

Association of Pituitary Gland Volume in Adults with Body Mass Index: A Cross-sectional Study

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ABSTRACT

Introduction: The pituitary gland is central to endocrine regulation influencing growth, metabolism, and reproduction. Magnetic Resonance Imaging (MRI) provides a reliable non-invasive method for assessing pituitary morphology. Variations in pituitary volume have been reported in relation to age, sex, and body stature and Body Mass Index (BMI).

Aim: To estimate pituitary gland volume using MRI and analyse its correlation with BMI.

Materials and Methods: The present cross-sectional study was conducted on 285 adults (18-85 years) undergoing MRI for non-endocrine neurological indications in the Department of Radiodiagnosis, Institute of Medical Sciences, Puducherry, India, from May 2023 to May 2025. Pituitary dimensions {Antero-Posterior (AP), Cranio-Caudal (CC) and Transverse (TR)} were

measured on standardised T1 and T2-weighted images, and volume was calculated using ellipsoid formula. Demographic data (age, sex, height, weight, BMI) were recorded. Correlation and comparative analyses were performed.

Results: The mean pituitary volume was 532.3 ± 166.2 mm³. Females (560 ± 168.4 mm³) had a higher mean pituitary volume than males (512 ± 162.7 mm³); however, the difference did not reach statistical significance ($p=0.08$). Pituitary volume showed a strong positive correlation with BMI ($r=0.715$, $p<0.001$) and body weight ($r=0.762$, $p<0.001$). Age demonstrated a negative correlation with gland volume ($r=-0.234$, $p<0.001$)

Conclusion: MRI-based volumetry of the pituitary gland reliably reflects its association with BMI. BMI emerged as the strongest determinant of pituitary size, while age showed an inverse effect.

Keywords: Body stature, Endocrine regulation, Magnetic resonance imaging, Volumetry

INTRODUCTION

The pituitary gland, often referred to as the “master gland,” plays a pivotal role in regulating various endocrine functions within the human body. Its significance is underscored by its influence on growth, metabolism, and reproductive functions through the secretion of hormones such as Growth Hormone (GH), Thyroid-Stimulating Hormone (TSH), and Adrenocorticotrophic Hormone (ACTH) [1].

The measurement of pituitary gland volume via MRI has emerged as a critical tool in understanding its morphology and function, particularly in relation to body stature and BMI [2]. Recent studies have highlighted the necessity for standardised measurement protocols for the pituitary gland, particularly in diverse populations. Mukkada PJ et al., emphasised the need for accurate volumetric assessments in the Indian paediatric population, noting that mean pituitary volume and stalk height significantly increase with age, suggesting a dynamic growth pattern that necessitates further investigation into normative values across different demographics [3]. This is echoed by Naik D, who found that the mean pituitary height and volume in Indian adolescents were comparable to other studies, yet underscored the need for more precise measurement techniques to differentiate between normal and abnormal gland sizes [4]. Such findings are crucial as they lay the groundwork for understanding how variations in pituitary volume may correlate with physical growth parameters, including stature and BMI. Volumetric studies in paediatric population with GH deficiency further confirm reduced pituitary size as a marker of impaired growth, while enlargement may occur in conditions such as Fontan circulation after surgery [5,6]. These studies collectively suggest that the pituitary gland's morphology is not only a reflection of its functional capacity but also a determinant of growth outcomes in

paediatric populations. Obesity is another determinant of pituitary volume. Fehrenbach U et al., showed positive associations between pituitary size, BMI, and stature suggesting a feedback link between metabolic demand and endocrine morphology. Conversely under nutrition is associated with reduced gland size [7].

Age and sex-related differences have also been well documented. Pituitary volume peaks during puberty and early adulthood, with a gradual decline thereafter [8,9]. Females generally exhibit larger volumes than males, particularly during reproductive years, reflecting hormonal influences [10].

Taken together, these studies highlight the importance of establishing population-specific normative values for pituitary volumetry. Such data can improve diagnostic accuracy in differentiating physiological variations from pathological enlargement or hypoplasia, particularly in growth and metabolic disorders [11]. The present study aimed to estimate pituitary gland volume using MRI and analyse its correlation with BMI.

MATERIALS AND METHODS

The present hospital-based cross-sectional study was conducted at Department of Radiodiagnosis, Pondicherry Institute of Medical Sciences in Puducherry, India, between May 2023 and May 2025 after obtaining approval from the Institutional Ethics Committee (IEC: RC/2023/27). A total of 285 participants were analysed using convenience sampling.

Inclusion criteria: Individuals undergoing MRI of the brain, cervical spine or whole spine within the age group of 18 to 85 years of all gender.

Exclusion criteria:

- Individuals with known pituitary pathologies.

- Individuals with growth abnormalities.
- Individuals with any intracranial pathologies known to affect the pituitary glands.

