# Morphometric Evaluation of Pons Development in Pediatric Population According to Age and Gender by Magnetic Resonance Imaging

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**Abstract**

**Aim:** Pons is an important posterior fossa structure that contains vital centers. It is essential to know the average morphometric measurement values of the pons in the early diagnosis of developmental and acquired diseases of this structure.

**Method:** Our study was conducted in a healthy pediatric population. There are four age groups: 0-2 years (infants), 3-6 years (young children), 7-11 years (children), and 12-17 years (adolescents), and 50 women and 50 men from each age group. Brain magnetic resonance imaging (MRI) examinations, clinical examinations, and follow-ups of these cases were evaluated as normal. The MRI examination was obtained from the Philips Achieva MR device with a 1.5 Tesla magnetic field strength.

**Results:** Pons area and pons craniocaudal (CC) length increased with age in both genders. On the other hand, the pons anterior-posterior (AP) diameter increased significantly until the 7-11 age group, and then this increased rate decreased and became a plateau. When the genders were compared, the pons area was significantly larger in males than females in all age groups except the 7-11 age group. Pons AP diameter was significantly greater in the 0-2 age group in the males than in females. Pons CC length was significantly greater in the male gender in all groups except the 3-6 age group.

**Conclusion:** This study is essential in the morphological development of the pons and the differences in this structure between the genders. The data obtained in this study may help the differential diagnosis of posterior fossa pathologies in routine clinical practice.

**Keywords:** Magnetic resonance imaging, pediatric population, pons.

**Özgün Araştırma Makalesi (Original Research Article)**
**Geliş / Received:** 12.11.2021 & **Kabul / Accepted:** 09.08.2022
*DOI: https://doi.org/10.38079/igusabder.1022860*

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*ETHICAL STATEMENT: The Regional Ethical Review Board approved the research protocol in The University of Adıyaman Ethics Committee (Date: 21.07.2020, Decision Number: 2020/7-14).*

**Pediatrik Popülasyonda Pons Gelişiminin Yaşa ve Cinsiyete Göre Manyetik Rezonans Görüntüleme ile Morfometrik Değerlendirilmesi**

**Öz**

**Amaç:** Pons, vital merkezleri içeren önemli bir posterior fossa yapısıdır. Bu yapının gelişimsel ve edinsel hastalıklarının erken tanısında ponsun ortalama morfometrik ölçüm değerlerinin bilinmesi önemlidir.

**Yöntem:** Çalışmamız sağlıklı bir pediatrik popülasyonda yapıldı. Dört yaş grubu vardır: 0-2 yaş (bebekler), 3-6 yaş (küçük çocuklar), 7-11 yaş (çocuklar) ve 12-17 yaş (ergenler) ve her yaş grubundan 50 kız ve 50 erkek. Bu olguların beyin manyetik rezonans görüntüleme (MRG) tetkikleri, klinik muayeneleri ve takipleri normal olarak değerlendirildi. MRG incelemesi Philips Achieva MR cihazından 1,5 Tesla manyetik alan gücünde elde edildi.

**Bulgular:** Pons alanı ve pons kraniyo-kaudal (KK) uzunluğu her iki cinsiyette de yaşla birlikte arttı. Öte yandan, pons anteriyor-posteriyor (AP) çapı 7-11 yaş grubuna kadar önemli ölçüde artmış ve daha sonra bu artış hızı azalarak plato haline gelmiştir. Cinsiyetler karşılaştırıldığında 7-11 yaş grubu hariç tüm yaş gruplarında pons alanı erkeklerde kadınlara göre anlamlı olarak daha büyüktü. Pons AP çapı erkeklerde 0-2 yaş grubunda kadınlara göre anlamlı olarak daha büyüktü. Pons KK uzunluğu, 3-6 yaş grubu dışındaki tüm gruplarda erkek cinsiyette anlamlı olarak daha yüksekti.

