

# Age and Gender Related Morphometric Analysis of the Fourth Ventricle Using MRI in Healthy Adults: A Cross-Sectional Study

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## Abstract

**Objective:** To analyze age- and gender-related differences in the length and width of the fourth ventricle using MRI in healthy adults in two different age groups.

**Methodology:** This cross-sectional study was conducted in the Department of Anatomy and Radiology of Jinnah Postgraduate Medical Centre, Karachi, from November 2019 to December 2021. The study was carried out on 206 healthy subjects divided into two age groups: Group A (20–40 years) and Group B (41–60 years). Both groups included male and female participants with no clinical symptoms or metallic implants. Images were acquired using a thin-slice (1 mm) 3D brain MRI protocol on a 1.5-Tesla scanner (T1-weighted, T2-weighted, and FLAIR sequences). Fourth-ventricle dimensions were measured on axial images using MicroDicom: length was measured craniocaudally at the midline (roof-to-floor), and width was measured transversely at the level of the lateral recesses.

**Results:** The fourth ventricle was slightly larger in males than in females in both age groups. In Group A (20–40 years), males had a mean length of  $14.3 \pm 1.16$  and width of  $13.6 \pm 1.36$ , compared to females (length  $13.8 \pm 0.91$ , width  $12.9 \pm 1.35$ ;  $p = 0.007$ ). In Group B (41–60 years), males were slightly larger (length  $14.7 \pm 1.19$ , width  $13.9 \pm 1.19$ ) than females (length  $14.5 \pm 1.02$ , width  $13.6 \pm 1.21$ ), without statistical significance. Age-related comparison showed a significant increase in females' length ( $p = 0.001$ ) and width ( $p = 0.005$ ), while males showed no significant change (all values in mm).

**Conclusion:** The study provides MRI-based normative reference values for fourth-ventricle dimensions in healthy Pakistani adults, demonstrating modest gender differences and age-related enlargement, particularly in females. These population-specific measurements serve as an important baseline for distinguishing normal anatomical variation from pathological ventricular dilation in clinical practice.

**Keywords:** Fourth ventricle, Magnetic resonance imaging, Normative reference values, Ventricular morphometry

## Introduction

The fourth ventricle is a cerebrospinal fluid (CSF)-filled cavity situated in the posterior cranial fossa between the pons, medulla oblongata and the cerebellum. It forms a crucial segment of the brain's ventricular system linking the cerebral aqueduct with the third ventricle above, and central canal of spinal cord below.<sup>1</sup> It is adjacent to critical brainstem structures and CSF pathways so its size and/or shape is often subjected to the changes, associated with conditions such as hydrocephalus, posterior cranial fossa masses, or obstruction to CSF flow.<sup>2,3</sup> Precise evaluation of fourth ventricular dimensions is therefore important to distinguish normal anatomical variations from pathological ventricular enlargements in clinical practice.<sup>4,5</sup>

Neuro-circuitry development in the human brain continues until approximately 30–40 years of age; however, degenerative changes gradually appear as the age advances. Age-related cortical atrophy, accompanied by compensatory ventricular enlargement, poses a significant challenge for physicians, neurologists, and radiologists when distinguishing normal aging from pathological conditions.<sup>6</sup> Pathological dilatation of the ventricles can compress nearby critical structures, further complicating clinical assessment.<sup>7</sup> Before the advent of non-invasive imaging modalities such as CT and MRI, clinicians relied on invasive and hazardous techniques, including pneumoencephalography and contrast ventriculography. In the present study, MRI was selected instead of CT because MRI provides safer imaging without ionizing radiation and offers superior visualization of brain fluids and soft tissues in sagittal, axial, and oblique planes without requiring changes in patient posture.<sup>8,9</sup>

Despite several international studies examining ventricular dimensions to differentiate normal from diseased brains, there remains a clear lack of population-specific, MRI-based normative reference values for the fourth ventricle in Pakistan.

