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# PROSPECTIVE CROSS-SECTIONAL STUDY: MORPHOMETRIC ASSESSMENT OF FRONTAL, TEMPORAL AND OCCIPITAL HORN WIDTHS OF LATERAL VENTRICLES ON CT IN ADULTS OF SIALKOT, PAKISTAN

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**Abstract**

*Background: The most clinically applied linear measures in routine reporting of the cranial CT are the max transverse widths of the frontal, temporal and occipital horns of the lateral cerebral ventricles and each of these measures are taken bilaterally as distinct right and left values. The right frontal horn width is a CT-based measure of central ventricular expansion and proximity to the caudate, while the left frontal horn width is also a CT measure of central expansion and proximity to the caudate; the right and left temporal horn widths are CT-based measures of medial temporal lobe volume; and the right and left occipital horn widths are CT-based measures of posterior ventricular expansion. Further, the Evans Index is a derived ratio based on the maximum frontal horn width and is used widely as a tool to diagnose normal pressure hydrocephalus. Normative CT reference values of these parameters for adults of Pakistan are not available although all six bilateral measurements vary with age and differ between sexes. Objective: To create age and sex stratified normative CT reference values of right and left frontal, temporal and occipital horn widths of lateral cerebral ventricles in healthy Pakistani adult population and to determine the effects of age and sex on these bilateral measurements. Methods: This was a prospective cross-sectional study at Idrees Hospital, Sialkot, Pakistan for a period of six months. One hundred and forty healthy adults (70 males & 70 females) in the age range of 18-80 years were enrolled by convenient sampling, further divided into seven age groups (consisting of 10 subjects in each group) of 10*

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*subjects per sex. Results: Overall mean widths of 140 healthy Pakistani adults (70 males and 70 females) aged between 18 and 80 years varied from 5.2 to 5.8 mm for the six bilateral horn measurements. The age had a very high and significant positive correlation with all six parameters (Spearman's r ranging from 0.913 to 0.945, $p < 0.001$). No statistically significant difference was found between sexes for any of the six measurements (all $p > 0.05$). The right temporal horn was much larger than the left ($Z = -3.807$, $p < 0.001$) but not significantly different from the left for the frontal and occipital horns. Conclusion: This study provides the first age- and sex-stratified normative reference values of bilateral frontal, temporal and occipital horn width of lateral ventricles in healthy adult population of Pakistan. All horn widths show a strong positive correlation with age, are not sex dependent and show an anatomical right to left difference in the temporal horns that can be measured as a normal variant. These reference values should guide the regular reporting and screening of cranial computed tomography in Pakistan.*

## INTRODUCTION

Lateral cerebral ventricles are the largest paired chambers of the cerebral ventricular system which are subdivided anatomically into frontal horns, body, atrium, temporal horns and occipital horns with distinct topographic relationship with the surrounding neural structures throughout (Lejeune et al., 2011; Scelsi et al., 2020). They are reproducible, clinically actionable parameters without needing any specialized post-processing, correlate acceptably with the volumetric measures of the ventricles and can be measured on standardized axial cuts of the CT scan and each can be directly compared bilaterally within the subject (Bao et al., 2016; Bourne et al., 2013; Zhuravlova & Montgomery, 2023). Specifying the width of the right and left horns separately—as is done with the existing normative morphometric studies—will allow estimation of absolute dimensions and of inter-hemispheric asymmetry itself, a parameter of great clinical interest because slight lateral ventricular asymmetry is reported to be a normal anatomical variant in 5-12% of the general population (Kiroğlu et al., 2008; Zhuravlova & Montgomery, 2023). Together these 6 measurements represent the quantitative basis of CT-based lateral ventricular assessment under a wide variety of neurological conditions, and their normative (age- and sex-dependent) characterization is the basis for correct reporting of the cranial CT measurements (Bourne et al., 2013; Scelsi et al., 2020).

Measurements of the right and left frontal horn widths (FHW) are the maximum transverse diameters of the right and left frontal horn at the level of the caudate nuclei heads, and represent the amount of central expansion of the ventricle at the point where the heads of the caudate nuclei form the lateral wall of the ventricle (Bao et al., 2016; Scelsi et al., 2020). Normative studies in literature show right and left FHW separately, including one study that found the left frontal horn to be slightly larger than the right, which is normal cerebral hemispheric lateralization (Bao et al., 2016; Zhuravlova & Montgomery, 2023). Maximum frontal horn width is also included as the numerator in the Evans Index, the global accepted radiological measure of ventriculomegaly and is essential for the diagnosis of idiopathic normal pressure hydrocephalus (NPH) (EVANS, 1942; Relkin et al., 2005). In addition to this indirect use, the bilateral FHW measurement itself is of diagnostic value: progressive bilateral FHW is an indicator of central cerebral atrophy (Ghorbanlou et al., 2024) and unilateral FHW is a part of the CT based differential diagnosis of progressive supranuclear palsy, multiple system atrophy, and unilateral hydrocephalus (Kutyłowski et al., 2023; Yang et al., 2024).

