

## Characterization of the Corpus Callosum Morphology in Healthy Sudanese Adults using MRI

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### Abstract

**Background:** The aim of this study was to characterize the morphological differences of the corpus callosum (CC) concerning gender- and age-related variations, and establish reference values of the CC measurements for Sudanese participants using magnetic resonance imaging (MRI).

**Methods and Results:** MRI scans from 196 males and 189 females, ranging in age from 18 to 84, were reviewed. Only MRI studies without pathological findings were included in the analysis. The following measurements were done: the longitudinal dimensions of the brain, CC, the genu of CC, the splenium of CC, as well as craniocaudal height of the body of CC. Callosal longitudinal dimensions were measured using the Witelson division method. The longitudinal dimension of the genu was found to be larger in females (11.12±1.54 mm) than in males (10.73±1.75 mm) ( $P=0.021$ ). The longitudinal dimension of the brain was greater in males (161.6±7.2 mm) than in females (159.3±7.6 mm) ( $P=0.002$ ). There was a weak statistically significant direct correlation between age and CC ratio ( $r=0.271$ ,  $P<0.05$ ).

**Conclusion:** The results revealed that only the genu length showed sexual dimorphism and was larger in females than in males. This study showed variabilities regarding the CC dimensions in Sudanese participants compared to the Caucasian, Indian, and Japanese population. (International Journal of Biomedicine. 2020;10(3):215-220.)

**Key Words:** corpus callosum • gender • age • magnetic resonance imaging • Sudanese population

### Abbreviations

APL, anterior-posterior length; CC, corpus callosum; CCI, corpus callosum index; MRI, magnetic resonance imaging

### Introduction

The corpus callosum (CC) is unique to placental mammals in the brain structure that connects the right and left hemispheres.

It consists of approximately 200 million neural fibers and is responsible for the interhemispheric transfer of information and higher-order cognition.<sup>(1)</sup> The most parsimonious explanation for callosal evolution is that it arose to facilitate long-distance

integration within large brains.<sup>(2)</sup> Callosal fibers are first found in human embryos at 10–11 weeks of gestation, and by 12–13 weeks, a rudimentary callosal plate can be seen.<sup>(3)</sup> It connects the non-olfactory areas of the right and the left cerebral cortex. Initially, it forms a small bundle in the lamina terminals. As a result of the continuous expansion of the neopallium, however, it extends first anteriorly and then posteriorly, arching over the thin roof of the diencephalon.<sup>(3)</sup> The CC first enlarges caudally then develops rostrally. Myelination occurs relatively slowly over the lifespan, with the process completing in puberty.<sup>(4)</sup> Myelination progresses caudally to rostrally, much as the CC develops, from the splenium to the genu and rostrum. It begins to develop around the 12th week of gestation and matures through a complex process of neuronal migration, development, and eventual neuronal pruning.<sup>(1,4)</sup> By week 20, the CC can be seen on a sonogram or fetal MRI.<sup>(4)</sup> Although the CC may be considered fully developed by around age, as with most neural structures, it likely continues to change over the lifespan.<sup>(5,6)</sup>

The majority of the literature has found that outcomes are better for individuals with dysgenesis of the CC when compared to individuals with complete agenesis of corpus callosum, though there is some conflicting evidence. Moderate evidence suggests that the presence of the anterior commissure which consists of the rostrum and the genu correlates with better cognitive and/or developmental functioning, though very few child studies have documented the degree of dysgenesis or which segments of the CC.<sup>(7,8)</sup>

The variability of the adult CC may vary with gender and age. There are, however, little data on the morphology of the CC in the Sudanese population. The purpose of this study was to investigate the relationship between morphometric CC measurements, age, and gender and establish CC reference values in Sudanese adults using MRI.