Study Procedure

Demographic and anthropometric data, including age, sex, height, weight and BMI were recorded. Height and weight were measured by radiology technicians using a calibrated stadiometer and digital weighing scale, respectively, at the time of MRI examination. Height was recorded to the nearest 0.1 cm with participants standing barefoot in an erect posture, and weight was measured to the nearest 0.1 kg with participants wearing light clothing. Each measurement was obtained twice, and the average of the two readings was used for analysis. BMI was calculated as weight in kilograms divided by height in kg/m².

The MRI studies were performed on a standard clinical scanner using dedicated brain and spine protocols. The CC and AP dimensions of the pituitary were measured on midsagittal T1-weighted images, while the TR dimension was obtained from coronal T2-weighted images. Pituitary volume was estimated using the scalene ellipsoid formula: $V=1/6 \times (AP \times CC \times TR)$ [Table/Fig-1,2].



[Table/Fig-1]: Midsagittal T1W MR Image. Blue arrows indicate the length (AP) and central line indicates the height (CC) of pituitary gland.



[Table/Fig-2]: Coronal T1W MR image. The white arrows indicate width (T) of pituitary gland.

STATISTICAL ANALYSIS

Data were analysed using Statistical Package for Social Sciences (SPSS) version 26. Normality of continuous variables was assessed using the Shapiro-Wilk test. As pituitary dimensions and volumetric data did not follow a normal distribution, non-parametric tests were applied. Correlations between pituitary volume and age, height,

weight, and BMI were evaluated using Spearman's rank correlation coefficient. Comparisons of pituitary volume between two groups (male vs female) were performed using the Mann-Whitney U test, while comparisons across multiple BMI categories were conducted using Kruskal-Wallis test. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 285 students were included in the study, with a mean age of 47.9±16.2 years (range: 18-85 years). The study population showed a predominance of males {58.6% (n=167)} compared to females {41.4% (n=118)}. The mean BMI of the study population was 23.98±5.29 kg/m² [Table/Fig-3].

Variables	Value- Mean±SD
Age (years) (18-85 years)	47.9±16.2
18-25 years	26 (9.1%)
26-35 years	45 (15.8%)
36-45 years	58 (20.4%)
46-55 years	56 (19.6%)
56-65 years	52 (18.2%)
>65 years	48 (16.9%)
Sex	
Male	167 (58.6%)
Female	118 (41.4%)
Height (m)	1.68±0.08
Weight (kg)	68.3±14.8
Body Mass Index (BMI) (kg/m²)	23.98±5.29

[Table/Fig-3]: Demographic and anthropometric characteristics.

Based on the World Health Organisation (WHO) BMI classification, participants were categorised as underweight (BMI <18.5 kg/m²), normal weight (18.5-24.9 kg/m²), and over-weight (25.0-29.9 kg / m²), and obese (>30.0 kg / m²). Of the 285 participants, 50 (17.5%) were underweight, 117 (41.1%) had normal weight, 71 (24.9%) were overweight and 47 (16.5%) were obese [12]. Analysis by gender showed females had slightly larger mean values across all pituitary dimensions. These differences, though consistent, were not statistically significant [Table/Fig-4].

Parameters	Males (n=167) Mean±SD	Females (n=118) Mean±SD	p-value*
Craniocaudal extent (mm)	4.93±1.05	5.04±1.09	0.28
Anteroposterior (AP) extent (mm)	8.74±1.24	8.98±1.26	0.19
Transverse (TR) extent (mm)	11.77±1.54	12.25±1.59	0.07
Pituitary volume (mm ³)	512.41±162.7	560.20±168.4	0.08

[Table/Fig-4]: Sex-based comparison of pituitary gland dimensions and volume.

Underweight subjects had the smallest mean CC extent (4.33 mm) and pituitary volume (386.71 mm³), whereas obese individuals had the greatest mean CC extent (5.88 mm) and pituitary volume (720.99 mm³) [Table/Fig-5].

Descriptive analysis showed mean pituitary volume was 532.34±166.2 mm³, indicating substantial physiological variability [Table/Fig-6].

Spearman's correlation analysis demonstrated a negative correlation between pituitary gland volume and age ($r=-0.234$, $p < 0.001$). Strong positive correlations were observed between pituitary volume and body weight ($r=0.762$, $p < 0.001$) and BMI ($r=0.715$, $p < 0.001$). [Table/Fig-7].

Correlation analyses of individual pituitary gland dimensions (CC, AP and TR extents) with age and anthropometric parameters are summarised in [Table/Fig-8-10].

BMI category	n (%)	Mean value of cranio-caudal (CC) extent	Mean value of Antero-posterior (AP) extent	Mean value of Transverse (TR) extent	Mean and SD values of pituitary volume
Underweight	50 (17.5%)	4.33±0.89	8.01±1.12	10.82±1.41	386.71±112.54
Normal weight	117 (41.1%)	4.85±0.96	8.63±1.19	11.63±1.48	498.26±138.92
Overweight	71 (24.9%)	5.21±1.02	9.21±1.27	12.34±1.55	612.84±151.36
Obese	47 (16.5%)	5.88±1.10	9.74±1.32	13.08±1.62	720.99±168.47

[Table/Fig-5]: Pituitary gland dimensions and volume across BMI categories.