Direct CT surrogates of medial temporal lobe volume consist of the right and left temporal horn widths (THW) measured at the widest point of transversion of the right and left temporal horn, respectively. The medial wall of the temporal horn is formed by the head of the hippocampus and hence the transverse width of temporal horn has been quantitatively validated as a sensitive imaging measure of hippocampal volume loss: CT temporal

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horn width had 93% sensitivity and 80% specificity for AD, and 0.80 convergent validity with hippocampal volumetry by MRI (Frisoni et al., 2002). The bilateral THWs are individually evaluated in standardized CT and MRI imaging protocols for the differential diagnosis of adult-onset hydrocephalus, with enlargement differentiating the communicating from obstructive type (Sedlák et al., 2023). Bilateral THW is a sensitive early marker of neurodegenerative change seen on routine CT which has been documented in aging and cognitively impaired brain (Todd et al., 2018). Bilateral THW has been found to have substantial interrater agreement at standardized axial levels and has good but clinically significant correlation with total ventricular volume in iNPH (Bao et al., 2016).

Of the three segments of horns, the right (OHWr) and left (OHWl) occipital horn widths (measured at the level of the maximum transverse breadth of each occipital horn) are the most morphologically variable bilateral measurements. The left occipital horn is normally longer and wider than the right, and the horns are occasionally elongated on one or both sides or are negligibly prominent as common normal anatomical variants (Scelsi et al., 2020; Zhuravlova & Montgomery, 2023). Direct bilateral OHW measurement is therefore necessary for recording the normative distribution of occipital asymmetry and to give the context within which to recognize deviations with confidence. The width of each pair of bilateral horns (FHW, THW, OHW) also gradually increases across increasing age and are thought to reflect the effects of chronic cerebral volume loss and compensatory CSF space expansion; indeed, in normal adult populations, the $R^2$ values of age correlation with transverse horn width can be as high as 0.62 in CT-based morphometric studies (Dunham et al., 2016; Ghorbanlou et al., 2024). In normative studies (using computed tomography (CT) and magnetic resonance imaging (MRI) for brain measurements) of various populations, males were consistently found to have wider horns on both sides of the calvarium than similarly aged females, which was accounted for by their higher absolute intracranial and brain volume and not pathological enlargement (Silva et al., 2025; Trimarchi et al., 2013).

In most clinical settings in Pakistan, computed tomography is still the main neuroimaging tool for lateral ventricle assessment and use of CT-derived linear measurements of the bilateral ventricles have been shown to correlate with three dimensional volumetric measures and have been shown to reflect clinically important outcomes (Bourne et al., 2013; Dunham et al., 2016; Hedderich et al., 2022; Huang et al., 2025). Normative CT data have been produced for specific populations, including Sudanese (Mohammed & Hassan, 2022), Nepalese (Yadav & Yadav, 2025), Central Indian (Dhok et al., 2020), Saudi Arabian (Alomar & Ghoneim, 2024) and others (Gameraddin et al., 2015) and they all demonstrate that there are significant differences in absolute and bilateral dimensions between different populations that make it impractical to accept or apply foreign normal data to an ethnically different group. To date there are no normative data for CT measures of the bilateral frontal, temporal or occipital horn width of the lateral ventricles for Pakistani healthy adults. This study was aimed at filling this important gap in the literature and providing the first ever age- and sex-based normative CT reference values for all 6 bilateral HW measurements in healthy Pakistani adult population.

