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ORIGINAL ARTICLE

Automatic Segmentation of the Cerebellum in Healthy Individuals: A volBrain (CERES) Study

Sağlıklı Bireylerde Serebellumun Otomatik Segmentasyonu: Bir volBrain (CERES) Çalışması

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ABSTRACT

Aim: We aimed to investigate the total cerebellum volume and the volume of healthy individuals' right and left cerebellum lobes according to age groups and sex.
Methods: 3D T1-weighted Magnetic Resonance Images of 200 individuals (100 females, 100 males) of both sexes between the ages of 18-78 were included in our study. Total cerebellum volume and volume results of cerebellum lobules will be calculated from these images with the sub-tab CERES of the volBrain software program.
Results: The total cerebellum volume in our study was found to be 115.41±12.25 cm3 in females and 126.27±14.78 cm3 in males, and the valueswere statistically significant (p<0.001). The right side lobule I-II, lobule IV, lobule crus II, lobule VIIB, lobule VIIIA, and lobule X valuesof the cerebellum were statistically higher than the left side (p<0.05). On the left side, lobule V, VIIIB, and IX values were statistically higher than the right side (p<0.05). When evaluated according to sex, the values of males were statistically higher than females in all parameters except for the total lobule I-II, right lobule I-II, left lobule I-II, right lobule V, total lobule VI and right lobule VI values(p<0.05). According to age groups, except for total lobule I-II, right lobule I-II, and left lobule I-II values, all other parameters were statistically lower in the 50 years old and above group than in the under 50 years old group (p<0.05).
Conclusion: We believe that knowing the total cerebellum volume and volumetric analysis of its lobules in healthy adults will define the disease group and its prognosis

Keywords: Age, Cerebellum, Magnetic Resonance Imaging, Sex, volBrain, Volume

ÖZ

Amaç: Sağlıklı bireylerin toplam cerebellum hacmi ile sağ-sol cerebellum loblarının hacmini yaş grupları ve cinsiyete göre araştırmayı amaçladık.
Metod: Çalışmamıza 18-78 yaş arası her iki cinsiyete ait 200 bireyin (100 kadın, 100 erkek) 3D T1 ağırlıklı Manyetik Rezonans Görüntüleri dahil edilmiştir. Bu görüntüler üzerinden volBrain yazılım programının alt sekmesi CERES ile toplam cerebellum hacmi ve cerebellum loblarının hacim sonuçları hesaplanacaktır.
Bulgular: Çalışmamızın toplam cerebellum hacmi kadınlarda ortalama 115.41±12.25 cm3, erkeklerde ise 126.27±14.78 cm3 olarak bulundu ve değerler istatistiksel olarak anlamlıydı (p<0.001). Cerebellum'un sağ taraf lobul I-II, lobul IV, lobul crus II, lobul VIIB, lobul VIIIA ve lobul X değerleri sol tarafa göre istatistiksel olarak yüksekti (p<0.05). Sol tarafta ise lobul V, lobul VIIIB ve lobul IX değerleri sağ tarafa göre istatistiksel olarak yüksekti (p<0.05). Cinsiyete göre değerlendirildiğinde toplam lobul I-II, sağ lobul I-II, sol lobul I-II, sağ lobul V, toplam lobul VI ve sağ lobul VI değerleri dışındaki diğer tüm parametrelerde erkeklerin değerleri kadınlara göre istatistiksel olarak yüksekti (p<0.05). Yaş gruplarına göre toplam lobul I-II, sağ lobul I-II ve sol lobul I-II değerleri dışındaki diğer tüm parametrelerde 50 yaş ve üzeri grubun değerleri 50 yaş altındaki gruba göre istatistiksel olarak düşüktü (p<0.05).
Sonuç: Sağlıklı yetişkinlere ait toplam cerebellum hacmi ve loblarının hacimsel analizinin bilinmesi hastalık grubunun tanımlanması ve prognozu açısından anlamlı olacağını düşünmekteyiz.

