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Assessing Brainstem Dimensions By MRI: A Linear Analysis Based on Age, Gender, and BMI

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Abstract

Background: The brainstem is vital for autonomic functions and serves as a key anatomical landmark in neuroimaging. This study aimed to establish normative reference values for brainstem diameters and assess variations based on age, gender, and body mass index (BMI) in an Indian population.
Methods: A cross-sectional MRI-based study was conducted on 157 subjects (69 males, 88 females) aged 20–60 years. Linear midsagittal measurements of the midbrain (MBAP), pons (PAP), and medulla at the pontomedullary (MPMJ) and cervicomedullary (MCMJ) junctions were obtained. Subjects were categorized by age, gender, and BMI. Statistical analyses included independent sample t-tests, one-way ANOVA, post hoc Tukey tests, and Pearson correlation.
Results: The mean AP diameters were: midbrain 1.77 ± 0.12 cm, pons 2.28 ± 0.15 cm, MPMJ 1.39 ± 0.10 cm, and MCMJ 1.07 ± 0.12 cm. Significant gender differences were found in MCMJ ($p < 0.05$). Age-wise, significant differences were observed in MBAP, PAP, and MPMJ ($p < 0.05$), with decreasing values in older age groups. Gender-based differences within age and BMI categories were also evident, particularly in MCMJ. No overall differences in brainstem diameters were noted across BMI groups, though correlations existed between some parameters.
Conclusion: This study provides normative brainstem measurements and demonstrates that age and gender significantly influence brainstem diameters. The inclusion of BMI adds a novel dimension, revealing gender-based variations in MCMJ. These findings support the use of MRI in evaluating brainstem morphology and may aid in early detection of pathological changes.

Keywords: MBAP**:** Midbrain Anteroposterior Diameter, PAP: Pons Anteroposterior Diameter, MPMJ**:** Medulla Pontomedullary Junction, MCMJ **:**Medulla Cervicomedullary Junction, BMI**:** Body Mass Index

1. INTRODUCTION

The human brainstem, a vital structure that regulates autonomic functions, is essential for diagnosing and early detecting neurodegenerative, metabolic, and congenital disorders. It connects the cerebrum with the spinal cord and consists of the midbrain, pons, and medulla oblongata (1). Advancements in imaging modalities, particularly Magnetic Resonance Imaging (MRI), have enabled more accurate and non-invasive visualization of intracranial structures. Linear measurements of the brainstem on MRI have become a reliable method for assessing subtle structural changes, influenced by physiological and demographic factors like age, gender, and BMI. MRI-based morphometric studies mostly focus on gross brain volumes and cortical regions, neglecting the brainstem, especially in healthy individuals (2-3). Age-dependent alterations and gender-based differences are less studied. BMI affects brain structure but its effect on brainstem morphology is unclear. Abnormalities in the midbrain, pons, and medulla oblongata are linked to diseases (4).

The research gap in normative brainstem measurements in healthy populations, particularly in the Indian context, is significant. Previous studies have focused on brain volumes or cortical regions, but few have examined the linear diameters of brainstem components, particularly their relationship with age, gender, and BMI (5-9). The available literature often lacks regional representation and population-specific data for Vadodara, Gujarat, a region with immense ethnic, genetic, and environmental diversity. This knowledge gap limits clinicians' ability to accurately interpret brainstem changes in MRI scans and hinders early identification of at-risk individuals. Establishing normative data on brainstem dimensions in individuals from this region is crucial for improving diagnostic accuracy in clinical neuroimaging and enhancing early detection of pathological changes(10-11). This study aims to bridge the gap by providing reference values for brainstem dimensions based on linear MRI measurements in healthy individuals from Vadodara, Gujarat, while analyzing the influence of age, gender, and BMI.

The need for this study arises from the lack of region-specific reference values, which are essential for accurate clinical assessment, early detection of neurological disorders, and improved understanding of physiological changes in the brainstem structure across different population subgroups (12-14). By correlating brainstem dimensions with age, gender, and BMI, the study aims to enhance diagnostic precision and contribute to personalized neuroimaging interpretations. This aims to investigate the influence of age, gender, and Body Mass Index (BMI) on brainstem morphology by assessing the anteroposterior (AP) diameters of the midbrain, pons, and medulla junctions using linear measurements on MRI brain examinations in individuals from Vadodara. The objective is to establish normative data and evaluate how these demographic and physiological factors affect brainstem dimensions, which can serve as a valuable reference for distinguishing between normal anatomical variations and early pathological changes.