## METHODS

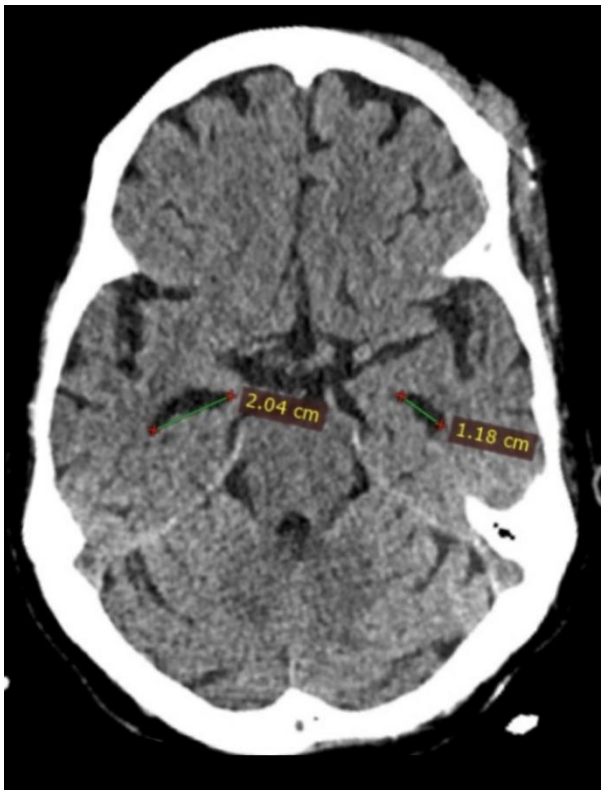
The study was conducted at Idrees Hospital, Sialkot, Pakistan, as a prospective cross-sectional study for six months after obtaining approval by institutional review board and written informed consent from all participants. One hundred forty (70 male/70 female) healthy adults aged 18 to 80 years were recruited with a non-probability convenient sampling method and stratified by 7 age groups (18–20 years, 21–30 years, 31–40 years, 41–50 years, 51–60 years, 61–70 years, and 71–80 years) and by sex (n = 10 per sex per age group); the sample size was based on the number in a similar published normative study (n = 108) with the addition of a 25% contingency plan for potential attrition. The cranial CT scans were performed in 5 mm axial slices without the use of contrast medium, using the Toshiba Aquilion 16-slice multi-detector CT scanner (model CXXG-010A),

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and images were acquired and processed with the RADIANT DICOM advanced visualization platform, and with the integrated scale measurement tools of the Activision 16 software. The maximum transverse widths of the right and left frontal horns, the right and left temporal horn widths, and the right and left occipital horn widths were each measured at the level of the heads of the caudate nuclei, at the point transverse to the temporal horns that was the widest of the temporal horns, and at the level of maximal transverse extent of the occipital horns respectively, resulting in 6 independent bilateral measurements per participant. Measurements were taken by a trained observer from the built-in scale measurement tool and were all made by the same observer. All measurements were made in millimeters (mm). Male and female subjects ranging in ages from 18 to 80 years who had radiologically normal ventricular systems were included, while those with intracranial pathology that distorted the ventricular architecture, space-occupying lesions, previous surgery, pregnant females, motion artifact, or poor visualization of the ventricular horns were excluded. Data were analyzed using IBM SPSS Statistics v.25.

***Fig 1: CT axial slice showing a transverse measurement taken for the temporal horns***



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*Fig 2: CT axial slice showing a transverse measurement taken for the frontal horns*

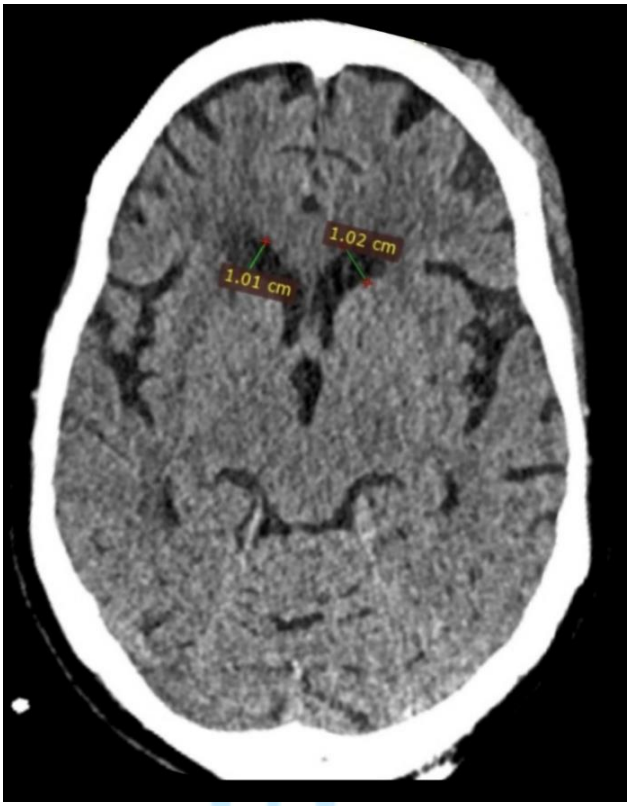



*Fig 3: CT axial slice showing a transverse measurement taken for the occipital horns*



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## RESULTS

In this research, the different portions of the lateral ventricles of the brain and their relation with age and sex were assessed. The width of the right and left lateral ventricles was compared in the entire sample. The collected data were first explored by analyzing basic statistical parameters.

