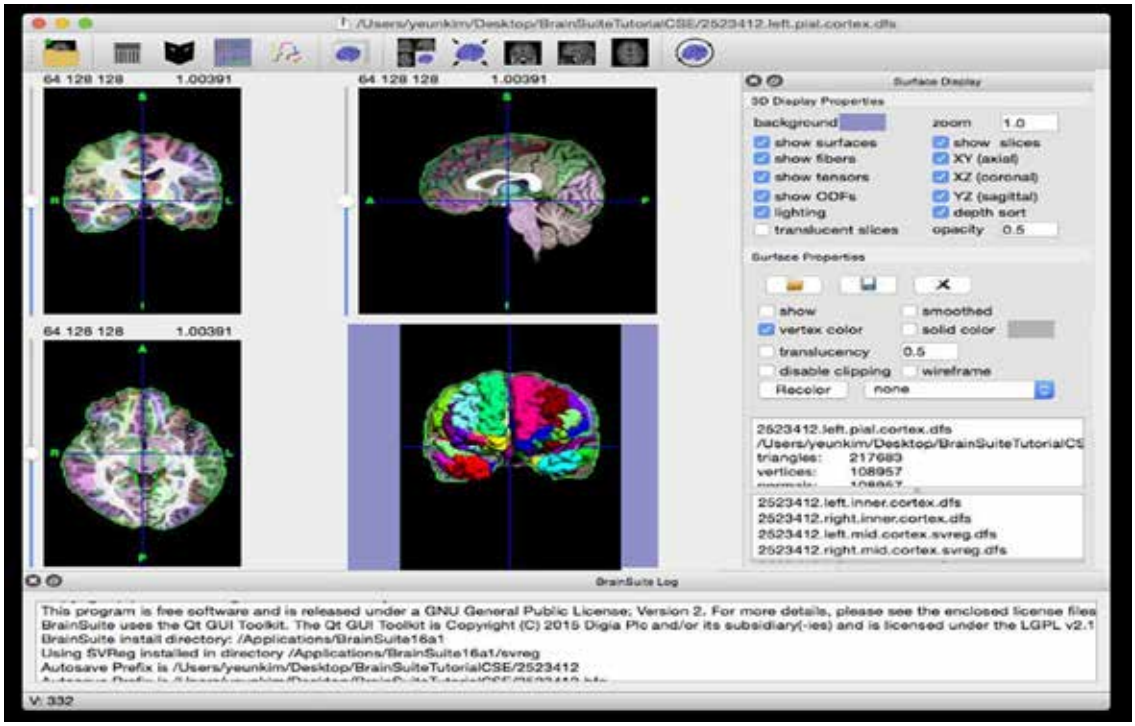

Figure 5*.Volume/surface registration [Shattuck D, Leahy R, 2002].*

sample for automatic labeling and comparison. This enables easier and faster registration and analysis of all samples (automatic labeling). This step can be done manually by an expert neuroanatomist (manual labeling). Volume/Surface registration is the name of this last step (Fig. 5) [*Shattuck D, Leahy R, 2002*].

Data analysis: Data was reviewed, ordered, and coded. Statistical Package for the Social Sciences, version 28.0 was used for data analysis. Descriptive statistics were performed for all variables through means and standard deviations for numerical data and frequency and percentage for categorical data. Inferential statistics were done in the form of T-tests to compare the total volume of the left and right cingulate gyrus and these volumes between males and females. In addition, linear regression and Pearson correlation tests were used to study the relationship between age and body mass index to the total volume of the cingulate gyrus. P-values less than 0.05 were considered statistically significant.

Results

Cingulate gyrus volume: For the Right cingulate gyrus, the mean cortical thickness was 4.0 ± 0.2 mm^3, and cortical volume was 20.9 ± 3.3 cm^3. For the left cingulate gyrus, the mean cortical thickness was 4.0 ± 0.3 mm^3, and cortical volume was 22.3 ± 3.7 cm^3 (Table 1).