2. MATERIALS AND METHOD

A prospective, observational, clinical-based study was conducted at the Department of Radioology, Primary Tertiary Hospital, Vadodara, Gujarat, India. The study included 157 patients who visited the hospital's outpatient department for general check-ups over 1 year.

Inclusion Criteria: The study will include both male and female subjects within the age range of 20 to 60 years.

Exclusion Criteria: Subjects below the age of 20 years will be excluded from the study. Additionally, individuals with a history of trauma, known brain pathologies, prior neurosurgical interventions, or any contraindications to MRI examination will not be considered for inclusion.

Parameter

The morphometric evaluation of the brainstem in this study involves linear measurements of the anteroposterior (AP) diameters at three specific levels using MRI. The midbrain AP diameter is measured as the distance between the superior and inferior colliculi. For the pons, the AP diameter is obtained by measuring the distance from the anterior surface of the pons to the floor of the fourth ventricle. In the case of the medulla**,** the AP diameter is measured perpendicular to the longitudinal axis at two distinct anatomical landmarks: the pontomedullary junction and the cervicomedullary junction.

Statistical Analysis:-

The collected data were summarized by using the Descriptive Statistics: frequency, percentage; mean, and S.D. The Independent sample “t” test was used to compare the brainstem diameters according to gender. The One way ANOVA was used to compare brainstem diameters according to age groups and BMI. The Post hoc analysis, Tukey test was used for the multiple comparisons of brainstem diameters: MBAP, PAP, and MPMJ according to age groups. To find the relation between the various parameters of brainstem diameters, the Pearson correlation coefficient (“r”) was used. The p value < 0.05 was considered as significant. Data were analyzed by using the SPSS software (SPSS Inc.; Chicago, IL) version 29.0.10.

3. RESULTS

This study comprised a total of 157 participants, including 69 males and 88 females. The participants had a mean age of 37.81 years, with a standard deviation of 11.87 years, indicating a moderately wide age distribution among the study population. The demographic details of the subjects, including the gender distribution and age statistics, are summarized in Table 1.

Table 1: Descriptive Statistics for age, height, weight, BMI and brainstem diameters

(n = 157)	Range	Mean	S.D.
Age (Years)	20 to 60	37.81	11.87
Height	134.1 to 182.8	156.97	8.80
Weight (Kg)	40 to 80	60.89	9.20
BMI (Kg/M^2)	14.43 to 36.15	24.78	3.78
MBAP	1.45 to 2.19	1.77	0.12
PAP	1.91 to 2.63	2.28	0.15
MPMJ	1.11 to 1.62	1.39	0.10
MCMJ	0.81 to 1.61	1.07	0.12

Table 2: Distribution of gender, age and BMI

(n = 157)		Frequency	%
Gender	Male	69	43.9
	Female	88	56.1
Age groups	20-30	56	35.7
	31-40	38	24.2
	41-50	34	21.7
	51-60	29	18.5
BMI	Under weight (< 18.5)	5	3.2
	Healthy weight (18.5 to 24.9)	77	49.0
	Over weight (25 to 29.9)	53	33.8
	Obese (30 to 39.9)	22	14.0

Table 2 above shows the frequency of patients by gender, age groups, and BMI.In gender, females were maximum as 88 with 56.1% , in age groups 20-30 years maximum subjects as shown as 56 with 35.7%, in age groups 31-40, frequency 38 subjects with 24%,in age groups 41-50 frequency 34 subjects with 21.7%, in age groups 51-60, frequency 29 subjects with 18.5%. BMI underweight frequency was 5 with 3.2%, healthy weight frequency was 77 with 49.0%, which was the maximum in overall BMIs, overweight frequency was 53 with 33.8%, and obese frequency was 22 with 14.0%, respectively.