Ventricular size is known to vary with ethnic, genetic, and anthropometric factors, yet no MRI study has established normative fourth-ventricular measurements for Pakistani adults, which represents a significant diagnostic gap. Although some regional studies have addressed ventricular morphometry, most have relied on CT imaging, which provides inferior soft tissues contrast and less accurate delineation of ventricular boundaries compared to MRI.<sup>10,11</sup> Furthermore, age- and gender-related variations in fourth-ventricle dimensions remain poorly documented, particularly in adults aged 20–60 years, despite evidence that ventricular size changes with aging and differs between males and females. This lack of regional reference population datasheet is clinically important because the fourth ventricle lies close to several essential nuclei and plays a critical role in cerebrospinal fluid circulation.<sup>12,13</sup> Even subtle deviations in its dimensions may signal early hydrocephalus, CSF-flow obstruction, posterior-fossa tumors, Chiari malformation, or Dandy–Walker malformations.<sup>7,14</sup>

Despite extensive research on the lateral and third ventricles, global data on fourth-ventricle morphometry remain limited, and to our knowledge, no MRI-based normative measurements exist for the Pakistani population. Accurate morphometric data are essential for identifying abnormal ventricular enlargement or posterior fossa pathologies, yet clinicians in Pakistan currently lack reference standards for comparison. To address this gap, the present study was undertaken to provide detailed morphometric measurements of the fourth ventricle in healthy Pakistani adults aged 20–60 years of both genders. The objective was to evaluate age- and sex-related variations in fourth-ventricle dimensions, thereby establishing foundational MRI-based normative data for clinical and research applications in the local population.

## Methodology

This analytical cross-sectional study was conducted in the Department of Anatomy, Basic Medical Sciences Institute (BMSI), in collaboration with the Department of Radiology, Jinnah Postgraduate Medical Centre (JPMC), Karachi. The study was conducted from November 2019 to December 2021 after approval by the Institutional Review Board (Ref. #F.2-81/2019-GENI/35808/JPMC, dated 25 October 2019). The study period was prolonged due to intermittent interruptions in imaging services during the COVID-19 pandemic. All patient data were anonymized and handled with strict confidentiality in accordance with ethical standards. A total of 206 adult volunteers were recruited. Participants were considered clinically healthy for research purposes. However, the sample was not fully representative of the general population. A selection bias was present because many volunteers approached the radiology department for mild, non-specific complaints such as headaches, vertigo, or visual discomfort, and a subset requested MRI due to a family history of brain tumors. These factors are explicitly acknowledged as potential contributors to population bias. Although these symptoms were not linked to any diagnosed neurological condition and did not meet exclusion criteria, they were unevenly distributed across groups. Participants were divided into two age groups to assess age-related variation in fourth-ventricle morphology: Group A (20–40 years) and Group B (41–60 years). In Group A, reported symptoms included headaches (34%), visual disturbances (29.4%), vertigo (22.8%), and mood changes (17.9%). In

Group B, vertigo was more common (44%), followed by visual disturbances (16%), headaches (18%), and mood changes (7%). Notably, approximately 15% of Group B participants were asymptomatic and underwent MRI due to a positive family history of brain tumors. All individuals were clinically evaluated and deemed neurologically fit prior to inclusion.

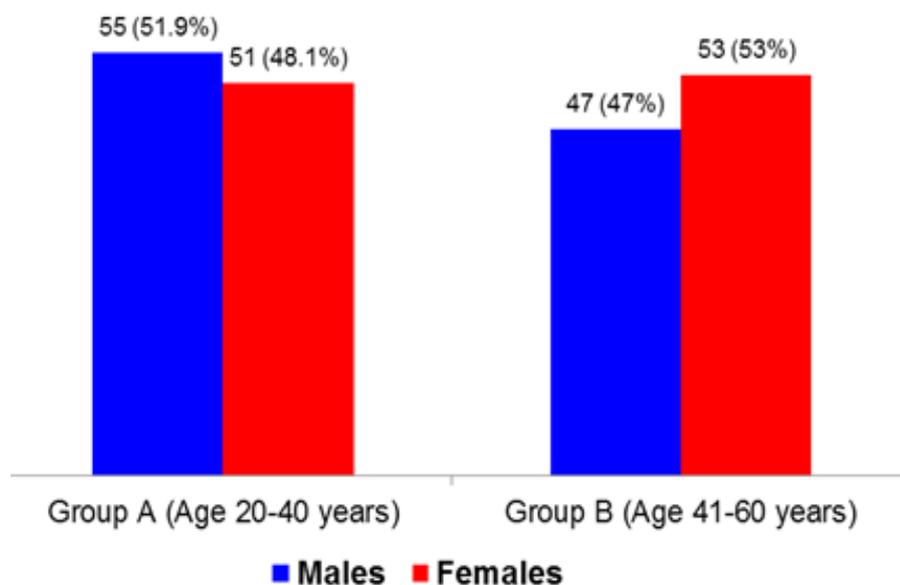
The sample size was calculated using OpenEpi, with a 95% confidence interval and 5% margin of error. Consecutive sampling was used to recruit healthy adults aged 20–60 years. Participants with neurological disorders, brain abnormalities, or prior cranial surgery were excluded. Both males and females were included, as ventricular measurements may vary with age and gender. Before imaging, all participants received an explanation of the study and signed written informed consent. A brief medical and neurological screening was performed. Exclusion criteria included any history of intracranial surgery, diagnosed neurological disorders (such as stroke, tumors, or demyelinating disease), systemic conditions that could alter brain morphology, and MRI contraindications like pacemakers or metallic implants. MRI scans were obtained using a Toshiba Vantage Elan 1.5-Tesla scanner (2017) at the JPMC Radiology Department. Standardized brain MRI protocols were followed. T1-weighted and T2-weighted images were acquired in the axial plane, while FLAIR sequences were acquired in the coronal plane. All sequences used a 1-mm slice thickness, appropriate for precise morphometric assessment of ventricular boundaries. Repetition time (TR) and echo time (TE) values were selected according to standard diagnostic protocols. Total scan time was approximately 25–30 minutes.<sup>15</sup> All scans were performed by a senior MRI technologist with over 10 years of experience, and images were reviewed by an Associate Professor of Radiology.