The difference in the cortical volume and cortical thickness of the left and right cingulate gyrus

There were no statistically significant differences in the mean cortical thickness between the right and left cingulate gyrus (p>0.05). However, the cortical volume of the left gyrus was significantly higher than the right one (p=0.04).

Table 1.

Descriptive statistics of the cingulate gyrus

Characteristic	Overall, N = 60[1]
Right cingulate gyrus	
Mean cortical Thickness (*mm*)	4.0 ± 0.2
cortical Volume (GM+WM) (cm^3)	20.9 ± 3.3
Left cingulate gyrus	
Mean cortical Thickness (*mm*)	4.0 ± 0.3
cortical Volume (GM+WM) (cm^3)	22.3 ± 3.7

TABLE 2:

Differences in the mean cortical thickness and volume of the cingulate gyrus between genders

Characteristic	Female	Male	P-value[2]
Right cingulate gyrus			
Mean cortical Thickness (*mm*)	4.0 ± 0.2	4.1 ± 0.3	0.3
cortical Volume (GM+WM) (cm^3)	19.5 ± 2.3	22.4 ± 3.5	**<0.001**
Left cingulate gyrus			
Mean cortical Thickness (*mm*)	4.0 ± 0.3	4.0 ± 0.2	>0.9
cortical Volume (GM+WM) (cm^3)	20.4 ± 2.6	24.2 ± 3.8	**<0.001**

Gender differences in the cortical thickness and volume of the cingulate gyrus

There was no statistically significant difference in the mean cortical thickness of the right and left cingulate gyri between males and females. However, the cortical volumes of the left and right gyri were significantly higher in males than in females (p=0.001) (Table 2).

Correlation between the cingulate gyrus volume, age, and body mass index

There is no significant correlation between age and the cortical volume of the right (R = -0.09, p=0.5) or left cingulate gyrus (R = -0.12, p=0.36). Hence, age has no impact on the total volume of the right and left cingulate gyrus.

There is no significant correlation between body mass index and the cortical volume of the right or left cingulate gyrus (p>0.05).

DISCUSSION

The present study revealed a statistically significant asymmetry in the right and left cingulate gyrus volume. The left cingulate gyrus cortical volume is greater than the right. This may be because all participants are right-handed, and the brain's left hemisphere is dominant.

Males and females showed no differences in the mean cortical thickness of the right and left cingulate gyrus. In contrast, males had significantly higher cortical volumes in the left and right gyrus in our study. Conversely, earlier studies reported that females had more grey matter in the cingulate gyrus than males. This difference may result from body shape, environmental factors, or genetics [*Good C et al., 2001; Chen X et al., 2007; Mann S et al., 2011*].

This study is consistent with M. Yucel (2001), Smith C. (2007) and their co-authors, a study in which the cingulate gyrus volume did not show a significant correlation with the study participants' age [*Yücel M et al., 2001; Smith C et al., 2007; Szczerbak G et al., 2007*]. However, Bergfield K. and colleagues (2010) reported a significant correlation between age and cingulate gyrus volume [*Rumiati R et al., 2004; Di Paola Á et al., 2012*]. The reduction of cingulate gyrus volume is critical to the healthy aging process since it affects the anterior cingulate part, while the midcingulate is relatively preserved. This difference might result from the present study not including participants under 20 and over 40 years old. Lastly, in this study, body mass index showed an insignificant correlation with the cortical volume and thickness of the cingulate gyrus.

In conclusion, our study concluded that the Cingulate gyrus cortical volume is higher in the left gyrus compared to the right. Meanwhile, it is significantly different between gender, which is larger in males compared to females.

Nevertheless, neither genders nor left and right cingulate gyrus cortical thickness shows any statistical differences. On the other hand, there is no correlation between age or body mass index with the cingulate gyrus volume.

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