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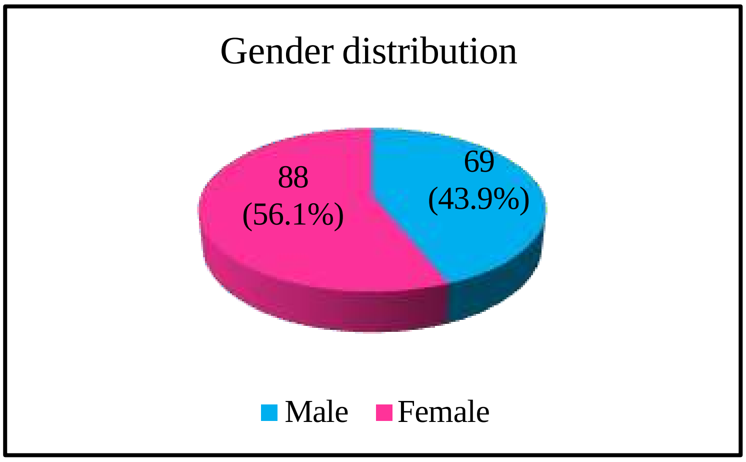

Fig 2: Represent the gender distribution

Above figure 2 shows gender distribution according to gender the male frequency of 88 with 56.1% and in female frequency of 69 with 43.9% respectively.

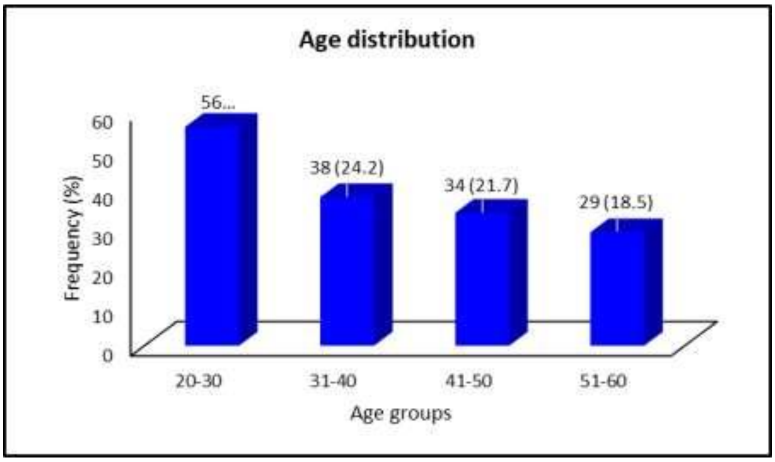

Fig 3: Represent the age distribution

In age groups 20-30 years maximum subjects as shown in fig 3 as 56 with 35.7%, in age groups 31-40, the frequency 38 subjects with 24.2%, in age groups 41-50 frequency 34 subjects with 21.7%, in age groups 51-60 frequency 29 subjects with 18.5% respectively.

BMI underweight frequency 5 with 3.2%, healthy weight frequency 77 with 49.0% which were the maximum in overall BMI's, overweight frequency 53 with 33.8% and obese frequency 22 with 14.0% respectively.

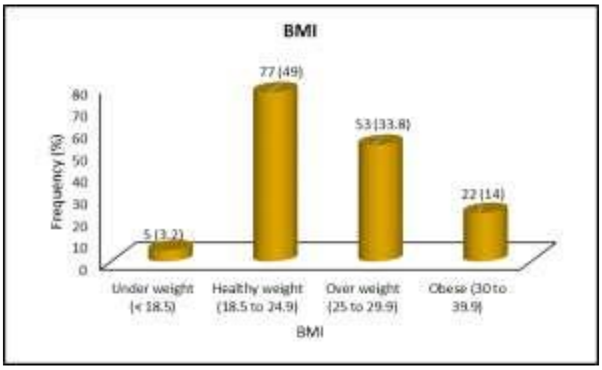

Fig 4: Represent the BMI distribution

The table above shows age groups for males and females. In the 20-30 age group, males are 29.0% and females are 40.9 %, which is the maximum. In the 31-40 age group, males are 26.1% and females are 22.7%. For the 41-50 age group, males are 20.3% and females are 22.7%. In the 51-60 age group, males are 24.6% and females are 13.6%. Regarding BMI, males and female ,male underweight and 44.9% overweight, with 13.0% classified as obese. Females are 39.1% underweight and 25.0% overweight, with 14.8% classified as obese. Additionally, 39.1% of males and 56.8% of females are at a healthy weight.