Fourth-ventricle measurements were performed on axial MRI images using MicroDicom software. Although MRI scans were acquired in 3D, 2D axial measurements were used because these planes provide the clearest and most reproducible view of ventricular boundaries, allow comparison with previous studies, and reflect clinically relevant dimensions. Length was measured craniocaudally at the midline, and width transversely at the lateral recesses. All measurements were repeated by the same observer to assess intra-observer reliability, and a subset was measured independently by a second observer for inter-observer reliability using consistent anatomical landmarks. Data was analyzed using SPSS version 19.0. Quantitative variables were compared between age groups using the independent samples t-test, provided normality assumptions were satisfied. A p-value < 0.05 was considered statistically significant.

## Results

Study subjects were 206, divided into group A, which comprises 106 (51.5%), and group B, which comprises of 100 (48.5%) subjects. The total number of males and females in both groups was 102 (49.5%) and 104 (50.5%), respectively, as shown in Figure 1.

Morphometric measurements of the fourth ventricle were recorded in millimeters (mm) for both length and width. In Group A, males had a greater mean length ( $14.3 \pm 1.16$ )



**Figure 1:** Gender distribution of participants across age groups.

compared with females ( $13.8 \pm 0.91$ ). Similarly, mean width was higher in males ( $13.6 \pm 1.36$ ) than in females ( $12.9 \pm 1.35$ ), with the difference reaching statistical significance ( $p = 0.007$ ). In Group B, males also showed slightly higher values than females, with mean length of  $14.7 \pm 1.19$  in

males versus  $14.5 \pm 1.02$  in females, and mean width of  $13.9 \pm 1.19$  versus  $13.6 \pm 1.21$ , although these differences were not statistically significant. The results are summarized in Table 01 and Figure 2.

**Table 1:** Gender-based comparison of fourth ventricle dimensions within age groups

Dimensions	Male (n=55)	Female (n=51)	P-value
<b>Group A (20-40) years</b>			
Length	$14.3 \pm 1.16$	$13.8 \pm 0.91$	0.007
Width	$13.6 \pm 1.36$	$12.9 \pm 1.35$	0.007
<b>Group B (41-60) years</b>			
Length	$14.7 \pm 1.19$	$14.5 \pm 1.02$	0.317
Width	$13.9 \pm 1.19$	$13.6 \pm 1.21$	0.170