## Materials and Methods

This study was approved by the local ethics committee and the Institutional Review Board (IRB) of the Faculty of Radiology, University of Medical Sciences and Technology (UMST), Khartoum, Sudan. A group of 385 participants (196 males and 189 females), presenting at the MRI units of Al-Zytouna Specialized Hospital, Royal Care Hospital, Al-Ribat Teaching Hospital, Antalya Hospital, Dar Al-Elaj Specialized Hospital, Fedail Hospital, and Al-Amal Hospital (Khartoum, Sudan), were recruited between March 2015 and August 2015 for this descriptive study. A disclaimer of the informed consent form was conceded as per institutes rules. Participants who gave data of a formerly known CC or the history of any neurological disease were excluded.

MRI brain examinations were conducted on a 1.5 Tesla MRI machine (Toshiba Medical Systems, Tokyo, Japan) at the Al-Zaytouna Specialist Hospital, Dar Al-Elaj Specialized Hospital, and Royal Care Hospital. A 1.5 Tesla MRI unit (Siemens Medical Systems, Munich, Germany) was used to examine participants at Fedail Hospital and Al-Ribat teaching hospital. In addition, a 1.5 Tesla MRI unit (Philips Medical Systems, Amsterdam, Netherlands) and (GE Healthcare Medical Systems, Chicago, United States) was used in Al-

Amal Hospital and at Antalya Hospital, respectively.

Each patient was scanned supine on the examination couch with his or her head within the head coil. The head is adjusted so that the interpupillary line is parallel to the couch. The brain MRI protocol included the following imaging planes: a) sagittal T<sub>1</sub>-weighted images, b) axial T<sub>1</sub>-weighted images, c) axial T<sub>2</sub>-weighted images, d) axial fluid-attenuated inversion recovery (FLAIR) protocol, and e) coronal T<sub>2</sub>-weighted images. Slice thickness/interslice gap of 5/1.5 mm and matrix size of 256×192 were used.

In this study, we measured the longitudinal and vertical dimensions of the corpus callosum and its various parts. For each case, using a mid-sagittal view of the cerebral hemispheres, the following global dimensions were measured<sup>(2,9,10)</sup> (Fig.1.): AB - Longitudinal dimension of the brain from the frontal to the occipital pole (anterior-posterior length (APL) of the brain); EZ - Length of CC from the most anterior point of the genu to the most posterior point of the splenium. Using the Witelson division method, the longitudinal dimensions of the genu (E/3), and splenium (E/5) were measured. The width of the CC middle portion was considered as the body dimension.<sup>(11)</sup>



**Fig 1.** Brain MRI image demonstrates the measured dimensions.

A - Frontal pole of the brain; B - Occipital pole of the brain; E - Genu of CC; Z - Splenium of CC<sup>(9)</sup>

Each image was recalled from the MRI computer's hard disk; brightness and contrast were set to approximate images used for clinical evaluation; the area of the CC was computed with the standard MRI software.

The obtained data were analyzed using the standard Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) version 20. Continuous variables were presented as the mean, standard error of the mean (SEM), standard deviation (SD). For data with normal distribution, inter-group comparisons were performed using Student's t-test. Pearson's correlation coefficient (r) was used to determine the strength of the relationship between the two continuous variables. A probability value of  $P < 0.05$  was considered statistically significant.

## Results and Discussion

A total of 385 Sudanese individuals participated in the study, aged from 18 to 84 years, with a mean of  $41.7 \pm 18.6$

years. Of the 385 participants, there were 196(50.9%) males (mean age of  $44.9 \pm 19.37$  years) and 189(49.1%) females (mean age of  $38.4 \pm 17.19$  years).

CC morphometric measurement parameters are shown in Table 1. The study revealed that the mean values for the longitudinal dimensions of the CC, genu, splenium, and body width were  $74.23 \pm 5.12$  mm,  $10.92 \pm 1.6$  mm,  $10.92 \pm 1.47$  mm, and  $5.43 \pm 0.89$  mm, respectively, while the mean value for the longitudinal dimension of the brain was  $160.5 \pm 7.5$  mm.

