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ORIGINAL ARTICLE

The impact of age, gender, and quality of life on hippocampal volume and cognitive function in apparently healthy Sudanese elderly individuals

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ABSTRACT

BACKGROUND:
The hippocampus plays a crucial role in memory and cognition, and its structural changes have been linked to altered memory performance, especially in older adults. Understanding these associations can provide information on the mechanisms underlying cognitive ageing and inform interventions to promote healthy brain ageing.

OBJECTIVE:
This study aimed to investigate the impact of age, gender, and quality of life on the volume of gray matter of the hippocampus and cognitive function in apparently healthy Sudanese elderly people aged 60 to 65 years.

METHODS:
This was a community-based, cross-sectional study conducted in Khartoum, Sudan, involving 80 healthy participants aged 60 to 65 years. Participants were evaluated using the Mini Mental State Examination (MMSE) to measure cognitive function and the validated 15D Quality of Life (QoL) questionnaire to evaluate their quality of life. Structural magnetic resonance imaging was used to quantify the volume of gray matter in the hippocampal using BrainSuite 19a software. Data collection was carried out using a three-stage cluster sampling technique. Multiple regression and correlation analyses were conducted on data from 80 healthy elderly participants using SPSS version 25.

RESULTS:
Out of the 80 healthy Sudanese elderly participants, the majority were females(57.5%), and two third of the study participants were at primary/secondary school level(73.8%). Age was a significant negative predictor of hippocampal volume of both right (B=-0.047, $p<0.001$) and left (B=-0.032, $p=0.010$) hippocampi in regression analyses. MMSE score was a significant negative predictor of right hippocampal volume (B=-0.069, $p=0.038$). Education and quality of life did not significantly predict hippocampal volume.

CONCLUSION:
No gender differences were observed in the mean of the hippocampus gray matter volume. While there was a negative correlation between the age and hippocampus gray matter volume for some groups, none was detected among education level and the quality of life.

KEYWORDS:
Hippocampus, Gray Matter Volume, Mini-Mental State Examination, Quality of Life, BrainSuite 19a

INTRODUCTION

The hippocampus lies within the inferomedial floor of the temporal horn of the lateral ventricle. This structure interconnects through various pathways with various telencephalic and diencephalic centers. The invagination of the primitive cortex develops the hippocampus to produce the serpentine, multilayered structure characteristic of the adult brain[1, 2].

The inequality in memory performance between younger and older populations could be caused by decreased hippocampal volumes that cause an alteration in declarative memory behaviours. Conjointly, older people perform poorly and are more biased towards incorrectly labelling a visually similar item[3]. The hippocampus is considered a fundamental structure for human cognition. Thus, a change in the structure of the hippocampus appears to play an essential role in dementia. However, the hippocampal volume is also well-documented to decline with normal ageing. The decrease in hippocampal volume was significantly associated with a decline in cognitive subdomains, including episodic memory, working memory, processing speed and executive function[4].

Long-term memory declines in old age (ability to encode novel events), and this impairment is related to dysfunction of the mesial temporal lobe (MTL), hippocampus and parahippocampal regions[5]. Conscious awareness, often linked to explicit memory, relies on the hippocampus along with other regions within the brain's medial temporal lobes for retention[6, 7]. Working memory areas are connected to the hippocampus and the adjacent parahippocampal parts of the medial temporal cortex[8]. Memory functions are influenced by the hippocampal connections to the diencephalon. For instance, individuals with alcohol-related brain damage often exhibit recent memory impairments, which are associated with pathological changes in the mamillary bodies that are extensively connected to the hippocampus through the fornix[6, 9]. Another critical connection is the diffuse cholinergic projection from the nucleus basalis of Meynert in the basal forebrain to the hippocampus, amygdala, and neocortex. The severe loss of these cholinergic fibers is a well-documented characteristic of Alzheimer's disease, highlighting their importance in cognitive function[10]. Furthermore, the amygdala, which is closely associated with the hippocampus, is essential for encoding and recalling emotionally charged memories[6].