**Sonuç:** Bu çalışma, ponsun morfolojik gelişiminde ve bu yapının cinsiyetler arasındaki farklılıklarında esastır. Bu çalışmada elde edilen veriler, rutin klinik uygulamada posterior fossa patolojilerinin ayırıcı tanısına yardımcı olabilir.

**Anahtar Sözcükler:** Manyetik rezonans görüntüleme, pediatrik popülasyon, pons.

## Introduction

The brainstem, a subdivision of the brain, includes part of the hypothalamus (diencephalon), midbrain (mesencephalon), pons, and medulla oblongata. Pons is a vital transmitter of sensory and motor information from the forebrain to the cerebellum and plays an essential role in maintaining breathing, sleep, swallowing, eye movements, hearing, facial movements, facial sensation, posture, and consciousness[1].

In humans, the pons is about 2.5 centimeters (0.98 inches) long, and it often appears as a broad anterior protrusion over the medulla. Posteriorly, it consists mainly of two pairs of thick stalks called cerebellar peduncles, and they connect the cerebellum to the pons (middle cerebellar peduncle) and midbrain (superior cerebellar peduncle). During embryonic development, metencephalon develops from rhombencephalon and forms pons and cerebellum[2].

The pons consists of the ventral part and the dorsal tegmentum. The ventral part of the pons mainly contains longitudinal fibers such as corticospinal, corticobulbar, and corticopontine tract.

The dorsal tegmentum of pons contains the trigeminal (V), abducens (VI), facial (VII), and vestibulocochlear (VIII) cranial nerve nuclei. Dorsal tegmentum also includes white matter axon pathways such as medial longitudinal fasciculus, medial lemniscus, lateral lemniscus, spinothalamic pathway, and central tegmental pathway. The trapezoid body, a part of the auditory pathway in the localization of the sound, is also located on the pons. The vascular supply of the pons is provided by the medial branches of the upper cerebellar arteries, the branches of the basilar artery, and the anterior inferior cerebellar arteries[3].

Many conditions such as neuro-psychiatric, neurological, genetic-developmental, vascular and metabolic diseases, nutritional deficiencies, infection, and trauma can change the development and morphometric structure of pons[4].

Although studies on fetal pons development are available[5-7], less is known about pons development in the postnatal period, especially at the cellular level. A better understanding of the growth and development dynamics of the pons, especially in the postnatal period, can provide insight into the development of this critical brain region and, with this, may help understand pons abnormalities such as developmental malformations and pediatric gliomas[8].

Since the brain stem has a complex structure and vital importance, there is an increased risk of mortality and morbidity in surgical procedures of its lesions[9]. For this reason, radiological methods have an important place in diagnosis, evaluation of its morphology, and its relationship with neighboring anatomical structures. Soft-tissue resolution of computed tomography (CT) is low, so it is insufficient to analyze changes in the brainstem, and the CT contains ionizing radiation. Magnetic resonance imaging (MRI), on the other hand, enables us to distinguish pathological conditions and evaluate normal brain development due to its high soft-tissue resolution. It appears as a valuable imaging method, especially in the childhood age group, since it does not contain ionizing radiation[10].

In this study, we aim to know the average morphometric values of the pons according to age and gender. We aim to compare the normal and pathological dimensions of this structure in diseases we encounter in childhood. We think that our study will contribute to the literature on the earlier diagnosis of degenerative and congenital diseases that impair the development of the pons.

## Material and Method

Ethics Committee Approval: The Regional Ethical Review Board approved the research protocol in The University of Adıyaman Ethics Committee (Date: 21.07.2020, Decision Number: 2020/7-14). In this study, archives were retrospectively examined. “Informed consent” was not obtained from parents as the study was retrospective. The cases included in the study did not provide personal information and were presented anonymously.