Anahtar Kelimeler: Yaş, Cerebellum, Manyetik Rezonans Görüntüleme, Cinsiyet, volBrain, Hacim

Introduction

The cerebellum (1), the small tongue in Latin, is located in the fossa cerebellaris of the occipital bone (2). It constitutes 10% of the total brain volume and is also a part of the metencephalon, which contains approximately half as many neurons as all neurons in the brain (2, 3). It connects to the brainstem via three peduncles (4). The cerebellum consists of two hemispheres called hemispheric and is connected by the vermis. It is divided into 3 main sub-lobes: the anterior lobe (lobules I-V), posterior lobe (lobules VI-IX), and flocculonodular lobe (lobules X) by the primary fissure and posterolateral fissure (5, 6). Lobules IV, V, VI, and VIII are effective in motor tasks, while lobules VI, Crus I, Crus II, VIIB, IX, and X are effective in cognitive tasks (7). It is stated that the cerebellum plays a role in motor skills, balance, coordination functions, and higher cognitive tasks (8, 9).

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Previous studies have reported that schizophrenia (10), depression (11), multiple sclerosis (12), tinnitus (13), alcohol (14) and drug use (15, 16) affect the cerebellum. Studies have reported age-related volumetric decreases in different parts of the cerebellum (17, 18, 19). Han et al. (20) reported that the cerebellum hemispheres showed a more significan volumetric decrease with age than the vermis lobules. In addition to these studies, the cerebellum volume does not change with age (21, 22). When the cerebellum volume results were evaluated according to male and female sex, differences were reported (23-25).

Recently, it has been observed that the volBrain software program is used for automatic volume analysis and segmentation of the cerebellum in different age groups and diseases (11, 26). With volBrain's sub-segmentation tool CERES, we obtain information about the cerebellum lobes and tissues (27, 28). Therefore, the present study aimed to evaluate the interaction of the volume of the right/left hemispheres at the lobules level with age groups and sex, as well as the total cerebellum volume, using the volBrain CERES program.

Material Method

Participants

Magnetic Resonance (MR) images of 200 healthy individuals (100 females, 100 males) between the ages of 18-78 were included in the study. Healthy individuals who applied to Ankara Etlik City Hospital with headaches, who did not have a neurological diagnosis, and who did not undergo brain surgery were included in the study. Approval was received from the Ankara Etlik City Hospital Scientific Research Evaluation and Ethics Committee with the decision number AEŞH-BADEK-2024-770.

MR Protocol

MR images were examined using a standard head coil on a 3 Tesla (Philips Ingenia Elition, 2020). For more detailed imaging of the body structure, a high-resolution, sagittal plane, T1-weighted 3D TFE sequence was obtained. Repetition Time (TR): 6.8 ms, Echo Time (TE): 3.2 ms, Field of View (FOV): 256x256 mm2, matrix: 256x256, slice thickness was 1 mm. A total of 195 slices were obtained with the specified parameters in an average of 2 minutes and 35 seconds.

MR segmentation

MR images of participants of both sexes (n=200) included in the study were exported with Picture Archiving and Communication Systems (PACS) in the first stage. In the second stage, these data in Digital Imaging and Communications in Medicine (DICOM) format were anonymized with MRIcron (https://www.nitrc.org/projects/mricron). Then, they were converted to the Neuroimaging Information Technology Initiative format with the same program. The processed MR images were uploaded to volBrain's segmentation tools, the CERES pipeline system. The CERES pipeline is an online, open-access, web-based data processing system that automatically segments cerebellum tissues and lobules. Analysis results are presented as PDF and CSV files (27) (Figure 1)

Image Information

Orientation	radiological
Scale factor	0.67
SNR	14.79
Total intracranial volume (cm^3)	1225.17