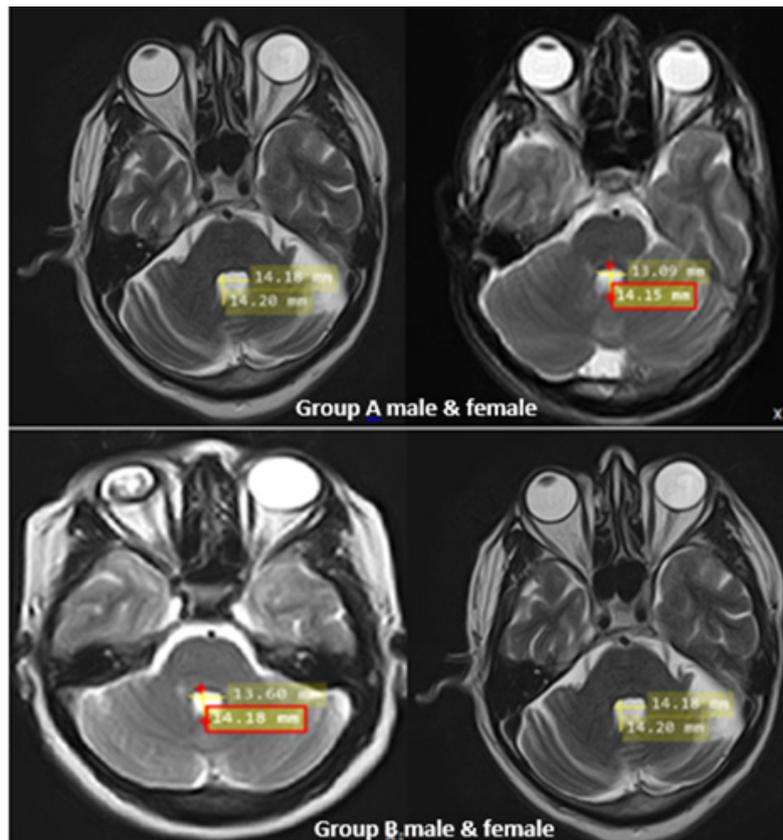
**Table 2:** Age-based comparison of fourth ventricle dimensions stratified by sex

Dimensions	Age (20-40) years	Age (41-60) years	P-value
<b>Male</b>			
Length	$14.3 \pm 1.16$	$14.7 \pm 1.19$	0.081
Width	$13.6 \pm 1.36$	$13.9 \pm 1.19$	0.184
<b>Female</b>			
Length	$13.8 \pm 0.91$	$14.5 \pm 1.02$	0.001
Width	$12.9 \pm 1.35$	$13.6 \pm 1.21$	0.005

Morphometric measurements were recorded in millimeters (mm) for both length and width. Comparison of males between Group A and Group B showed no significant differences in length ( $14.3 \pm 1.16$  vs.  $14.7 \pm 1.19$ ) or width ( $13.6 \pm 1.36$  vs.  $13.9 \pm 1.19$ ). In females, however, Group B showed significantly larger dimensions than Group A, with length of  $14.5 \pm 1.02$  versus  $13.8 \pm 0.91$  ( $P = 0.001$ ) and width of  $13.6 \pm 1.21$  versus  $12.9 \pm 1.35$  ( $P = 0.005$ ). These findings are summarized in Table 02 and Figure 02.

## Discussion

The study provides MRI-based morphometric dimensions of fourth-ventricle in Pakistani healthy adults and age- and sex-related variations among two age groups. Observations exhibit that males generally have slightly larger measurements of fourth-ventricle than females. Group A males have length and width  $14.3 \pm 1.16$  mm and  $13.6 \pm 1.36$  mm whereas females have  $13.8 \pm 0.91$  mm and  $12.9 \pm 1.35$  mm respectively (Table 1, Figure 2).



**Figure 2:** Comparison of fourth ventricle measurements across age groups and sex

Comparison between two age groups show no significant change in males, whereas Group B females in comparison to Group A females demonstrate a significant increase in length as well in width (Table 2, Figure 2). These results provide standard parameters for Pakistani population and distinguish normal anatomical dimensions from pathological enlargement of fourth ventricles.

The observed sex variances are constant with well-known biological patterns, as males typically have larger cranial fossae, contributing to slightly greater ventricular dimensions. Age-related enlargement in females reveals physiological parenchymal atrophy, which gradually decreases posterior fossa parenchymal volume and allows fourth ventricle modest compensatory expansion. These anatomical based changes are physiological rather than pathological or disease-related alterations. These physiological tendencies line up with previous morphometric observations of different regions show mild increases in ventricular measurements with age and gender differences in healthy adults.<sup>15,16</sup> Comparisons with other studies point out both methodological and population-based variations. Multiple Indian CT-based studies have demonstrated larger fourth-ventricle measurements than those in our study. CT-based study from Jaipur reveal fourth-ventricle mean values (12.57 mm in males and 11.58 mm in females), with significant age and sex related variations; and from South Indian reported mean dimensions (12.16 mm in males and 11.38 mm in females), also showing sex-related differences.<sup>18</sup> A study from North India also shows the same result.<sup>19</sup> A Bangladeshi CT research reveal larger fourth-ventricle dimensions in males and with progressively enlargement with age and sex.<sup>20</sup> An MRI-based study from Northern India exhibits fourth-ventricle dimensions