Our study included 400 cases, 200 males and 200 females, who had undergone non-contrast brain MRIs between January 2018 and January 2020. Brain MRI examinations, clinical examinations, and follow-ups of these cases were evaluated as usual. Elements unrelated to brain parenchymas like sinusitis, mastoiditis, and adenoid hypertrophy were ignored and accepted as usual.

There are four age groups: 0-2 years (infants), 3-6 years (young children), 7-11 years (children), and 12-17 years (adolescents), and 50 women and 50 men from each age group. With the information obtained from the archive research, cases with a congenital or acquired disease and low MR image quality were excluded. Comparisons were made between male-female gender and age groups in pons area, pons craniocaudal (CC), pons anterior-posterior (AP) dimensions.

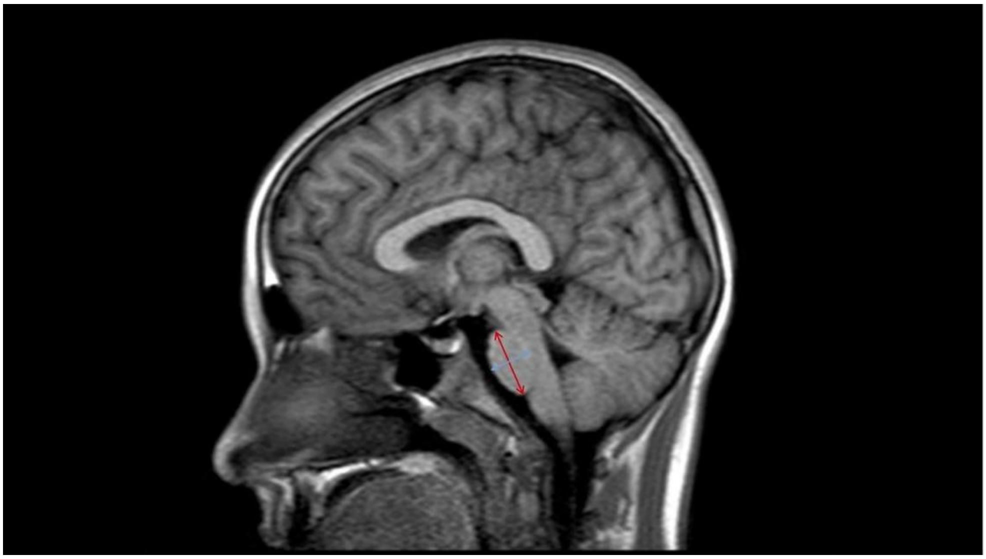
**MRI Protocol and Imaging Analysis**

The MRI examination was obtained from the Philips Achieva MR device (Philips Medical Systems, Best, Netherlands) with a 1.5 Tesla magnetic field strength using a head coil. From the T1 FLAIR-weighted images taken in the sagittal plane, the cross-section through the cranial midline where the mass intermedia can be seen was examined. [time to repeat (TR): 1665 ms, time to echo (TE): 20 ms, FOV: 220x230, slice thickness: 5 mm, matrix: 292x214, NSA: 1, gap :1 mm, voxel: 0.75x1.07x5, slices : 24 sections]

Images were evaluated at Philips Achieva Rev R5 v30-rev.02 workstation and our hospital's PACS system and measurements were made in mm and $mm^2$.

Pons, one of the structures that make up the brain stem, consists of two basic parts, the round-shaped part (ventral part) and the pontis tegmentum (dorsal part). The CC length of the round-shaped structure called the basis pontis in midsagittal sections was manually measured in mm by joining the top and bottom points. AP diameter was measured by joining the front and rear ends of the basis pontis (Figure 1).

**Figure 1.** Measurement of the Craniocaudal Length (red line) and Anterior-Posterior Length (blue line) of the Pons in the midsagittal sections in the T1 FLAIR Sequence on MRI



Pons area in mm² has been calculated automatically by combining the boundaries of the basis pontis manually (Figure 2).