Table 4: BMI according to age groups

BMI	Age groups							
	20-30		31-40		41-50		51-60	
	n	%	n	%	n	%	n	%
Under weight (< 18.5)	4	7.1	1	2.6	0	0	0	0
Healthy weight (18.5 to 24.9)	40	71.4	19	50.0	14	41.2	4	13.8
Over weight (25 to 29.9)	9	16.1	14	36.8	13	38.2	17	58.6
Obese (30 to 39.9)	3	5.4	4	10.5	7	20.6	8	27.6

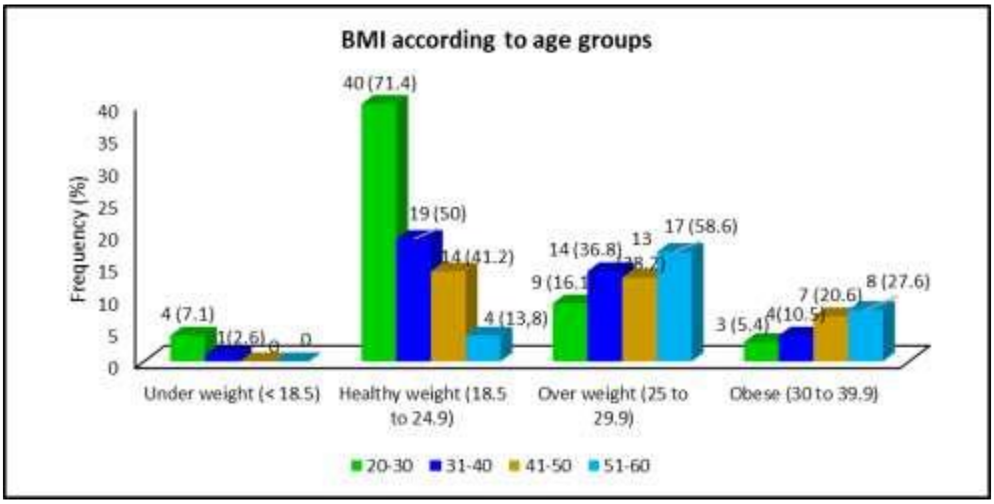

Fig 6: Represent the BMI according to age groups.

The above table 5.4 and graph 5.5 shows BMI according to age groups 20-30 under weight (7.1%), 31-40 (2.6%), 41-50 (0%) and 51-60 (0%), healthy weight age groups 20-30 (71.4%),31-40 50.0%, 41-50 (41.2%) and 51-60 (13.8%), over weight with age groups 20-30 (16.1%),31-40 (36.8%), 41-50 (38.2%) and 51-60 (58.6%) , obese with age groups 20-30 (5.4%), 31-40 (10.5%), 41-50 (20.6%) and 51-60 (27.6%) respectively.

Table 5: Comparison of brainstem diameters according to gender

	Gender	Mean	S.D.	"t"	p value
MBAP	Male	1.76	0.14	-0.77	0.442
	Female	1.77	0.11		
PAP	Male	2.30	0.15	1.59	0.113

	Female	2.26	0.15		
MPMJ	Male	1.40	0.09	1.50	0.136
	Female	1.38	0.10		
MCMJ	Male	1.10	0.11	2.79	0.006*
	Female	1.05	0.12		

(“t” = Independent sample “t” test; * Significant)
The Independent sample “t” test was used to compare the brainstem diameters according to gender. There was a difference (p < 0.05) in MCMJ between males and females. [Table – 5 and Figure 7]

Table 6: Comparison of brainstem diameters according to age groups

	Age Groups	Mean	S.D.	"F"	p value
MBAP	20-30	1.80	0.14	9.79	< 0.001*
	31-40	1.82	0.10		
	41-50	1.72	0.11		
	51-60	1.69	0.10		
PAP	20-30	2.23	0.15	3.99	0.009*
	31-40	2.30	0.13		
	41-50	2.33	0.11		
	51-60	2.30	0.18		
MPMJ	20-30	1.35	0.11	3.99	0.009*
	31-40	1.40	0.09		
	41-50	1.40	0.08		
	51-60	1.41	0.09		
MCMJ	20-30	1.08	0.15	0.59	0.62
	31-40	1.05	0.09		
	41-50	1.08	0.11		
	51-60	1.06	0.09		

(“F” = One way ANOVA; * Significant)
One way ANOVA was used to compare brainstem diameters according to age groups. There was a difference (p < 0.05) in MBAP, PAP, and MPMJ according to the age groups. [Table – 6]