Volumes[1]	Total (cm^3/%)	Right (cm^3/%)	Left (cm^3/%)	Asym.(%)[2]
Cerebellum	106.86 (8.7224) [7.9791, 10.7199][5]	53.70 (4.3833) [4.0144, 5.3808]	53.16 (4.3391) [3.9516, 5.3522]	1.0142 [-3.1662, 5.1619]
Lobule I-II	0.19 (0.0154) [0.0000, 0.0269]	0.08 (0.0068) [0.0000, 0.0127]	0.11 (0.0086) [0.0000, 0.0147]	-24.1135 [-44.3086, 37.2144]
Lobule III	1.78 (0.1450) [0.0736, 0.1604]	0.86 (0.0706) [0.0355, 0.0796]	0.91 (0.0744) [0.0361, 0.0828]	-5.2592 [-24.9907, 19.1816]
Lobule IV	3.54 (0.2892) [0.2191, 0.4142]	2.04 (0.1668) [0.0981, 0.2096]	1.50 (0.1224) [0.1110, 0.2146]	30.7026 [-33.9661, 22.2315]
Lobule V	7.55 (0.6166) [0.2191, 0.4142]	3.68 (0.3000) [0.0981, 0.2096]	3.88 (0.3166) [0.1110, 0.2146]	-5.3710 [-33.9661, 22.2315]
Lobule VI	14.73 (1.2025) [0.9752, 1.6064]	7.41 (0.6047) [0.4834, 0.8151]	7.32 (0.5977) [0.4755, 0.8075]	1.1596 [-15.0072, 17.5399]
Lobule Crus I	17.54 (1.4313) [1.4170, 2.3812]	8.87 (0.7237) [0.7127, 1.2107]	8.67 (0.7076) [0.6884, 1.1863]	2.2453 [-10.5788, 15.9092]
Lobule Crus II	13.12 (1.0710) [0.8399, 1.5195]	6.86 (0.5599) [0.4169, 0.7846]	6.26 (0.5111) [0.4054, 0.7525]	9.1140 [-15.4607, 23.0644]
Lobule VIIB	8.46 (0.6906) [0.5018, 0.8782]	3.93 (0.3204) [0.2474, 0.4548]	4.54 (0.3702) [0.2391, 0.4386]	-14.4333 [-19.2651, 26.3492]
Lobule VIIIA	10.45 (0.8528) [0.6226, 1.0599]	4.97 (0.4055) [0.2964, 0.5293]	5.48 (0.4473) [0.3047, 0.5522]	-9.8109 [-26.9777, 19.8886]
Lobule VIIIB	6.85 (0.5589) [0.4352, 0.7265]	3.47 (0.2831) [0.2089, 0.3722]	3.38 (0.2758) [0.2103, 0.3702]	2.6121 [-24.8315, 24.9395]
Lobule IX	7.01 (0.5719) [0.3760, 0.7454]	3.67 (0.2999) [0.1914, 0.3737]	3.33 (0.2721) [0.1821, 0.3743]	9.7143 [-10.9810, 14.9470]
Lobule X	1.11 (0.0903) [0.3760, 0.7454]	0.57 (0.0468) [0.1914, 0.3737]	0.53 (0.0435) [0.1821, 0.3743]	7.3627 [-10.9810, 14.9470]

Lobule segmentation

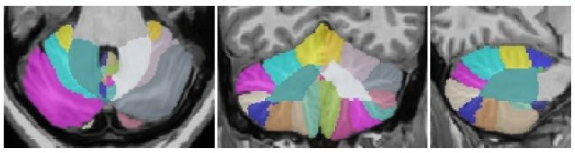

Figure 1. VolBrain CERES segmentation result of a participant

CERES data were visualized in three dimensions with ITK-Snap (https://www.itksnap.org) and 3D Slicer (https://www.slicer.org/, version 5.6.2) (Figures 2 and 3).

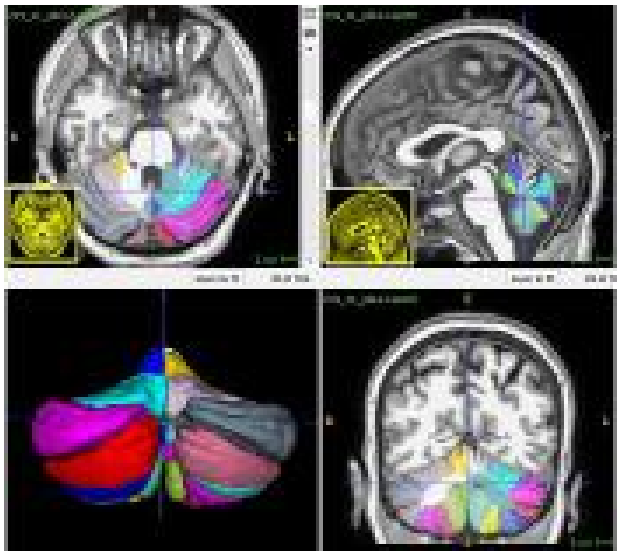

Figure 2. Visualization of volBrain CERES data with ITK-Snap

Figure 3. Visualization of volBrain CERES data with 3D Slicer

Results

A total of 200 healthy individuals, 100 males, and 100 females, were included in the study. The ages of the participants ranged from 18 to 78 years, and the mean age was 43.9±15.7 years. According to Table 1, total cerebellum and right and left cerebellum volume values were statistically higher in males than in females ($p<0.05$). According to Pearson correlation coefficient analysis, a statistically significant negative correlation was found between total cerebellum, right and left cerebellum volumes, and age ($p<0.05$; r1=-0.368, r2=-0.363, and r3=-3.68, respectively).