The Mini-Mental State Examination (MMSE) is frequently used to assess cognitive function, and there were clear relationships between MMSE score and hippocampal volume atrophy with mild cognitive impairment and Alzheimer's Disease (AD) have been established. However, AD also affects large areas of the brain outside the hippocampus, especially within the temporoparietal episodic memory network, in addition to the parahippocampal[11]. In the same line, another study revealed that the hippocampal volume is correlated with the MMSE in mild cognitive impairment patients[12]. But when looking at an age-related decline in episodic long-term memory, it is typically detected after the age of 60 years, but there is obvious variability in both commencement and rate of decline. Structural brain changes in the hippocampus and other medial temporal lobes had been suggested to account for the episodic-memory change in ageing [13]. The hippocampus and other medial temporal lobes (MTL) regions are vital for episodic memory. Magnetic resonance imaging (MRI) studies have revealed marked age-related shrinkage in the hippocampus. Other studies, however, observed no relation between hippocampal atrophy and episodic memory decline[14]. They predicted that gray-matter changes in the medial temporal lobe and hippocampus would account for age-related changes in episodic memory. The decline in episodic memory covaries with the decline in other cognitive functions[15, 16].

MMSE score correlated positively with the total brain volume and the volumes of the cerebral cortex, cerebral WM and hippocampus[11]. A study that correlates gray matter volume with cognitive of healthy elder revealed a significant positive correlation between the regional gray matter volumes of the right hippocampus and cognitive performance [17]. Structural MRI covariance patterns associated with normal ageing and neuropsychological functioning study, and by analysing subcortical areas, revealed correlations between

decreased hippocampal volume and diminished memory performance in the elderly[18], but the most important finding was the significantly lower gray matter volume in the hippocampus proper on both sides [19].

Study titled as minute effects of sex on the aging brain on healthy and Alzheimer's disease, indicated that, sex exerts minute and unstable effects on age differences in brain morphometry, in healthy ageing. Men had larger residual volumes of hippocampus than women, and in women's brains, the cerebral cortex and the hippocampus occupy a larger part of the total brain volume than in men's[20]. Studies found no significant volume differences between the left and right hippocampus[21]. While ageing of the brain study determined, the age-related volume loss is significantly higher in males than females in the whole brain, but it is higher in females than in males in the hippocampus and parietal lobes[22]. A study that provided normative data on hippocampal volume relative to age found that males generally had a larger mean total volume of gray matter compared to females. This study also observed that the right hippocampus was larger than the left[23]. But after adjusting for head size, no significant gender differences in mean hippocampal volume were noted[23, 24]. Additionally, both genders exhibited a larger right hippocampus, and higher education levels were correlated with larger hippocampal volumes, though education did not significantly affect total gray matter volume[23].

A study about one domain of quality of life examined the association between gait velocity and hemispheric volumetric measures, revealed only smaller right hippocampal volume was associated with a decrease in gait velocity[25]. Despite the existing research on the relationship between hippocampal volume, cognitive function, and aging, the interplay of these factors with quality of life remains unclear, particularly within the Sudanese population. Further investigation is needed to understand how these variables interact in this demographic. This study contributes evidence by examining the relationship between hippocampal gray matter volume, cognitive function (MMSE), and quality of life in healthy elderly individuals aged 60 to 65 in Khartoum, Sudan. The objective of this study is to evaluate the influence of age, gender, and quality of life on hippocampal gray matter volume and cognitive function in apparently healthy elderly individuals aged 60 – 65 years.

METHODS

Ethical Considerations

Ethical approval for this study was obtained from the research department of the Ministry of Health in Khartoum State (Sudan) in September/12/2019. Written informed consent for participation and publication was obtained from all participants. The study also adhered to the recommendations of the Helsinki Declaration.

Study Design

Community-based, cross-sectional study.

Study Area

The study was conducted in 12 administrative units within Khartoum state localities (Sudan)[26].