Table 7: Multiple comparisons of MBAP, PAP, and MPMJ according to age groups

(Multiple comparisons)			Mean Difference	p value
MBAP	20-30	31-40	-0.013	0.95
		41-50	0.083	0.007*
		51-60	0.109	< 0.001*
	31-40	41-50	0.095	0.003*
		51-60	0.122	< 0.001*
	41-50	51-60	0.027	0.79
PAP	20-30	31-40	-0.070	0.10
		41-50	-0.100	0.009*
		51-60	-0.068	0.17

	31-40	41-50	-0.030	0.81
		51-60	0.002	1
	41-50	51-60	0.032	0.81
MPMJ	20-30	31-40	-0.052	0.044*
		41-50	-0.052	0.05
		51-60	-0.058	0.037*
	31-40	41-50	0.000	1
		51-60	-0.006	0.99
	41-50	51-60	-0.006	0.99

(* Significant)

The Post hoc analysis, Tukey test was used for the multiple comparisons of brainstem diameters: MBAP, PAP, and MPMJ according to age groups. There was a difference ($p < 0.05$) in MBAP between the age groups: 20-30 and 41-50 years; 20-30 and 51-60; 31-40 and 41-50; as well as 31-40 and 51-60 years. The PAP exhibited a difference ($p < 0.05$) between the age groups 20-30 and 41-50 years. Also, the MPMJ was found to be different between the age groups: 20-30 and 31-40 as well as 20-30 and 51-60. [Table –7]

Table 8: Comparison of brainstem diameters between males and females within the age group

	Age groups	Male		Female		"t"	p value
		Mean	S.D.	Mean	S.D.		
MBAP	20-30	1.81	0.17	1.80	0.12	0.46	0.64
	31-40	1.80	0.11	1.83	0.08	-0.85	0.40
	41-50	1.70	0.12	1.74	0.11	-1.05	0.30
	51-60	1.70	0.10	1.68	0.09	0.47	0.64
PAP	20-30	2.27	0.15	2.21	0.15	1.46	0.15
	31-40	2.31	0.15	2.29	0.12	0.57	0.57
	41-50	2.34	0.11	2.32	0.12	0.37	0.71
	51-60	2.30	0.18	2.29	0.18	0.09	0.92
MPMJ	20-30	1.37	0.12	1.35	0.10	0.73	0.47
	31-40	1.44	0.08	1.38	0.10	2.03	0.05*
	41-50	1.41	0.08	1.40	0.07	0.13	0.90
	51-60	1.40	0.08	1.43	0.09	-1.01	0.32
MCMJ	20-30	1.14	0.15	1.04	0.14	2.50	0.01*
	31-40	1.06	0.07	1.04	0.10	0.53	0.59
	41-50	1.10	0.11	1.07	0.11	0.96	0.34
	51-60	1.09	0.08	1.03	0.10	1.58	0.12

(“t” = Independent sample “t” test; * Significant)

The Independent sample “t” test was used to compare the brainstem diameters according to gender within the age groups. There was a difference ($p < 0.05$) IN MPMJ between males and females within the age group 31-40 years. Also, a difference ($p < 0.05$) in MCMJ was found between males and females within the age group: 20-30 years. [Table –8]

Table 9: Comparison of brainstem diameters according to age group within gender

		Male	Female

	Age groups	Mean	S.D.	"F"	p value	Mean	S.D.	"F"	p value
MBAP	20-30	1.81	0.17	4.07	0.01*	1.80	0.12	6.19	0.00*
	31-40	1.80	0.11			1.83	0.08		
	41-50	1.70	0.12			1.74	0.11		
	51-60	1.70	0.10			1.68	0.09		
PAP	20-30	2.27	0.15	0.65	0.58	2.21	0.15	3.41	0.02*
	31-40	2.31	0.15			2.29	0.12		
	41-50	2.34	0.11			2.32	0.12		
	51-60	2.30	0.18			2.29	0.18		
MPMJ	20-30	1.37	0.12	1.77	0.16	1.35	0.10	3.23	0.02*
	31-40	1.44	0.08			1.38	0.10		
	41-50	1.41	0.08			1.40	0.07		
	51-60	1.40	0.08			1.43	0.09		
MCMJ	20-30	1.14	0.15	1.96	0.12	1.04	0.14	0.29	0.83
	31-40	1.06	0.07			1.04	0.10		
	41-50	1.10	0.11			1.07	0.11		
	51-60	1.09	0.08			1.03	0.10		