There was no statistically significant relationship between lobule I-II total, lobule I-II right, lobule I-II left, lobule V right, lobule VI total, and lobule VI right volume values of males and females ($p>0.05$). In all other lobe measurements, the measurement values of males were statistically higher than females ($p<0.05$). In the Pearson correlation coefficie t findings, no statistically significant relationship was found between age and lobule I-II total, lobule I-II right, lobule I-II left, and lobule III right volume values ($p>0.05$). A statistically significant negative correlation was found between all other lobe volumes and age ($p<0.05$) (Table 2).

Total cerebellum and right and left cerebellum volume values were statistically lower in the 50 and over group compared to the under 50 group ($p<0.05$) (Table 3).

According to Table 4, the differences between the lobule I-II total, lobule I-II right, and lobule I-II left volume values of the under 50 and 50 and over groups were not statistically significant ($p>0.05$). In all other parameters, the volume results of the 50 and over group were statistically lower than the under 50 group ($p<0.05$).

The right side lobule I-II, lobule IV, lobule crus II, lobule VIIB, lobule VIIIA, and X volume values were statistically higher than the left side ($p<0.05$). The lobule V, VIIIB, and IX volume values were statistically higher on the left side ($p<0.001$). There was no statistical difference in the volume values of lobule III, lobule VI, and lobule crus I on the right and left sides ($p>0.05$) (Table 5).

Statistical Method

Data were evaluated using the Statistical Package for Social Sciences for Standard Concurrent User, version 29.0 (SPSS, IBM Corp., Armonk, New York, USA). Descriptive statistics were given as mean ± standard deviation. Two-group comparisons were made using the t-test in independent samples. Differences between right and left-side volume measurements were compared using the paired t-test. Relationships

Table 1. Comparison of Cerebellum Volume by Sex and Correlation of Measurements with Age

Variables		Sex				Age (years)	
		Female	Male	t value	*p* value†	r	*p*
Cerebellum volume (cm^3)	T	115.417±12.258	126.277±14.784	5.655	**<0.001**	**-0.368**	**<0.001**
	R	57.938±6.202	63.340±7.498	5.552	**<0.001**	**-0.363**	**<0.001**
	L	57.479±6.104	62.937±7.443	5.670	**<0.001**	**-0.368**	**<0.001**

Data are summarized as mean±standard deviation. †: Independent samples t-test. *r*: Pearson correlation coefficient (T: Total, R: Right, L: Left)

Table 2. Comparison of Cerebellum Lobe Measurements Under Sex and Correlation with Age