**Table 1.**

**Descriptive statistics of study variables (n=385)**

Variables	Minimum	Maximum	Mean	SD
Splenium dimension (mm)	6.1	16.9	10.92	1.47
Genu dimension (mm)	4.4	15.6	10.92	1.6
Body dimension (mm)	2.3	7.9	5.43	0.89
Length of CC (mm)	59.8	86.6	74.23	5.12
APL of the brain (mm)	139	183	160.5	7.5
Age	16	84	41.76	18.60

Differences between males and females with their levels of significance are summarized in Table 2. We found that the genu length was greater in females ( $11.12 \pm 1.54$  mm) than in males ( $10.73 \pm 1.75$  mm) ( $P=0.021$ ). Our findings were not similar to the results obtained by Mourgila et al.<sup>(2)</sup> for the Greek population and Takeda et al.<sup>(12)</sup> for the Japanese population. In addition, there were no statistically significant gender-related differences for the longitudinal dimensions of the CC and corpus callosal splenium, as well as for the corpus callosal body dimension. Our findings were not similar to the results obtained by Suganthi et al.<sup>(13)</sup> for the Indian population. There was a statistically significant gender-related difference for anterior-posterior length (APL) of the brain:  $159.3 \pm 7.6$  mm in females and  $161.6 \pm 7.2$  mm in males ( $P=0.002$ ) (Table 2).

**Table 2.**

**Dimensions of CC in the Sudanese participants according to gender**

Variables	Gender	n	Mean	SD	SEM	P-value
Age (yrs)	Male	196	44.94	19.37	1.38	0.001
	Female	189	38.47	17.19	1.25	
Genu dimension (mm)	Male	196	10.73	1.75	0.12	0.021
	Female	189	11.12	1.54	0.11	
Body dimension (mm)	Male	196	5.38	0.95	0.06	0.270
	Female	189	5.48	0.82	0.05	
Splenium dimension (mm)	Male	196	10.84	1.46	0.10	0.316
	Female	189	10.99	1.47	0.10	
Length of CC (mm)	Male	196	74.58	4.87	0.34	0.168
	Female	189	73.86	5.35	0.38	
APL of the brain (mm)	Male	196	161.6	7.2	0.50	0.002
	Female	189	159.3	7.6	0.50	

In this study, the CC index (CCI) was estimated by the following formula:  $CCI = (\text{genu dimension} + \text{body dimension} + \text{splenium dimension}) / \text{APL of the brain}$ . The current findings reported that the mean value of CCI was  $0.170 \pm 0.021$ . There was a statistically significant gender-related difference for CCI:  $0.173 \pm 0.020$  in females and  $0.167 \pm 0.021$  in males ( $P=0.004$ ) (Table 3).

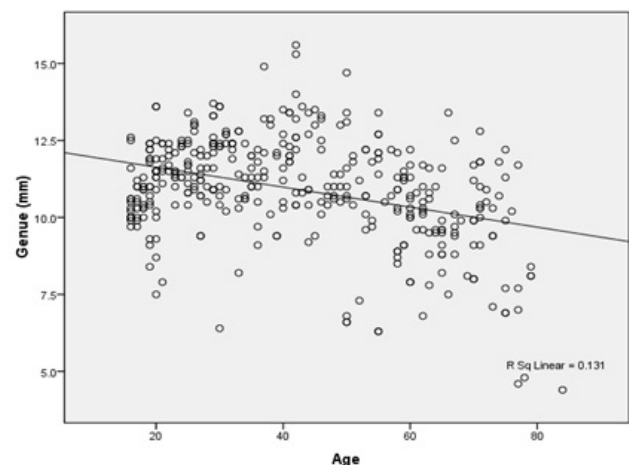
We found a weak but statistically significant indirect correlation between age and CCI ( $r=-0.370$ ,  $P<0.05$ ) (Fig 7).