of 13.12 mm in males and 12.62 mm in females highlight regional anatomical similarities.<sup>21</sup> MRI-based study in Nepalese reveal that fourth-ventricle sizes increase a little with age and are larger in males than females, reflecting patterns comparable to those in our Pakistani population (Singh et al., 2020; Yadav & Yadav, 2025).<sup>22</sup> In Saudi Arabia, CT-based morphometric study by Gameraddin et al. (2015) reported fourth-ventricle dimensions, endorsing sex-related size variants and reflects the importance of population-specific reference measurements.<sup>23</sup> Similar differences have been shown in a Nigerian study.<sup>24</sup>

All over the South Asia, fourth-ventricle dimensions are influenced by both gender and age, stressing the need for regional data rather than relying on external references (Patra et al.2025).<sup>20</sup> CT-based studies may overvalue dimensions due to thicker slices and partial-volume effects, while our 1-mm thin-slice 3D MRI allows precise dimension (Sinha et al., 2023; Kolsur et al. 2018).<sup>16,18</sup> Variations of measurements in different regional studies might be due to direction and planes of slices, and demographic factors. These factors spot the novelty and clinical status of our MRI-based normal anatomical data sheet for Pakistani population in reference to differentiate from pathological enlargement. Clinically, regional reference values are important for accurate measuremental deviations in fourth-ventricular dimensions that may indicate early hydrocephalus, CSF-flow obstruction, Chiari malformation, or other posterior fossa lesions.<sup>8,25</sup>

These measurements from our study provide a baseline for radiologists and neurosurgeons to distinguish anatomical dimensions from pathological lesions, and should be

interpreted cautiously in old adults; as mild enlargement may be physiological.

Over all, our study gives significant, regional-specific MRI data for our population and align up with global norms indicating age and gender related ventricular dilatation. Meanwhile the observational variations among the populations, highlight the importance of regional reference data sheets for clinical interpretation. It can enhance the diagnostic efficacy of MRI in distinguishing normal anatomical regional variation from pathological ventricular dilatation and play a foundation for future morphometric research in the population of South Asian.

### Limitations

The study has many limitations. It was conducted at a single center, which may restrict the generalizability of the results to broader populations. Although the data included 206 participants, divided by age and gender decrease the statistical analyses. Intra-observer and inter-observer reliability was assessed and evaluated for consistency of dimensions. However, 2D linear dimensions were used on selected axial slices rather than full 3D volumetric analysis, which may not catch complete ventricular dimensions. Engaging healthy volunteers for MRI was tough and time-taking, and lead to slower and more selective registration. Yet, this study creates the first MRI-based anatomical reference values for fourth-ventricle measurements in healthy Pakistani population and provides a foundation for future multicenter, longitudinal, and volumetric studies. Moreover, some participants underwent MRI for minor symptoms like headache and vertigo, or family history, which may lead selection bias and limit the presentation of the sample.

### Conclusion

This study generates the MRI-based anatomical morphometric dimensions for the fourth ventricle in healthy Pakistani population, demonstrating a major gap in regional reference neuroimaging data. This study establish that fourth-ventricle magnitudes are generally larger in males than females, with gradual age advancement, showing statistical significance observed among females of age groups 20–40 and 41–60 years. This study by developing the baseline measurements, helps the clinicians to distinguish normal age and sex-related changes from abnormal enlargement of the fourth ventricle. These anatomical values can improve diagnostic accuracy for pathological conditions.

**Authors' Contributions:** AS: Conception and design of the study; data acquisition; drafting of the manuscript; MM: Drafting and revising the manuscript for important intellectual content; HK: Data acquisition and data analysis; critical revision of the manuscript; KK: Critical revision of the manuscript and final approval of the version to be published. All authors meet the ICMJE criteria for authorship and approved the final manuscript.

**Conflict of interest:** None

**Funding:** None to declare

**Data Availability Statement:** The data that support the findings of this study, apart from the data already presented in the results section, are available from the corresponding author upon reasonable request.

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