Cerebellum lobe volume (cm^3)		Sex				Age (years)	
		Female	Male	*t* value	*p* value†	r	p
Lobule I-II	T	0.126±0.048	0.125±0.040	0.208	0.836	0.109	0.123
	R	0.064±0.021	0.063±0.021	0.077	0.939	0.083	0.245
	L	0.063±0.032	0.061±0.023	0.271	0.787	0.112	0.116
Lobule III	T	1.387±0.261	1.523±0.305	3.393	**0.001**	**-0.151**	**0.033**
	R	0.706±0.146	0.763±0.159	2.646	**0.009**	-0.134	0.059
	L	0.681±0.133	0.760±0.161	3.786	**<0.001**	**-0.152**	**0.032**
Lobule IV	T	4.142±0.615	4.690±0.737	5.716	**<0.001**	**-0.216**	**0.002**
	R	2.046±0.333	2.293±0.380	4.906	**<0.001**	**-0.260**	**<0.001**
	L	2.096±0.334	2.397±0.419	5.615	**<0.001**	**-0.147**	**0.037**
Lobule V	T	7.742±1.188	8.136±1.155	2.379	**0.018**	**-0.195**	**0.006**
	R	3.872±0.641	4.022±0.620	1.689	0.093	**-0.182**	**0.010**
	L	3.870±0.609	4.114±0.612	2.821	**0.005**	**-0.185**	**0.009**
Lobule VI	T	15.829±2.382	16.528±2.782	1.910	0.058	**-0.335**	**<0.001**
	R	7.937±1.245	8.256±1.500	1.639	0.103	**-0.331**	**<0.001**
	L	7.892±1.210	8.272±1.392	2.060	**0.041**	**-0.316**	**<0.001**
Lobule Crus I	T	22.627±3.514	24.550±4.037	3.593	**<0.001**	**-0.359**	**<0.001**
	R	11.424±1.833	12.463±1.995	3.833	**<0.001**	**-0.339**	**<0.001**
	L	11.202±1.761	12.087±2.128	3.204	**0.002**	**-0.363**	**<0.001**
Lobule Crus II	T	14.961±2.259	16.275±2.696	3.738	**<0.001**	**-0.318**	**<0.001**
	R	7.607±1.191	8.305±1.474	3.684	**<0.001**	**-0.308**	**<0.001**
	L	7.354±1.181	7.970±1.350	3.437	**0.001**	**-0.299**	**<0.001**
Lobule VIIB	T	8.360±1.199	9.346±1.547	5.039	**<0.001**	**-0.266**	**<0.001**
	R	4.222±0.627	4.770±0.921	4.920	**<0.001**	**-0.259**	**<0.001**
	L	4.138±0.658	4.576±0.762	4.354	**<0.001**	**-0.234**	**0.001**
Lobule VIIIA	T	10.296±1.488	12.202±2.007	7.630	**<0.001**	**-0.274**	**<0.001**
	R	5.086±0.829	5.951±1.046	6.480	**<0.001**	**-0.249**	**<0.001**
	L	5.209±0.798	6.251±1.110	7.620	**<0.001**	**-0.266**	**<0.001**
Lobule VIIIB	T	7.173±0.957	8.389±1.211	7.881	**<0.001**	**-0.261**	**<0.001**
	R	3.516±0.517	4.112±0.636	7.264	**<0.001**	**-0.213**	**0.003**
	L	3.656±0.504	4.277±0.678	7.349	**<0.001**	**-0.278**	**<0.001**
Lobule IX	T	6.614±1.278	7.279±1.297	3.652	**<0.001**	**-0.272**	**<0.001**
	R	3.379±0.653	3.721±0.678	3.628	**<0.001**	**-0.251**	**<0.001**
	L	3.234±0.635	3.558±0.638	3.592	**<0.001**	**-0.287**	**<0.001**
Lobule X	T	1.115±0.154	1.194±0.188	3.251	**0.001**	**-0.256**	**<0.001**
	R	0.567±0.079	0.605±0.104	2.898	**0.004**	**-0.234**	**0.001**
	L	0.548±0.080	0.590±0.091	3.402	**0.001**	**-0.263**	**<0.001**

Data are summarized as mean ± standard deviation. †: Independent samples t-test. *r*: Pearson correlation coefficient (T: Total, R: Right, L: Left)

Table 3. Comparison of Cerebellum Measurements According to Age Groups

Variables		Groups		Test Statistics	
		<50	≥50	t value	*p* value†
Cerebellum volume (cm^3)	T	125.116±15.151	114.444±11.037	5.413	**<0.001**
	R	62.747±7.657	57.478±5.652	5.270	**<0.001**
	L	62.369±7.627	56.966±5.441	5.473	**<0.001**

Data are summarized as mean±standard deviation. †: Independent samples t-test (T: Total, R: Right, L: Left)