**Table 3.**

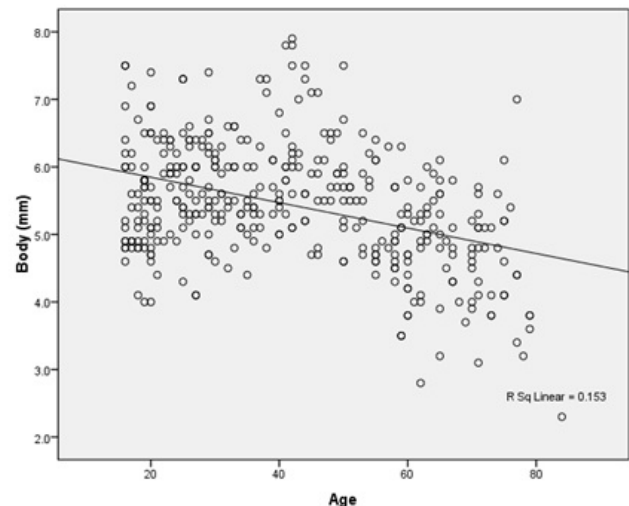
**The statistics of CCI in Sudanese participants according to gender**

Variable	Gender	n	Mean	SD	SEM	P-value
CCI	Male	196	0.167	0.021	0.0015	0.004
	Female	189	0.173	0.020	0.0014	

Our results showed a positive correlation between CC length and age. Also, there was a weak direct correlation between age and APL of the brain. Further, the relationship between age and dimensions of CC (genu, body, and splenium) and APL of the brain, CCI, and the CC ratio was presented in Figures 2-8.



**Fig. 2.** The relationship between age and the CC genu dimension



**Fig. 3.** The relationship between age and the CC body dimension

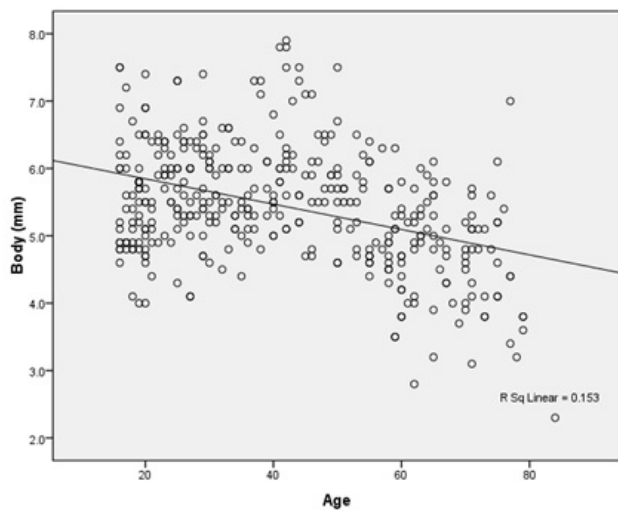


Fig 4. The relationship between age and the CC splenium dimension.

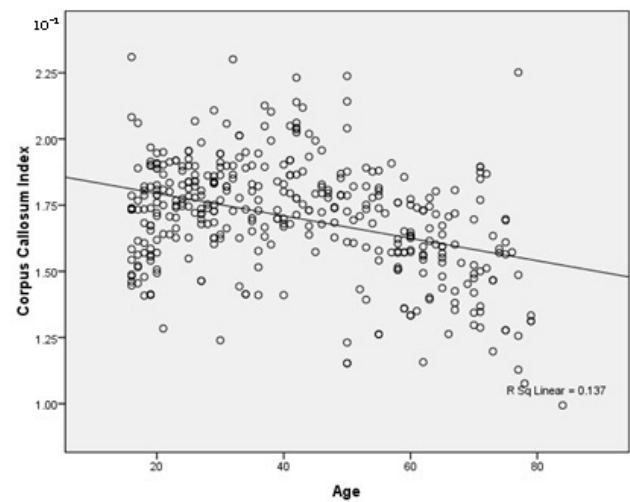


Fig. 7. The relationship between age and CCI.