(“t” = One way ANOVA; * Significant)
The One way ANOVA was used to compare brainstem diameters according to age group within gender. There was a difference ($p < 0.05$) in MBAP according to age groups among males. The MBAP, PAP as well as MPMJ exhibited a difference ($p < 0.05$) according to age groups among females. [Table –9]

Table 10: Comparison of brainstem diameters according to BMI

		Mean	S.D.	"F"	p value
MBAP	Under weight (< 18.5)	1.83	0.11	1.59	0.19
	Healthy weight (18.5 to 24.9)	1.78	0.11		
	Over weight (25 to 29.9)	1.76	0.15		
	Obese (30 to 39.9)	1.73	0.13		
PAP	Under weight (< 18.5)	2.35	0.14	1.21	0.30
	Healthy weight (18.5 to 24.9)	2.26	0.14		
	Over weight (25 to 29.9)	2.29	0.16		
	Obese (30 to 39.9)	2.32	0.15		
MPMJ	Under weight (< 18.5)	1.42	0.07	1.70	0.17
	Healthy weight (18.5 to 24.9)	1.37	0.09		
	Over weight (25 to 29.9)	1.41	0.10		
	Obese (30 to 39.9)	1.39	0.08		
MCMJ	Under weight (< 18.5)	1.19	0.14	2.65	**0.05***
	Healthy weight (18.5 to 24.9)	1.08	0.13		
	Over weight (25 to 29.9)	1.05	0.10		
	Obese (30 to 39.9)	1.06	0.11		

("F" = One way ANOVA)
The one way ANOVA was used to compare brainstem diameters according to BMI. There was no difference (p > 0.05) in MBAP, PAP, MPMJ, and MCMJ according to BMI. [Table –10]

Table 11: Comparison of brainstem diameters between males and females according to BMI

	BMI	Male		Female		"t"	p value
		Mean	S.D.	Mean	S.D.		
MBAP	Under weight (< 18.5)	1.90	0.13	1.78	0.08	1.37	0.263
	Healthy weight (18.5 to 24.9)	1.78	0.13	1.78	0.10	0.18	0.855
	Over weight (25 to 29.9)	1.73	0.15	1.80	0.14	-1.66	0.103
	Obese (30 to 39.9)	1.74	0.13	1.71	0.13	0.54	0.594
PAP	Under weight (< 18.5)	2.42	0.16	2.31	0.15	0.78	0.491
	Healthy weight (18.5 to 24.9)	2.29	0.14	2.25	0.14	1.33	0.187
	Over weight (25 to 29.9)	2.29	0.15	2.29	0.17	-0.16	0.875
	Obese (30 to 39.9)	2.37	0.14	2.28	0.14	1.54	0.140
MPMJ	Under weight (< 18.5)	1.45	0.07	1.39	0.08	0.84	0.461
	Healthy weight (18.5 to 24.9)	1.40	0.09	1.36	0.09	1.78	0.080
	Over weight (25 to 29.9)	1.40	0.10	1.42	0.11	-0.65	0.522
	Obese (30 to 39.9)	1.41	0.09	1.38	0.07	0.68	0.507
MCMJ	Under weight (< 18.5)	1.12	0.02	1.24	0.17	-1.01	0.387
	Healthy weight (18.5 to 24.9)	1.14	0.13	1.04	0.11	3.35	0.001*
	Over weight (25 to 29.9)	1.07	0.09	1.02	0.11	2.06	0.044*
	Obese (30 to 39.9)	1.06	0.08	1.06	0.13	0.07	0.943

("t" = Independent sample "t" test; * Significant)
The Independent sample "t test was used to compare the brainstem diameters according to gender within BMI status. There was a difference (p < 0.05) MCMJ between males and females among the healthy weight cases as well as overweight cases. [Table –11]