Study Setting

The study participants were interviewed in their homes within the selected administrative units: Khartoum Sharq, Kalaklat, Khartoum Bahrey, Soug Libiya, Al Thawra, Southern countryside (Salha), Al Mawredah, Wadnobawi, Abu Saad, Haj Yousif, Soba, and Al-Elaphone[26]. The MRI was conducted in the department of radiology of AL-Amal National Hospital at Khartoum Bahri[(26)]. The transportation to the hospital for MRI scans were by a study-provided car. The interviewed and scanned participants were the same individuals.

Study Population

The study population consisted of healthy individuals aged between 60 and 65 years old.

Inclusion Criteria

Participants aged between 60 and 65 years old, and had at least primary school education and the ability to read and write were included in the study.

Exclusion Criteria

Individuals with mental illness and dementia, brain vascular disorders (stroke), trauma at the head region, or central neurological disorders were excluded from the study.

Sample Size

The sample size of 80 subjects was determined using G-power version 3.1.9.7. A priori power analysis was conducted, assuming a large Cohen's effect size of 0.8, 0.05 type I error, 80% power, and about equal allocation. The three-stage cluster sampling technique was used, which resulted in an initial sample size of 52 subjects per arm. Change was made by a factor of 1.5 to account for the sampling technique, and 10% non-response was considered during data collection.

Sampling Technique

Three-stage cluster sampling was used to select the study participants. First, 12 administrative units were randomly selected. Second, 48 squares were randomly selected from the 12 administrative units. Finally, the healthy individuals were randomly selected from the eligible participants/sampling frame within the selected squares.

Data Collection

Participants completed the 15D Quality of Life (QoL) questionnaire, with scores ranging from 15 to 75. The Mini-Mental State Examination (MMSE) was utilized to assess cognitive function in participants. An unauthorized version of the MMSE was used by the study team without permission; however, this has now been rectified with Psychological Assessment Resources company (PAR). The MMSE is a copyrighted instrument and may not be used or reproduced in whole or in part, in any form or language, or by any means without written permission of PAR (www.parinc.com). Participant data was collected and recorded by the researcher. Structural MRI was done on healthy participants. Morphometric measurements were conducted blindly to clinical data by using an auto segmentation program BrainSuite19a, and the measurements from images were stored separately.

The 15D QoL questionnaire, assessed mobility, vision, hearing, breathing, sleeping, eating, speech, excretion, usual activities, mental function, discomfort and symptoms, depression, distress, vitality, and sexual activity[27]. The MMSE assessed orientation, registration, attention and calculation, recall, language and praxis, repetition, three-stage command, reading, writing, and copying. Scores were recorded on a data sheet with participant code number, age, and educational level[28-30].

Structural MRI were done for participants in the MRI section in the department of radiology of AL-Amal National Hospital. The MR scanner used was a PHILIPS Intera 1.5T. Standard-resolution structural MRI images were acquired using a T1 weighted magnetization-prepared rapid acquisition with gradient echo (MP-RAGE) sequence with these parameters: total scan duration was 5 minutes and 23.6 seconds, slice thickness was 1.0 mm, the field of view was 199 FH (mm) – 199 RL (mm) – 188 AP (mm), Act. TR/TE= 25/3.5 (ms), Act. WFS (pix) / BW(Hz)= 0.980/221.5, flip angle 15°, ECHO spacing = 7.5 ms, phase resolution = 100%, slice resolution = 50%. The images were made in the coronal section.

MRI Analysis

Handling and analysis of the DICOM images were done by using three downloadable software's and it was: RadiAnt DICOM Viewer (64-bit), ImageJ, and BrainSuite19a.

Data Analysis

The results of BrainSuite 19a were automatically saved, opened with Notepad windows software, and then transferred to Microsoft Excel 2016 worksheet. Data were subsequently analyzed using SPSS version 25. Descriptive statistics were used to summarize demographic characteristics and measurements. Independent t-tests were used to compare hippocampal volumes between genders. Pearson correlation coefficients were calculated to assess the relationships between hippocampal volume and age, education level, QoL, and MMSE scores. Multiple regression analyses were conducted to examine the independent effects of these variables on hippocampal volume.