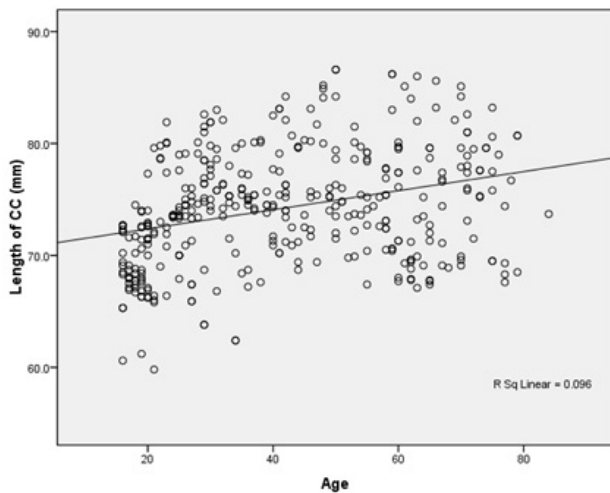


Fig. 5. The relationship between age and the CC length

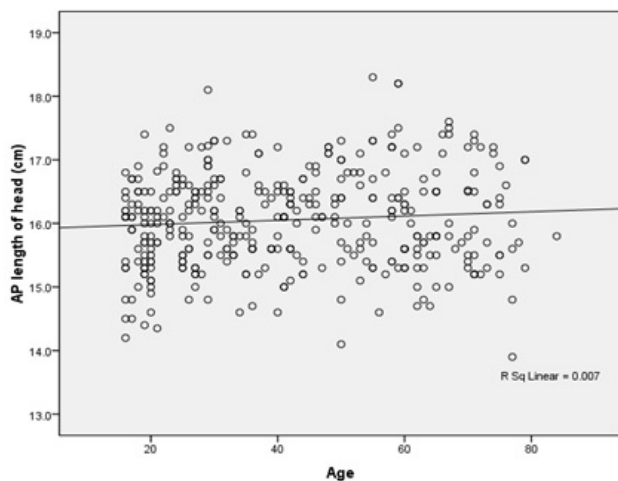


Fig. 6. The relationship between age and APL of the brain.

In this study the CC ratio was defined as CC length divided by APL of the brain.<sup>(2,9,10)</sup> The current findings reported that the mean value of the CC ratio was  $0.46 \pm 0.03$  ( $0.461 \pm 0.025$  in males and  $0.463 \pm 0.03$  in females,  $P > 0.05$ ) (Table 4). There was a weak but statistically significant direct correlation between age and CC ratio ( $r = 0.271$ ,  $P < 0.05$ ) (Fig 8).

Table 4.

The CC ratio statistics according to gender

Variable	Gender	n	Mean	SD	SEM	P-value
CC ratio	Male	196	0.461	0.025	0.001	0.502
	Female	189	0.463	0.033	0.002	

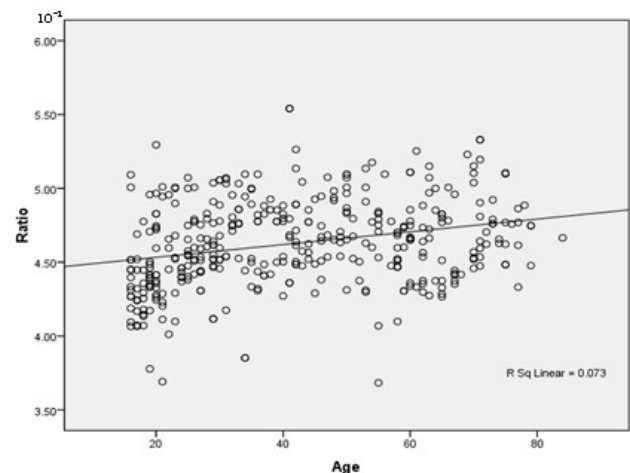


Fig. 8. The relationship between age and CC ratio.