Table 12: Comparison of brainstem diameters according to BMI within gender

		Male				Female			
		Mean	S.D.	"F"	p value	Mean	S.D.	"F"	p value
MBAP	Under weight (< 18.5)	1.90	0.13	1.44	0.238	1.78	0.08	1.68	0.178
	Healthy weight (18.5 to 24.9)	1.78	0.13			1.78	0.10		
	Over weight (25 to 29.9)	1.73	0.15			1.80	0.14		
	Obese (30 to 39.9)	1.74	0.13			1.71	0.13		
PAP	Under weight (< 18.5)	2.42	0.16	1.25	0.301	2.31	0.15	0.60	0.614
	Healthy weight (18.5 to 24.9)	2.29	0.14			2.25	0.14		
	Over weight (25 to 29.9)	2.29	0.15			2.29	0.17		
	Obese (30 to 39.9)	2.37	0.14			2.28	0.14		
MPMJ	Under weight (< 18.5)	1.45	0.07	0.22	0.883	1.39	0.08	2.17	0.098

	Healthy weight (18.5 to 24.9)	1.40	0.09			1.36	0.09		
	Over weight (25 to 29.9)	1.40	0.10			1.42	0.11		
	Obese (30 to 39.9)	1.41	0.09			1.38	0.07		
MCMJ	Under weight (< 18.5)	1.12	0.02	2.50	0.067	1.24	0.17	3.45	0.02
	Healthy weight (18.5 to 24.9)	1.14	0.13			1.04	0.11		
	Over weight (25 to 29.9)	1.07	0.09			1.02	0.11		
	Obese (30 to 39.9)	1.06	0.08			1.06	0.13		

(“t” = One way ANOVA)

The One way ANOVA was used to compare brainstem diameters according to BM within gender. There was no difference (p > 0.05) in MBAP, PAP, MPMJ and MCMJ according to BMI among males as well as females. [Table –12]

Table 13: Relation between the various parameters of brainstem diameters

		MBAP	PAP	MPMJ	MCMJ
MBAP	"r"	1	0.271	0.150	0.054
	p value	--	0.001*	0.061	0.498
PAP	"r"		1	0.596	0.177
	p value		--	< 0.001*	0.027*
MPMJ	"r"			1	0.215
	p value			--	0.007*
MCMJ	"r"				1
	p value				--

(“r” = Pearson correlation coefficient; * Significant)

The Pearson correlation coefficient (“r”) was used to find the relation between the various parameters of brainstem diameters. The PAP was positively correlated (p < 0.05) with MBAP, MPMJ and MCMJ. Also, there was a positive correlation (p < 0.05) between MPMJ and MCMJ. [Table – 13]

Table 14: Relation between the various parameters of brainstem diameters according to gender

			MBAP	PAP	MPMJ	MCMJ
Male	MBAP	"r"	1	0.437	0.183	0.146
		p value	--	< 0.001*	0.133	0.233
	PAP	"r"		1	0.581	0.121
		p value		--	< 0.001*	0.323
	MPMJ	"r"			1	0.188
		p value			--	0.122
	MCMJ	"r"				1
		p value				--
Female	MBAP	"r"	1	0.135	0.139	0.005
		p value	--	0.208	0.198	0.961
	PAP	"r"		1	0.597	0.177

		p value		--	< 0.001*	0.098
	MPMJ	"r"			1	0.199
		p value			--	0.063
	MCMJ	"r"				1
		p value				--

("r" = Pearson correlation coefficient; * Significant)

Table 5.15: Relation between the various parameters of brainstem diameters according to age groups

			MBAP	PAP	MPMJ	MCMJ
20-30	MBAP	"r"	1	0.516	0.388	0.049
		p value	--	< 0.001*	0.003*	0.722
	PAP	"r"		1	0.692	0.261
		p value		--	< 0.001*	0.052
	MPMJ	"r"			1	0.227
		p value			--	0.092
	MCMJ	"r"				1
		p value				--
31-40	MBAP	"r"	1	0.333	0.107	0.050
		p value	--	0.041*	0.523	0.764
	PAP	"r"		1	0.491	0.168
		p value		--	0.002*	0.312
	MPMJ	"r"			1	0.388
		p value			--	0.016*
	MCMJ	"r"				1
		p value				--
41-50	MBAP	"r"	1	-0.062	0.035	0.131
		p value	--	0.726	0.843	0.459
	PAP	"r"		1	0.343	0.105
		p value		--	0.047*	0.554
	MPMJ	"r"			1	0.090
		p value			--	0.613
	MCMJ	"r"				1
		p value				--
51-60	MBAP	"r"	1	0.517	0.170	0.136
		p value	--	0.004*	0.377	0.482
	PAP	"r"		1	0.584	0.132
		p value		--	0.001*	0.495
	MPMJ	"r"			1	0.286
		p value			--	0.133
	MCMJ	"r"				1
		p value				--