RESULTS

The study investigated differences in hippocampus gray matter volume (GMV) between males and females, as well as correlations between GMV and factors such as age, education, quality of life, and MMSE scores.

Demographic characteristics of the participants

Out of the 80 total participants, the majority (57.5%) were females. With regards to educational level, around two third (73.8%) of the study participants were at primary/secondary school level, as shown in Table 1.

Table 1. Demographic characteristics of the study participants by gender (n=80)

Variable	Male n=34 n(%)	Female n=46 n (%)	Total N=80 n (%)
Education			
Primary/secondary	20 (58.9)	39 (84.8)	59 (73.8)
High secondary	10 (29.4)	3 (6.5)	13 (16.3)
University	4 (11.8)	4 (8.7)	8 (10.0)
Age			
60	12 (35.3)	19 (41.3)	31 (38.8)
61	1 (2.9)	2 (4.3)	3 (3.8)
62	1 (2.9)	5 (10.9)	6 (7.5)
63	3 (8.8)	1 (2.2)	4 (5.0)
64	2 (5.9)	0 (0)	2 (2.5)
65	15 (44.1)	19 (41.3)	34 (42.5)

Hippocampus gray matter volume:

There was no significant difference in gray matter volume of the right hippocampus (p=0.267) and left hippocampus (p=0.530) among males as compared to females. The mean right hippocampus and left hippocampus of gray matter volume (p=0.618) was not significantly different among males (Table 2). However, among females, the mean gray matter volume of the right hippocampus (M=1.26, SD=0.19) was significantly greater (p<0.001) than the left hippocampus (Table 3).

Table 2. Comparison of the hippocampus gray matter volume by gender (Independent Samples t-test)

Brain part	Male n=34 M (SD)	Female n=46 M (SD)	MD (95% CI)	p-value
Right Hippocampus	1.19 (0.32)	1.26 (0.19)	-0.07 (-0.20, 0.06)	0.267
Left Hippocampus	1.18 (0.29)	1.14 (0.21)	0.04 (-0.08, 0.16)	0.530

M: Mean, SD: Standard deviation, MD: Mean difference, CI: Confidence interval.

Table 3. Comparison of right and left hippocampus gray matter volume by gender (Independent Samples t-test)

Gender	Right hippocampus M (SD)	Left hippocampus M (SD)	p-value
Male (n=34)	1.19 (0.32)	1.18 (0.29)	0.618
Female (n=46)	1.26 (0.19)	1.14 (0.21)	<0.001

M: Mean, SD: Standard deviation.

Right Hippocampus gray matter volume correlations

Gray matter volume of the right hippocampus was not significantly different by education level among both males (F=0.414, p=0.670) and females (F=0.66, p=0.520). There was negative significant correlation between the gray matter volume of the right hippocampus and age among males (r=-0.451, p=0.007) and females (r=-0.325, p=0.027). However, no significant correlation was observed with quality of life score (males: r=-0.018, p=0.920; females: r=-0.218, p=0.146), and MMSE score (males: r=-0.010, p=0.956; females: r=-0.051, p=0.736) (Table 4).

Left Hippocampus gray matter correlations

No significant correlation was seen between gray matter volume of the left hippocampus and educational level among males (F=0.15, p=0.860) and females

(F=1.89, p=0.163). Left hippocampus gray matter volume was significantly negative related with age among females only (r=-0.426, p=0.003). However, no significant correlation was seen with age (males: r=-0.301, p=0.084), quality of life (males: r=-0.148, p=0.402), and MMSE score (males: r=-0.006, p=0.975; females: r=0.132, p=0.382). There was negative significant correlation observed between left hippocampus gray matter volume and quality of life (females: r=-0.345, p=0.019) (Table 4).