Measurement	Mean±SD	Range
Cranio-caudal (CC) extent (mm)	4.97±1.07	3.0-9.1
Anteroposterior (AP) (mm)	8.84±1.25	4.9-12.4
Transverse (TR) extent (mm)	11.97±1.56	6.9-16.2
Volume (mm ³)	532.3±166.2	138.9-961.6

[Table/Fig-6]: Pituitary gland dimensions and volume.

Variables	Correlation coefficient	p-value
Age (m)	-0.234	<0.0001
Height (Kg)	0.134	0.03
Weight (kg/m ²)	0.762	<0.0001
BMI	0.715	<0.0001

[Table/Fig-7]: Correlation of pituitary volume with age, height, weight and BMI.

Variables	Spearman's r	p-value
Age (years)	-0.280	<0.001
Height (m)	0.140	0.02
Weight (kg)	0.564	<0.001
BMI (kg/m ²)	0.510	<0.001

[Table/Fig-8]: Correlation of Cranio-caudal (CC) extent with age and other anthropometric parameter.

Variables	Spearman's r	p-value
Age (years)	-0.040	0.71
Height (m)	0.110	0.06
Weight (kg)	0.512	<0.001
BMI (kg/m ²)	0.494	<0.001

[Table/Fig-9]: Correlation of Anteroposterior (AP) extent with age and anthropometric parameter.

Variable	Spearman's r	p-value
Age (years)	-0.307	<0.001
Height (m)	0.080	0.18
Weight (kg)	0.383	<0.001
BMI (kg/m ²)	0.363	<0.001

[Table/Fig-10]: Correlation of Transverse (TR) extent with age and anthropometric parameter.

DISCUSSION

Analysis of BMI categorisation shows that 41.1% of participants fall within the normal weight range, while a substantial proportion is classified as overweight (24.9%) or obese (16.5%). This distribution is particularly significant given the strong correlation observed between BMI and pituitary tumour volume, reinforcing previous research suggesting that obesity may contribute to increased pituitary gland size and associated disorders [13].

A negative correlation is observed between age and pituitary volume suggesting that pituitary size tends to decrease with age. This finding is consistent with earlier reports indicating that pituitary volume declines with aging, possibly due to reduced hormonal stimulation and pituitary cell atrophy [14]. The relationship between body weight and pituitary gland volume is particularly striking. This suggests that as body weight increases, so does pituitary volume, a finding that aligns with existing literature suggesting a link between metabolic factors and pituitary hypertrophy [15].

The impact of BMI is pronounced, with highly significant correlations observed between BMI and all pituitary dimensions and volume ($r=0.510$ for CC extent, $r=0.494$ for AP extent, $r=0.363$ for TR extent, and $r=0.715$ for volume, all $p<0.0001$). These results provide strong evidence that higher BMI is associated with increased pituitary gland volume. These observations were similar to a study conducted by Fehrenbach U et al., who found that in a cohort of 144 healthy adults, pituitary volumes were significantly higher in obese (>30 kg/m²) subjects than in overweight (BMI-25-30) and normal weight (BMI <25) groups. After controlling for gender, age, and height, BMI remained an independent predictor of increased pituitary volume [7].

In the present study, females showed slightly larger pituitary volumes than males, though the difference was not statistically significant. Similar trends have been reported previously by Singh A et al., who found larger pituitary dimensions in females, but the differences diminished after age stratification, suggesting hormonal influences during reproductive years [16]. In present study, a clear trend was observed where increasing BMI corresponds to larger pituitary gland dimensions. These findings provide robust support for the hypothesis that BMI plays a critical role in pituitary gland hypertrophy, potentially mediated through metabolic and hormonal pathways [17,18].

Increased BMI has been associated with alterations in endocrine function, including changes in GH and Insulin-Like Growth Factor-1 (IGF-1) levels, which may contribute to pituitary enlargement [19]. Additionally, obesity is linked to increased levels of leptin and insulin resistance, both of which may influence pituitary cell proliferation and function [20]. The observed increase in pituitary volume with higher BMI could therefore reflect adaptive or compensatory changes in response to metabolic and hormonal demands.

Limitation(s)

The cross-sectional design precludes causal inferences regarding the relationship between BMI and pituitary gland volume. Longitudinal studies are needed to establish whether BMI-related changes in pituitary volume are progressive or reversible. Additionally, while MRI provides high-resolution imaging of the pituitary gland, variations in scanning protocols and measurement techniques could introduce variability in volume estimations.

CONCLUSION(S)

The present study establishes a clear association between BMI and pituitary gland volume, suggesting that increased body mass contributes to pituitary enlargement, whereas age is linked with volume reduction. Gender showed minimal influence.

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