Several MRI studies were conducted to determine the dimensions, morphology, and gender-related differences of CC in different countries.<sup>2,12,13</sup> Mourgila et al.<sup>(2)</sup> found that there was minimal variability in the dimensions and relative



dimensions of the corpus callosum among all Greek subjects. The longitudinal dimensions of the genu (EZ/3) and total corpus callosum (EZ) were found to be larger in males, whereas the longitudinal dimension of the splenium (EZ/5) was larger in females. Although there was no statistical correlation between corpus callosum and brain dimensions, the authors noted that there was a symmetry between corpus callosum and brain size, with stable proportions, in every studied individual.

For Iranian subjects (n=100), Mohammadi et al.<sup>(9)</sup> found that the longitudinal dimensions of CC, genu, and splenium were larger in males than in females, but these differences were not significant. Furthermore APL of the brain was significantly larger in males than in females ( $P<0.05$ ). The length of CC increased with age and there was also a positive significant correlation between the CC length and APL of the brain.

For Japanese subjects (n=205), Takeda et al.<sup>(12)</sup> found that the width of the corpus callosum, including the rostrum, body and splenium, gradually decreased with age. No sex-related differences in the longitudinal dimensions of CC, including CC length (69.7±4.15 mm in males and 69.4±4.33 mm in females) were observed.

In a study performed by Suganthi et al.,<sup>(13)</sup> the size of the corpus callosum on midsagittal section was measured in 100 (50 males and 50 females) normal adult Indians. The authors reported that the corpus callosum was longer in males and the discriminant score to differentiate gender was determined with an accuracy of 66%; the length of the corpus callosum increased with age.

Bermudez and Zatorre<sup>(14)</sup> used MRI to measure midsagittal CC area in 137 young normal volunteers. Male subjects showed significantly larger absolute total area, as well as anterior third and posterior midbody. However, females showed relatively larger total area, anterior midbody, and splenium.

For North-West Indian population, Gupta et al.<sup>(10)</sup> showed that the CC length was 7.57 cm in males and 7.1 cm in females; the CC height was 3.27 cm in males and 2.59 cm in females. The authors revealed that the Indian values were found to be more than the Japanese values for length, height and most of the widths of CC. The length and width of CC were found to be less than those of Caucasian population.

In another study conducted by Gupta et al.<sup>(15)</sup>, the only CC parameter, which showed sexual dimorphism, was larger CC length in males.

In the current study, the dimension of the CC concerning the genu was found to be larger in females in contrast to the findings of Mourgela et al.<sup>(2)</sup> and Mohammadi et al.<sup>(9)</sup>

A statistically significant gender-related difference for (APL) of the brain found in our study (159.3±7.6 mm in females and 161.6±7.2 mm in males ( $P=0.002$ )) (Table 2) was in agreement with a previous study by Mohammadi et al.<sup>(9)</sup> In the current study, we found a weak positive direct correlation between age and APL of the brain. A statistically significant correlation between age and CC length revealed in the current study (Fig.3) was similar to results obtained by Mohammadi et al.<sup>(9)</sup> and Suganthi et al.<sup>(13)</sup>

In our study, only the genu length showed sexual dimorphism and was larger in females than in males. A longer

corpus callosum in the males has been reported in study by Suganthi et al.<sup>(13)</sup> Concerning the CC length (74.5±4.87 mm and 73.8±5.35 mm in females), our results were higher when compared to studies conducted by Mourgela et al.<sup>(2)</sup> and Takeda et al.<sup>(12)</sup>, in the other hand these findings were compatible with the results of Gupta et al.<sup>(10)</sup>

The differences in quantitative data of CC in various areas of the world, which were seen in different studies, might be due to racial/ethnic factors.<sup>(2,9,10,15)</sup> Further large-scale studies are needed to estimate differences among various ethnicity/races and establish the standard CC dimensions in each population.

**In conclusion**, the results revealed that only the genu length showed sexual dimorphism and was larger in females than in males. This study showed variabilities regarding the CC dimensions in Sudanese participants compared to the Caucasian, Indian, and Japanese population.

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## Competing Interests

The authors declare that they have no competing interests.

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