Table 4. Correlations of the measures of gray matter volume for the hippocampus by gender (Pearson Correlation Coefficients)

Variables		Male (n=34)		Female (n=46)	
Right Hippocampus					
Categorical Variable		**M (SD)**	**F (p-value)**	**M (SD)**	**F (p-value)**
Education	P/S	1.15 (0.25)	0.414 (0.670)	1.26 (0.19)	0.66 (0.520)
	HS	1.24 (0.42)		1.19 (0.20)	
	University	1.27 (0.43)		1.35 (0.22)	
Continuous Variable		**r**	**p-value**	**r**	**p-value**
Age		**-0.451**	**0.007**	**-0.325**	**0.027**
QoL		-0.018	0.920	-0.218	0.146
MMSE score		-0.010	0.956	-0.051	0.736
Left Hippocampus					
Categorical Variable		**M (SD)**	**F (p-value)**	**M (SD)**	**F (p-value)**
Education	P/S	1.16 (0.26)	0.15 (0.860)	1.12 (0.20)	1.89 (0.163)
	HS	1.19 (0.36)		1.11 (0.06)	
	University	1.24 (0.35)		1.33 (0.25)	
Continuous Variable		**r**	**p-value**	**r**	**p-value**
Age		-0.301	0.084	**-0.426**	**0.003**
QoL		-0.148	0.402	**-0.345**	**0.019**
MMSE score		-0.006	0.975	0.132	0.382

M: Mean, SD: Standard deviation, QoL: Quality of life, MMSE: Mini-mental state examination, P/S: primary or secondary, HS: Higher secondary

Multiple Regression Analysis Predicting Right and Left Hippocampal Gray Matter Volumes

Multiple regression analyses were employed to investigate the associations between age, educational attainment, quality of life, MMSE score, and hippocampal gray matter volume. Dependent variables were gray matter volumes from the right and left hippocampus, and independent variables were age, educational attainment, overall quality of life score, and MMSE score.

The results, shown in Table 5, indicated that the models were statistically significant for the right ($F(4, 75)=4.756$, $p=0.002$, adjusted $R^2=0.160$) and left ($F(4, 75)=3.888$, $p=0.006$, adjusted $R^2=0.128$) hippocampus. Age emerged as a significant negative predictor for both right ($B=-0.047$, $p<0.001$, $\beta=-0.424$) and left ($B=-0.032$, $p=0.010$, $\beta=-0.297$) hippocampal volume, indicating that increased age was correlated with reduced volumes, with a marginally more pronounced effect on the right hippocampus.

Table 5. Multiple Regression Analysis Predicting Right and Left Hippocampal Gray Matter Volumes

Predictor	Right Hippocampus B (95% CI)	Right Hippocampus β	p-value	Left Hippocampus B (95% CI)	Left Hippocampus β	p-value
Age (in years)	-0.047 [-0.072, -0.023]	-0.424	**<0.001**	-0.032 [-0.056, -0.008]	-0.297	**0.010**

Educational level	0.037 [-0.031, 0.105]	0.154	0.284	0.056 [-0.011, 0.122]	0.243	0.099
Quality of Life (QoL)	-0.003 [-0.019, 0.014]	-0.037	0.746	-0.014 [-0.030, 0.002]	-0.199	0.090
MMSE Score	-0.069 [-0.135, -0.004]	-0.314	**0.038**	-0.046 [-0.110, 0.017]	-0.219	0.153

B = Unstandardized regression coefficient; β = Standardized regression coefficient; CI = Confidence Interval; MMSE = Mini-Mental State Examination; QoL = Quality of Life.

The MMSE score was a significant negative predictor for right hippocampal volume (B=-0.069, p=0.038, β=-0.314), suggesting that diminished cognitive function was linked to a smaller volume on the right side. However, the MMSE score did not significantly predict left hippocampal volume (B=-0.046, p=0.153, β=-0.219).

Educational attainment (right: B=0.037, p=0.284, β=0.154; left: B=0.056, p=0.099, β=0.243) and quality of life (right: B=-0.003, p=0.746, β=-0.037; left: B=-0.014, p=0.090, β=-0.199) did not emerge as significant predictors of hippocampal volume on either side. Variance inflation factors suggested that multicollinearity was not a pressing concern, although a moderate correlation existed between educational attainment and MMSE score (VIF=1.919 and 2.078, respectively). These findings indicate that the selected predictors contribute to the variability in hippocampal volume among the study participants.