Table 4. Comparison of Cerebellum Lobe Measurements According to Age Groups

Cerebellum Lobe Volume (cm^3)		Groups		Test Statistics	
		<50	≥50	*t* value	*p* value†
Lobule I-II	T	0.123±0.043	0.129±0.046	-0.973	0.332
	R	0.063±0.022	0.064±0.018	-0.020	0.984
	L	0.060±0.024	0.066±0.033	-1.530	0.128
Lobule III	T	1.504±0.314	1.380±0.235	3.021	**0.003**
	R	0.760±0.167	0.696±0.127	2.899	**0.004**
	L	0.744±0.163	0.684±0.129	2.809	**0.005**
Lobule IV	T	4.562±0.777	4.197±0.596	3.568	**<0.001**
	R	2.252±0.393	2.046±0.318	3.909	**<0.001**
	L	2.311±0.434	2.151±0.344	2.772	**0.006**
Lobule V	T	8.189±1.254	7.564±0.965	3.776	**<0.001**
	R	4.072±0.660	3.759±0.544	3.520	**0.001**
	L	4.117±0.663	3.804±0.500	3.587	**<0.001**
Lobule VI	T	16.890±2.649	15.110±2.149	5.009	**<0.001**
	R	8.455±1.408	7.558±1.163	4.725	**<0.001**
	L	8.435±1.337	7.552±1.090	4.915	**<0.001**
Lobule Crus I	T	24.592±4.093	22.083±3.029	4.692	**<0.001**
	R	12.420±2.084	11.229±1.574	4.349	**<0.001**
	L	12.172±2.098	10.854±1.539	4.821	**<0.001**
Lobule Crus II	T	16.259±2.712	14.656±1.988	4.533	**<0.001**
	R	8.306±1.439	7.430±1.106	4.613	**<0.001**
	L	7.953±1.383	7.227±1.035	4.005	**<0.001**
LobuleVIIB	T	9.159±1.582	8.394±1.137	3.728	**<0.001**
	R	4.666±0.889	4.241±0.668	3.644	**<0.001**
	L	4.493±0.799	4.153±0.600	3.243	**0.001**
Lobule VIIIA	T	11.671±2.041	10.615±1.781	3.769	**<0.001**
	R	5.700±1.017	5.246±1.011	3.101	**0.002**
	L	5.971±1.148	5.369±0.906	3.941	**<0.001**
Lobule VIIIB	T	8.013±1.248	7.432±1.170	3.303	**0.001**
	R	3.915±0.645	3.661±0.632	2.749	**0.007**
	L	4.097±0.678	3.771±0.617	3.457	**0.001**
Lobule IX	T	7.252±1.378	6.487±1.104	4.153	**<0.001**
	R	3.696±0.711	3.331±0.585	3.816	**<0.001**
	L	3.556±0.682	3.157±0.534	4.413	**<0.001**
Lobule X	T	1.194±0.180	1.096±0.152	3.998	**<0.001**
	R	0.605±0.098	0.557±0.078	3.617	**<0.001**
	L	0.589±0.089	0.539±0.078	4.120	**<0.001**

Data are summarized as mean±standard deviation. †: Independent samples t-test (T: Total, R: Right, L: Left)

Table 5. Comparison of the Right- and Left-sided Measurements

Cerebellum lobe volume (cm^3)	Side		Test Statistics	
	Right	Left	*t* value	*p* value‡
Lobule I-II	60.639±7.378	60.208±7.320	3.565	**<0.001**
Lobule III	0.063±0.021	0.062±0.028	0.968	0.334
Lobule IV	0.735±0.155	0.720±0.153	2.062	**0.041**
Lobule V	2.169±0.377	2.247±0.407	-3.814	**<0.001**
Lobule VI	3.947±0.634	3.992±0.621	-1.536	0.126
Lobule Crus I	8.096±1.384	8.082±1.315	0.287	0.774
Lobule Crus II	11.943±1.981	11.645±1.998	5.247	**<0.001**

Lobule VIIB	7.956±1.382	7.662±1.302	5.260	**<0.001**
Lobule VIIIA	4.496±0.832	4.357±0.743	3.378	**<0.001**
Lobule VIIIB	5.519±1.036	5.730±1.096	-4.097	**<0.001**
Lobule IX	3.814±0.650	3.967±0.672	-4.909	**<0.001**
Lobule X	3.550±0.686	3.396±0.655	11.018	**<0.001**

Data are summarized as mean±standard deviation. ‡: Paired t-test

between age and volume values were evaluated using the Pearson correlation coefficient. A $p<0.05$ value was considered statistically significant

Discussion

The cerebellum is a neuroanatomical structure providing important connections with the brainstem. In the literature, volumetric studies of the cerebellum have been analyzed according to age and sex using different techniques. Our aim in this study was to investigate the right-left cerebellum volume of healthy individuals at the lobular level by creating groups of under 50 and over 50 years of age according to age/sex using the CERES program, which is the lower toolbar of volBrain.

Previous studies reported that the cerebellum volume varied according to sex using the stereological method, but age did not have a significant effect (29). In another study using the same method, cerebellum volume was estimated in 19 healthy Caucasian males aged between 19 and 84. The total cerebellum volume was reported to decrease by 16% without any neuronal loss. The same study also emphasized that there is a decrease in frontal lobe volume with age (30).