**Table 1: Summary of the width of the different portions of the lateral ventricles of the brain (Millimeters).**

| Summary of Width | Entire Sample, N=140 (100%) | | | | Females, N=70 (50%) | | | | Males, N=70 (50%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Left | | Right | | Left | | Right | | Left | | Right | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Temporal Horns | 5.4 | 2.7 | 5.6 | 3.0 | 5.4 | 2.7 | 5.6 | 3.2 | 5.3 | 2.8 | 5.5 | 2.8 |
| Frontal Horns | 5.6 | 2.8 | 5.2 | 2.8 | 5.5 | 2.8 | 5.6 | 2.7 | 5.6 | 2.9 | 5.5 | 2.9 |
| Occipital Horns | 5.8 | 2.7 | 5.8 | 2.8 | 5.8 | 2.6 | 5.8 | 2.8 | 5.8 | 2.8 | 5.8 | 2.9 |

SD: standard deviation

Across the entire sample (N=140), the mean widths of the left and right lateral ventricular portions were consistently between 5.2 mm and 5.8 mm. The largest mean width was observed in the occipital horns (left and right: 5.8 mm), while the frontal horns showed the smallest right-side mean (5.2 mm), all with standard deviations ranging from 2.6 to 3.0 mm (Table 1).

**Table 2: Correlation of the width of the different portions of the lateral ventricles of the brain with age**

| Variables of the width for the lateral ventricles | Left | | Right | |
|---|---|---|---|---|
| | Spearman's R, N=140 (100%) | P value | Spearman's R, N=140 (100%) | P value |
| Temporal Horns | 0.913 | <0.001 | 0.930 | <0.001 |
| Frontal Horns | 0.915 | <0.001 | 0.913 | <0.001 |
| Occipital Horns | 0.945 | <0.001 | 0.937 | <0.001 |

Correlation is significant at the 0.01 level (2-tailed)

All measured portions of the lateral ventricles showed strong positive correlations with age, with Spearman's r values ranging from 0.913 to 0.945 (all $p < 0.001$). The highest correlation was observed for the left occipital horn ($r = 0.945$), followed closely by the right occipital horn ($r = 0.937$). Both temporal and frontal horns also demonstrated highly significant associations with age on both sides. These findings indicate that widening of the lateral ventricles progresses consistently with increasing age across all examined regions (Table 2).