DISCUSSION

This study aimed to evaluate the influence of age, gender, and quality of life on hippocampal gray matter volume and cognitive function in apparently healthy elderly individuals aged 60 – 65 years. MMSE was used to measure the cognitive performance, 15D questionnaire was used for quality of life, and auto-segmentation tool (BrainSuite 19a) was used to measure the gray matter volume of the hippocampal gyri in males and females. The study sample consisted of 80 apparently healthy Sudanese participants; the majority were females. Their age ranged from 60 to 65 years old with the majority aged 65 and 60. Around two-thirds of the studied participants were at primary/secondary school level.

Paper-based MMSE was used to assess the cognitive functioning of study participants. The current study has shown that the males MMSE score was greater than females and in both, the score showed standard cognitive abilities. It revealed the participants at a high secondary school and university levels had greater MMSE scores than primary/secondary level while no differences between a high secondary school level and university. The MMSE score decreased with the advancing in age of participant, but with the present of educational levels effect the age doesn't affect cognitive performance of participants. The investigation employed multiple regression analyses to explore the associations among age, educational attainment, quality of life, MMSE score, and hippocampal gray matter volume. Age emerged as a significant negative predictor of both right and left hippocampal volumes, signifying that advancing age corresponds with reduced volumes, with a slightly greater impact observed on the right side. The MMSE score served as a significant negative predictor for the right hippocampus, but not for the left, that may suggest a correlation between diminished cognitive function and reduced right hippocampal volume.

Those findings agreed with some studies that showed the MMSE scores were related to gender and females scored significantly lower than males among Spanish elders[31], and gender was associated with the cognitive disability effects (women were affected 1.5 times more than men)[31, 32]. But disagrees with a study that revealed females had MMSE significantly higher than males[33]. MMSE score was highly significantly correlated with the advancing years of education[34]. So subjects with higher scores in MMSE were of more years of literacy and vice versa[35, 36]. Declining in episodic memory and cognitive abilities were typically seen with the advance in age after 60 years old[13, 16].

Males had higher MMSE scores than females due to education level differences and that could be explained because a few decades ago, female education did not interest Sudanese society, and this was clear in this study. The majority of female participants were at primary/secondary school levels; besides, education had a superior effect on cognition more than age. Neither educational attainment nor quality of life were significant predictors for either right or left hippocampus when applied multiple regression analyses. The variance inflation factor analysis revealed no substantial multicollinearity concerns. Collectively, the models were statistically significant, accounting for approximately 16% of the variance in right hippocampal volume and 12.8% in left hippocampal volume, indicating that the chosen variables substantially explain the variability in hippocampal volumes. The education has a significant impact on the maintenance of cognition in older people and the gender has no effect.

Males did not substantially vary in the mean gray matter and white matter volumes of the right and left hippocampi. However, the right hippocampus's mean volume percentage in males was substantially higher than its left counterpart. However, among females, the right hippocampus's mean gray matter volume was substantially higher than its left counterpart. The females' mean right hippocampus volume percentage was also considerably higher than their left hippocampus. However, among females, the mean white matter volume of the right hippocampus did not vary substantially from that of the left.

Several studies indicate varying results on hippocampal volume differences. While some research shows no significant differences between the left and right hippocampus[21], hippocampus volume fraction was higher on the right temporal lobe than left[37], and the hippocampus on cognitively normal subjects were more asymmetric in males than females and the right hippocampus was greater than the left hippocampus[38]. Others report that the right hippocampus is slightly larger in both women and men, and it was more significant among women[23]. The findings demonstrate that the gray matter volume of the right hippocampus is greater than the gray matter volume of the left hippocampus.

There was no significant difference in gray matter volume of the right hippocampus and left hippocampus among males as compared to females. There was a negative significant correlation between the gray matter volume of the right hippocampus and age among males and females. Left hippocampal gray matter volume was significantly related negatively with age among females only. Gray matter volume of the right and left hippocampus was not significantly different by education among both males and females. However, no significant correlation was seen between right hippocampus gray matter volume with quality of life score among males and females. There was a significant decrease in gray matter volume of the left hippocampus with an increase in quality of life among females, but no correlation among males. Right, and left hippocampal gray matter volume was not significantly correlated with MMSE score among both genders.