**Figure 2.** T1 FLAIR weighted sagittal image indicating the boundaries of the round structure called basis pontis. Boundaries were manually combined and the pons area was calculated automatically with the Workstation

## Statistical Analysis

The suitability of the data to normal distribution was evaluated with one sample Kolmogorov Smirnov test. All data showed normal distribution. One-way analysis of variance and Tukey HSD multiple comparison tests were used to determine the difference between age groups in terms of variables (measurements). Independent sample t-tests were used to determine gender differences in terms of variables (measurements). Results are given as mean and standard deviation. The significance level was accepted as at least p <0.05. All analyzes were performed using the software package program SPSS / PC (Version 22.0 SPSS, Chicago, II, USA). All data were managed, processed, compiled in Microsoft Office Excel.

## Results

In our study, there are four different age groups (infants, young children, children, adolescents), and the same-sex cases were compared between the age groups, and the cases in the same age group were compared between genders. In addition, all cases were compared among themselves by age groups without gender discrimination.

The difference in the pons area, pons CC length, and pons AP diameter between genders and age groups are shown in table 1. Pons area and pons CC length increased significantly in both genders as the age increased. This increase in pons AP diameter drew a plateau between both genders' childhood and adolescence age groups. Pons AP diameter increased significantly in both genders until childhood. However, the rate of increase of this value decreased towards adolescence.

**Table 1.** Statistical analysis of data between age groups and genders

| | | **0-2 Age Group** | **3-6 Age Group** | **7-11 Age Group** | **12-17 Age Group** | ***P* value*** |
|---|---|---|---|---|---|---|
| Pons Area | Female (n=50) | 229.32±37.61[a] | 265.94±37.1[b] | 301.36±34.26[c] | 321.96±37.56[d] | ***<0.001**** |
| | Male (n=50) | 244.76±37.79[a] | 281.12±35.55[b] | 315.78±39.6[c] | 339.34±35.62[d] | ***<0.001**** |
| | ***P** value*** | ***0.043**** | ***0.039**** | ***0.054*** | ***0.020**** | |
| Pons AP | Female (n=50) | 13.73±1.5[a] | 15.19±1.35[b] | 15.98±1.40[c] | 16.25±1.43[c] | ***<0.001**** |
| | Male (n=50) | 14.31±1.33[a] | 15.09±1.35[b] | 16.39±1.27[c] | 16.6±1.19[c] | ***<0.001**** |
| | ***P** value*** | ***0.046**** | ***0.713*** | ***0.136*** | ***0.196*** | |
| Pons | Female (n=50) | 21.30±2.12[a] | 23.56±1.74[b] | 25.18±1.57[c] | 26.11±1.42[d] | ***<0.001**** |

| | | | | | | |
|---|---|---|---|---|---|---|
| CC Length | Male (n=50) | 22.27±1.63[a] | 24.09±1.82[b] | 25.9±1.77[c] | 27.04±1.73[d] | ***<0.001**** |
| | ***P** value*** | ***0.012**** | ***0.144*** | ***0.034**** | ***0.004**** | |

**Notes:** abcd: Different letters in the same line show statistically significant difference (p <0.05) Mean ± standard deviation was used. Tukey HSD multiple comparison test was used. *: Indicates one-way analysis of variance. **: Two independent samples show t test results.

When the genders were compared, the pons area was significantly larger in males than females in all age groups except the 7-11 age group. Pons AP diameter was significantly greater in the 0-2 age group in the males than in females. Pons CC length was significantly greater in the male gender in all groups except the 3-6 age group.

Comparison of data in the general population by age groups without gender discrimination is summarized in table 2. Pons area, pons AP diameter, and pons CC length increased as age increased. Pons AP diameter increased significantly in both genders until childhood. However, the rate of increase of this value was decreasing towards adolescence.