In a study conducted on healthy volunteers, the total cerebellum volume remained constant until age 50 and decreased with age (17). Similarly, in our study, total cerebellum volume values in the group aged 50 and over were statistically lower than those under 50.

In the study of Yilmaz et al. (31), cerebellum volume was analyzed using three different software on MR images of 18 male individuals aged 22-30. With the volBrain CERES method, the total cerebellum volume was reported as 152.12±20.40 cm3 on mean, right cerebellum volume as 75.69±10.41 cm3, left cerebellum volume as 76.40±10.00 cm3. The findings were higher than our results. In the volBrain CERES study of Sahin et al. (13), which included 10 healthy groups (mean age 48 years), the total cerebellum volume was reported as 138.06 cm3 on mean lobules IV as 5.06 cm3, and lobules V as 8.62 cm3. In our study, which was conducted with the same method, lobules IV and V were partially similar, and the total cerebellum volume was lower. We think that the differences in the findings may be related to sample size and mean age.

In one part of the study by Özgen et al. (32), the total cerebellum volume of 24 healthy individuals with a mean age of 59.62±7.34 years was reported as 115.53±10.44 cm3, and the total flocconodular lobe volume as 1.29±0.71 cm3. In the literature, the flocculonodular lobe is expressed as lobules X (5, 6). Based on this, in our study, the total cerebellum volume of the 50-year-old and older group was 114.44±11.03 cm3, while the total lobules X volume was 1.09±0.15 cm3. The findings are consistent with our current study.

Romero et al. (33) reported that cerebellum volume was higher in males in the volBrain CERES study of a healthy group (1-94 years of age). It was reported that lobules IV, VIIIA, V, VI, VIIB, IX, and crus I differed according to sex. In another volBrain study, it was reported that the cerebellum volume of 20 depressed patients and 20 healthy groups did not show any statistical difference. The total cerebellum volume of the healthy group of the same study was reported as 143.70 cm3 in males and 141.26 cm3 in females. It was stated that cerebellar lobe volume was not statistically significant in the healthy group according to sex. According to the study of Özmen et al. (11), in which we used the same software program, it was seen that total cerebellum volume was higher than our results according to sex. In addition, in our current study, cerebellum volume and some lobule volume results were statistically higher in males. We think the sample size and average age will create differences in the measurements (11).

In a pediatric study of 670 individuals aged 1-18 years, it was reported by the volBrain CERES method that the absolute volumes of the total cerebellum and lobules were larger in males. In addition, when evaluated according to age groups, it was stated that there were greater sex differences in the volumes of lobules IV, VIIB, VIIIA, and VIIIB (26). Another pediatric study reported that the cerebellum volume of 100 healthy

individuals between 0-15 was positively correlated with age. In addition, it was reported that the values of lobules I-II, VI, VIIIB, IX, and X were statistically significant in the right and left cerebellum volume analysis (34).

Hutchinson et al. (35) evaluated the cerebellum volume of musician and non-musician groups according to sex. The cerebellum volume of male musicians was larger than that of non-musician males, while no difference was reported when looking at the female group.

Recently, we have seen many studies in the literature using up-to-date software on cerebellum volume. Thanks to this software, cerebellum volume results at the lobular level are presented objectively and reliably. In our current study, cerebellum volume measurements of healthy individuals were made using the CERES method, a sub-tab of the volBrain software program. As far as we know from the literature, results evaluating the cerebellum volume at the right/left lobular level and by creating age groups according to sex have not been reported so far.

Conclusion

Cerebellum volume varies according to age, sex, and disease type. Of course, in this situation, clinicians must evaluate the individual's development and follow the course of the disease.

In our study, the volumes of the cerebellum at the lobular level in healthy individuals were analyzed. In the parameters examined, except for lobule I-II total, lobule I-II right, lobule I-II left, lobule V right, lobule VI total, and lobule VI right values, the values of males were found to be statistically higher than those of females.

In all parameters except for lobule I-II total, lobule I-II right, and lobule I-II left values, participants aged 50 and over were statistically lower than those under 50. We believe that the results of our study will contribute to clinicians.

Conflict of Interest

The authors declare no conflict of interest

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Author contributions NGC

Idea/Hypothesis, Conception, design, supervision, data processing, analysis-interpretation, literature review, writer, critical review, approval of the version to be published. MO: Materials, data collection, data processing, analysis, interpretation, literature review, writer, critical review, approval of the version to be published.

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