**Figure 4: Dependence of the width of the different variables of the left lateral ventricle on age**

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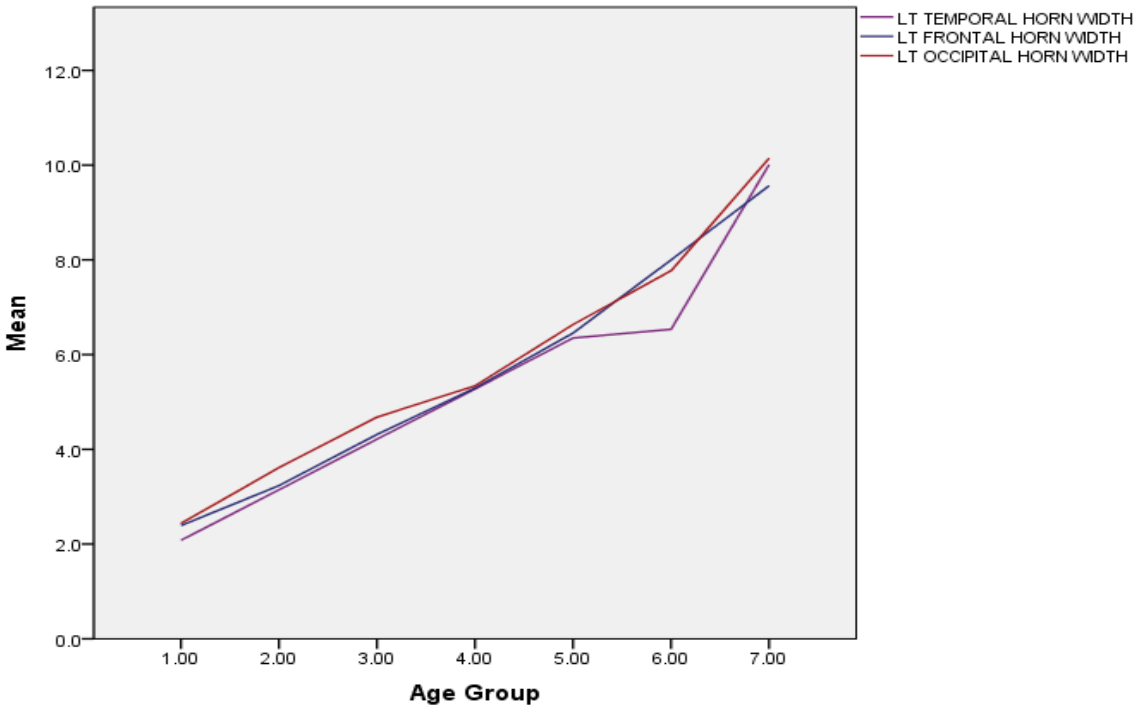
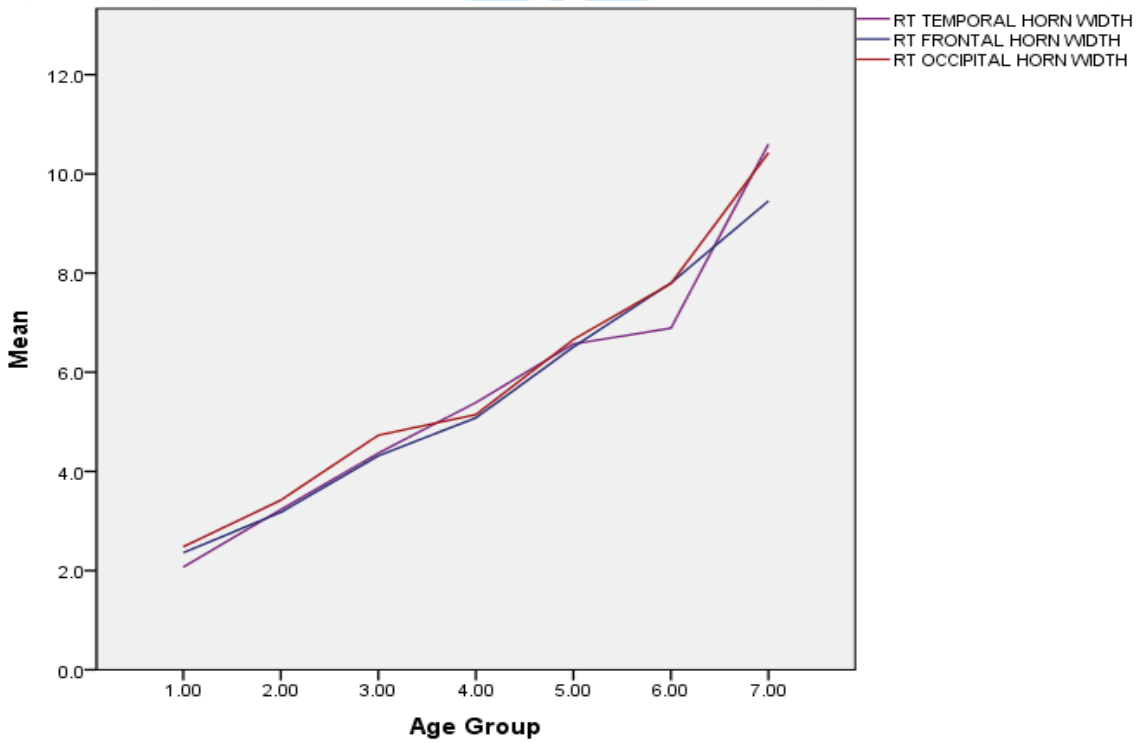



*Figure 5: Dependence of the width of the different variables of the right lateral ventricle on age*



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**Table 3: Comparison of the variables of the width of the right and left lateral ventricles (millimeters).**

| | Rt Temporal Horn – Lt Temporal Horn | Rt Frontal Horn – Lt Frontal Horn | Rt Occipital Horn – Lt Occipital Horn |
|---|---|---|---|
| Z | -3.807 b | -1.889 c | -0.287 c |
| P value | p < 0.001 | 0.059 | 0.774 |

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks
c. Based on positive ranks

A Wilcoxon signed-rank test was used to compare right and left ventricular widths. The right temporal horn was significantly larger than the left ($Z = -3.807$, $p < 0.001$). No statistically significant differences were found between the right and left frontal horns ($Z = -1.889$, $p = 0.059$) or between the right and left occipital horns ($Z = -0.287$, $p = 0.774$). These results indicate that lateral ventricular asymmetry is most pronounced in the temporal horn region, where the right side tends to be wider than the left (Table 3).