**Table 2.** Statistical analysis of the data between age groups without gender discrimination

| | | **0-2 Age Group (n=100)** | **3-6 Age Group (n=100)** | **7-11 Age Group (n=100)** | **12-17 Age Group (n=100)** | ***P* value*** |
|---|---|---|---|---|---|---|
| | Pons Area | 237.04±38.31[a] | 273.53±36.94[b] | 308.57±37.55[c] | 330.65±37.45[d] | ***<0.001**** |
| | Pons AP | 14.02±1.44[a] | 15.14±1.34[b] | 16.18±1.34[c] | 16.43±1.32[c] | ***<0.001**** |
| | Pons CC length | 21.78±1.94[a] | 23.82±1.79[b] | 25.54±1.70[c] | 26.58±1.65[d] | ***<0.001**** |

**Notes:** abcd: Different letters in the same line show statistically significant difference (p <0.05) Mean ± standard deviation was used. Tukey HSD multiple comparison test was used. *: Indicates one-way analysis of variance. **: Two independent samples show t test results.

Figure 3,4,5 scatter plots show the significant positive correlations between age and pons area, pons cc length, and pons AP diameter in both genders except that plateau of the pons AP diameter after the age of eleven.

**Figure 3.** Scatter plot of Pons AP Diamater and age

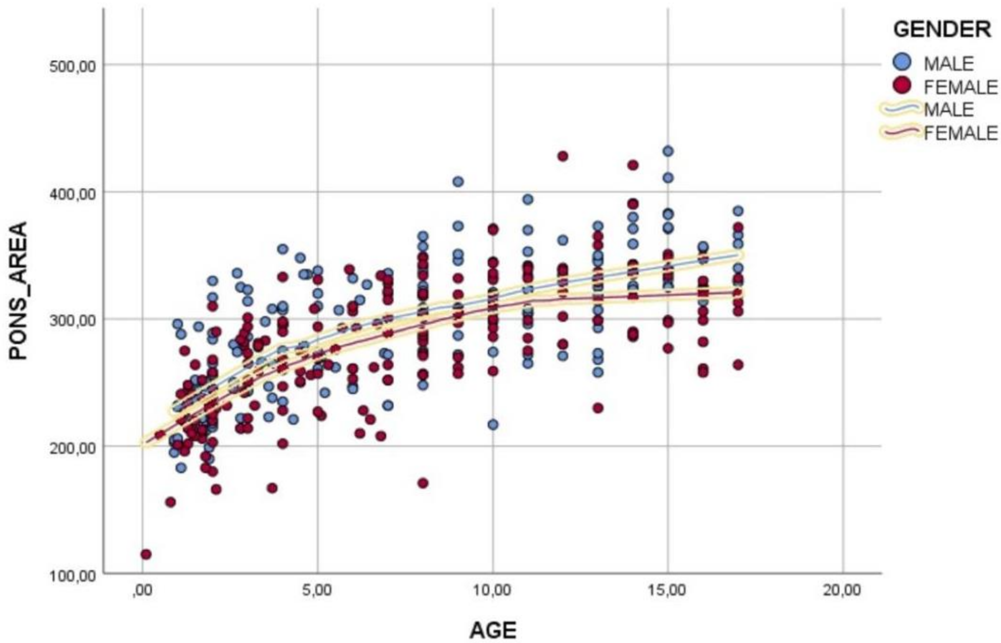



**Figure 4.** Scatter plots of Pons AP Diameter and age

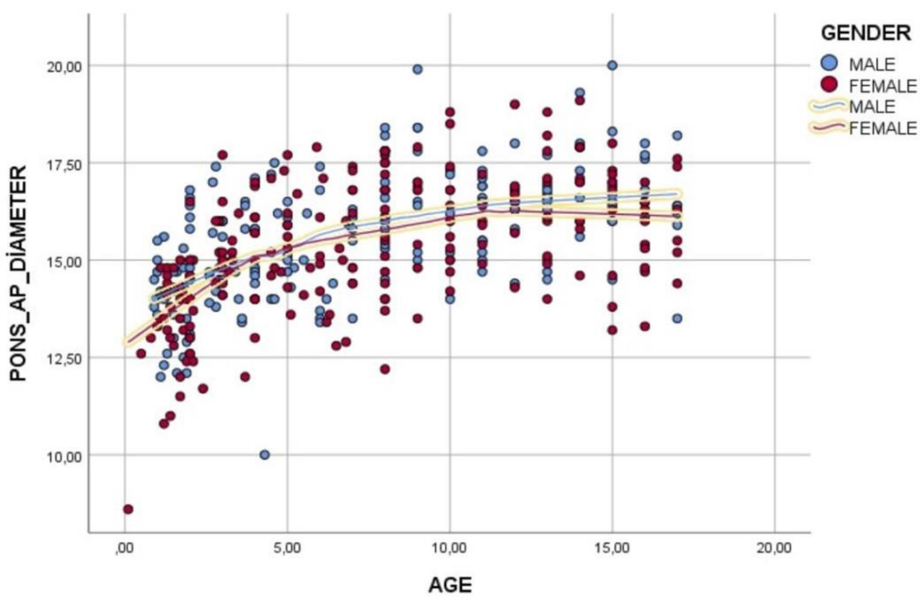
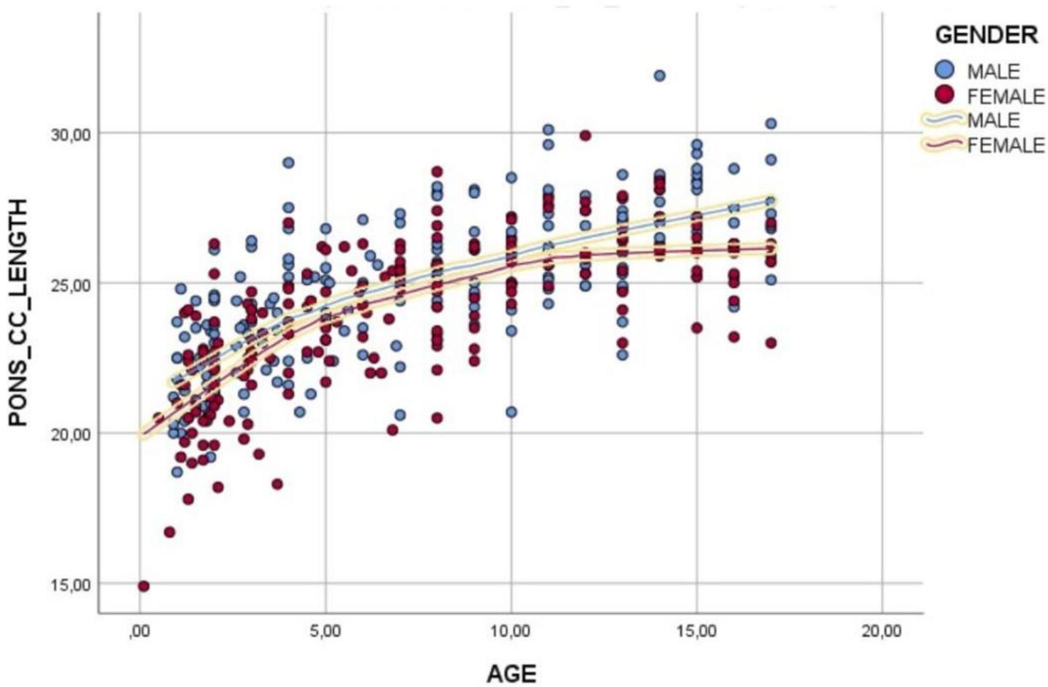


**Figure 5.** Scatter plots of Pons AP Diameter and age




## Discussion

The human basilar pons is a bridge between the cerebrum and the cerebellum by the renowned neuroanatomist Costanzo Varolio in 1573. Its name is derived as Pons Varolii or Varoli's bridge by associating it with the name pons, meaning in the Latin bridge. Today, this structure, known universally as pons Varolii, is accepted as the basis pontis containing corticospinal and pontocerebellar fibers[11].