The findings were coherent with regional brain changes in ageing healthy adults study, that revealed gender does not play a significant role in brain ageing [24]. They also followed literature that revealed an acceleration of hippocampal volume loss around age 60–65 years[23], and that there was a significant decrease in hippocampal gray matter volume in ageing participants[39]. But disagreeing with a study that revealed that the right hippocampal gray matter volume increased with education[40], and there was a slight significant positive effect of level of education on average hippocampal volume. Higher education levels were associated with volumes larger than lower education levels[23]. A coherent study about sleep quality in healthy elder adults showed that sleep quality was not associated with hippocampal volume or its atrophy[41]. But it was incoherent with a recent study in animals that shows the beneficial effect of physical activity through stimulation of neurogenesis in the hippocampus which shows that quality of life has a positive effect on hippocampal volume[22]. The present finding followed a study on the association between brain volumes with cognition in healthy elderly men, which demonstrated no association between hippocampal size and declarative memory[42]. It

disagreed with a study that correlates gray and white matter volume with the cognitive of healthy elders. They found a positive correlation between the regional gray matter volumes of the right hippocampus and cognitive performance[17], and a reduction of the hippocampal volume associated with impaired cognitive performance[18]. The findings might confirm the age effect on hippocampus gray matter volume which shows no association between education and cognitive performance.

One of the strengths of this study was the use of auto-segmentation tools, specifically BrainSuite 19a, which enabled precise and detailed measurements of hippocampal gray matter volume (GMV). The homogenous sample of healthy elderly participants reduced the influence of underlying health conditions. This study is not without its limitations. Its cross-sectional design makes it difficult to draw causal conclusions about the relationship between aging and hippocampal GMV. The small sample size, particularly of males, may limit generalizability. Additionally, the use of paper-based MMSE and self-reported quality of life assessments may introduce bias. Furthermore, while correlation analyses provided initial insights, we also employed multiple regression analyses to examine the independent and combined effects of age, education, quality of life, and MMSE score on hippocampal GMV. A key strength of this regression analysis is that it allowed us to control for the influence of multiple variables simultaneously. The regression models revealed that age was a significant negative predictor of hippocampal volume, even when accounting for the other factors. However, education level and quality of life did not emerge as significant predictors in these models. The study underscores age as the most significant factor influencing hippocampal GMV in older adults, a finding that aligns with existing research on brain aging. Interestingly, education level did not appear to have a meaningful impact on hippocampal size, nor were MMSE scores strongly correlated with hippocampal volume. These results highlight the multifaceted nature of cognitive aging and suggest the need for more comprehensive tools in future research.

CONCLUSION

The regression analyses revealed that age is a significant negative predictor of both right and left hippocampal gray matter volume, indicating that older age is associated with smaller hippocampal volumes. Specifically, for every year of increase in age, the right hippocampal volume decreases by 0.047 units, and the left hippocampal volume decreases by 0.032 units. Furthermore, the Mini-Mental State Examination (MMSE) score is a significant negative predictor of right hippocampal volume, suggesting that lower cognitive function is associated with smaller right hippocampal volumes. In contrast, educational level and quality of life did not significantly predict right or left hippocampal volume in these models.

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CONFLICT OF INTEREST

None declared.

AUTHORS' CONTRIBUTIONS

Tamer Sayed Jubartallah: substantial contributions to conception and design, drafting the article, interpretation of data, final approval of the version to be published. Amani Abdelrazag Elfaki: substantial contributions to conception and design, interpretation of data, final approval of the version to be published. Tahir Osman Ali: substantial contributions to conception and design, interpretation of data, final approval of the version to be published. Amira Mohammed Osman: substantial contributions to conception and design, interpretation of data, final approval of the version to be published. Dalya Ibrahim Ahmed: analysis and interpretation of data, final approval of the version to be published.

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