**Table 4: Mann-Whitney U test for sex effect on the widths of the different portions of the right and left lateral ventricles (millimeters).**

| | Lt Temporal Horn | Rt Temporal Horn | Lt Frontal Horn | Rt Frontal Horn | Lt Occipital Horn | Rt Occipital Horn |
|---|---|---|---|---|---|---|
| Z | -0.242 | -0.023 | -0.048 | -0.404 | -0.110 | -0.113 |
| P value | 0.809 | 0.982 | 0.962 | 0.686 | 0.912 | 0.910 |

Grouping variable: Sex

The Mann-Whitney U test revealed no statistically significant sex-related differences in the widths of any lateral ventricular portion, with all P-values exceeding 0.05 (ranging from 0.686 to 0.982). The right temporal horn showed the most negligible sex effect ($Z = -0.023$, $p = 0.982$), while the right frontal horn exhibited the largest Z-value among the six comparisons ($Z = -0.404$, $p = 0.686$). Overall, these results suggest that ventricular morphometry is not influenced by sex in this sample (Table 4).

## DISCUSSION

A progressive enlargement of all lateral ventricular horn compartments with increasing age is consistently observed in various groups and imaging techniques, reflecting a progressive accumulation of cerebral atrophy and a compensating expansion of CSF space. A statistically significant difference was seen with age in the widths of all parts of the lateral ventricles as measured in a normative CT study of 108 healthy adults between the ages of 17 and 86 years, with no statistically significant difference between male and female groups (Zhuravlova & Montgomery, 2023), which is similar for the present group of adults. The age correlations obtained for the six bilateral measurements were very high ($r = 0.913$-$0.945$), the widest adult age range being six decades in the present study in which very high age correlations were obtained, as compared to other similar norm data. The results of a PMC-indexed bilateral normative study of age on the other hand, were also consistent with this increased lateral ventricular expansion in older ages, with statistically significant effect noted for all measured widths, except the temporal width (Mohammed & Hassan, 2022). It is remarkable that there is no significant sex effect on any of the six measures. In a few volumetric MRI studies, males have been reported to have larger absolute volumes of the ventricles (Silva et al., 2025; Trimarchi et al., 2013). The strong right-left asymmetry in the width of the temporal horns ($p < 0.001$) that was found in the present study, where the right side is wider than the left side, is a known normal anatomical variation. A meta-analysis of 58 studies verified that lateral ventricular asymmetry is found in virtually every healthy population, and that the degree of asymmetry is related to total ventricular size, but not age or sex (Spierer et al., 2025). The direction of temporal asymmetry (right larger than left) is counter to the standard finding of left frontal horn predominance, and does not have a pathological significance if no other CT findings are present, but rather it may be attributed to individual anatomical variation. Moreover, population-specific reference data are needed since a normative study of frontal horns conducted in Bangladesh with CT showed significantly higher

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frontal horns width among males than females (Basak et al., 2024). Thereby demonstrating that the sex differences in ventricular dimensions are population- and age-group specific highlighting the need for locally developed normative values for frontal horn width.

**CONCLUSION**

This study establishes the first normative reference values for the width of frontal, temporal and occipital horns of the lateral ventricles for bilateral sections in healthy adults from Pakistan in a sex- and age-stratified manner. All six measurements showed very high positive correlation with age ($r = 0.913–0.945$, $p < 0.001$) and this strongly suggests that progressive bilateral ventricular expansion is a general feature of normal ageing throughout the adult life. No sex differences were found in any of the bilateral measurements and sex-specific reference ranges are not indicated for this population. A prominent right-left asymmetry was seen in the temporal horns with the right side tending to be broader and is a normal anatomic variation and should not be confused with unilateral pathological dilatation when reporting. The normative values provide a useful population-specific reference for radiologists and clinicians in Pakistan to assess the size of the lateral ventricles and their symmetry in a variety of neurological diseases such as hydrocephalus, neuro-degenerative diseases and age-related cerebral atrophy.

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