Due to the critical connections of the pons with the cerebellum and the brain, many studies have been carried out on the functions and development of the pons. Radiological and radio-anatomical evaluation of the pons has become more comfortable with the widespread use of radiological developments, especially magnetic resonance imaging. Although there are studies on morphometric evaluation of pons in adults[12] and changes in pons due to aging[13], studies on pons morphometry in children are limited. This study is the first study in the literature comparing both pons dimensions and pons area in children in the Turkish population by age and gender.

In cases with suspected brain anomalies such as Dandy-Walker complex, pontocerebellar atrophy, and rhombencephalosynapsis, basic information about the normal appearance and development of the fetal pons is required for any prenatal evaluation. Although fetal ultrasonography is vital in diagnosis, fetal MRI can be used to follow up on these anomalies[14].

Brain tumors in children are often found in the posterior fossa. Approximately 10% of these tumors are located in the brainstem. The most common primary brainstem neoplasia is low-grade glioma, and these lesions generally infiltrate the pons without causing contour defects and cause diffuse growth[15]. Studies in the literature show that diseases such as autism spectrum disorder[16] and Down syndrome[17] affect brainstem development in childhood. Pons size was lower than the general population in these studies. Therefore, it is crucial to know the average quantitative values of the pons in a healthy pediatric population.

In a study conducted by Baykan et al. in 4 different groups in the healthy pediatric population, age range 0-2, 3-6, 7-12, and 13-18, they found that the pons CC length and the pons AP diameter increased with age in both genders. They could not find a significant difference between men and women in pons cc length and pons AP diameter[18]. In the present study, unlike the study conducted by Baykan et al., we found that men in the 0-2 age group had a larger pons AP diameter than women. We also found that the pons cc length was taller in males than females in all age groups except the 3-6.

Garbade et al., in their study investigating brain stem development with age, found that the diameter of pons AP increased rapidly in the first decade of life, then a period in which this growth slowed by drawing a plateau, and finally, after the age of 60, there was a decrease in the diameter of pons AP[19]. Although our study is only in the pediatric population, it is similar to the results found by Garbade et al. We also found that the diameter of the pons AP began to draw a plateau from childhood to adolescence.

Our study found that the size of the pons increased rapidly in the first ten years of life, but this growth rate decreased in the second decade and began to draw a plateau. Raininko et al., on the other hand, showed that the pons diameter increased rapidly in the second decade of life, but there was no reduction in the size of the pons afterward. Besides, they could not find a difference in pons size between genders[20]. Unlike the results of theirs, we found statistically significant differences between genders in terms of pons size.

Hayakawa et al. found that the transverse and vertical length of the pons and the pons area grew exponentially until the age of 4, and this increase set a plateau after the age of 10-12. Also, they could not find a significant difference between the genders in terms of these values. Similar to their results, our study found that the pons transverse length (pons AP diameter) began to draw a plateau after 11 years of age. However, unlike them, we found that the pons vertical length (pons CC length) and pons area continued to increase rapidly until 18. Again, we found that there are significant differences between these values between the genders[21].

Measuring the Pons area is a simple and very little time-consuming method (less than 30 seconds). It is also an effective method that provides valuable information about the size and indirectly of the pons volume. With newly developed software and artificial intelligence techniques, these measurements can be reduced to the level of seconds.

This study has certain limitations. The first is the retrospective design of the study. The second is that clinical and laboratory data led to the consideration that cases were healthy and only accessed through the archives. Lastly, the ages at which adolescence began and individuals reached adulthood were not known.

## Conclusion

This study is critical because it gives normal morphometric values of the pons and facilitates the diagnosis of diseases that cause changes in pons size. The data obtained from this study can be used as a guide that includes the morphometric values of the pons in childhood.

**Informed Consent:** Informed consent was not obtained from parents as the study was retrospective.

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