("r" = Pearson correlation coefficient; * Significant)

Table 16: Relation between the various parameters of brainstem diameters according to BMI

			MBAP	PAP	MPMJ	MCMJ
Under weight (< 18.5)	MBAP	"r"	1	0.959	0.535	-0.591
		p value	--	0.010*	0.352	0.294
	PAP	"r"		1	0.409	-0.584
		p value		--	0.495	0.301
	MPMJ	"r"			1	0.314
		p value			--	0.607
	MCMJ	"r"				1
		p value				--
Healthy weight (18.5 to 24.9)	MBAP	"r"	1	0.160	0.101	0.033
		p value	--	0.164	0.383	0.778
	PAP	"r"		1	0.426	0.075
		p value		--	< 0.001*	0.517
	MPMJ	"r"			1	0.176
		p value			--	0.126
	MCMJ	"r"				1
		p value				--
Over weight (25 to 29.9)	MBAP	"r"	1	0.316	0.257	-0.039
		p value	--	0.021*	0.063	0.782
	PAP	"r"		1	0.787	0.304
		p value		--	< 0.001*	0.027*
	MPMJ	"r"			1	0.350
		p value			--	0.010*
	MCMJ	"r"				1
		p value				--
Obese (30 to 39.9)	MBAP	"r"	1	0.488	0.031	0.319
		p value	--	0.021*	0.890	0.148
	PAP	"r"		1	0.627	0.485
		p value		--	0.002*	0.022*
	MPMJ	"r"			1	0.206
		p value			--	0.359
	MCMJ	"r"				1
		p value				--

("r" = Pearson correlation coefficient; * Significant)

4. DISCUSSSION

The brainstem, functioning as the relay center of the human brain, connects the cerebrum to the spinal cord and is composed of the midbrain, pons, and medulla oblongata. It controls vital physiological functions and houses various cranial nerve nuclei (1). Additionally, it serves as a conduit for both ascending and descending neural pathways linking the spinal cord to higher centers of the nervous system. The present study aimed to establish normative reference data for midsagittal linear measurements of various parts of the brainstem, matched for age, gender, and BMI, which can serve as a baseline for identifying physiologic and pathologic alterations. A total of 157 subjects (69 male, 88 female) were included, with a mean age of 37.81 years, height of 156.97 cm, weight of 60.89 kg, and BMI of 24.78 kg/m2. The overall mean ± standard deviation of the midsagittal diameters were found to be 1.77 ± 0.12 cm for the midbrain, 2.28 ± 0.15 cm for the pons, 1.39 ± 0.10 cm for the medulla oblongata, and 1.07 ± 0.12 cm at the cervicomedullary junction (MCMJ). Notably, differences were observed in MCMJ diameters between males and females within BMI groups.

Our findings are comparable to previous studies, Amrutha et al. reported significant reductions in brainstem measurements with age, except at the pontomedullary junction of the medulla, which remained relatively constant. They did not find significant differences between males and females. However, in contrast, our study found significant differences in MCMJ diameters between males and females, as well as between healthy-weight and overweight individuals, demonstrating the influence of BMI on these dimensions (9).

Similarly, S.O et al. observed significant age-related reductions in brainstem diameters except for the medulla at the pontomedullary junction, without any significant gender differences. Our results agree with the preservation of medulla dimensions at the pontomedullary junction with age, but differ in identifying significant gender- and BMI-related differences at the MCMJ (1).

Singh et al. analyzed sagittal diameters of the midbrain, pons, and medulla at the cervicomedullary junction in healthy and overweight individuals. They noted no significant gender correlation but did observe significant differences at the MCMJ between healthy and overweight groups. They also highlighted that the sagittal diameter peaked around age 20, stabilized until 50, and then decreased significantly after age 70, particularly in the midbrain and medulla, while the pons remained relatively stable. This supports our observation of BMI-associated differences and suggests that age-related reductions may become more apparent after the sixth decade of life (19).

Elameen et al. reported mean brainstem diameters similar to our findings, with the pons measuring larger than both the midbrain and medulla. They also noted no significant relationship between age and brainstem diameter except at the cervicomedullary junction. However, similar to our findings, they documented significant differences in MCMJ measurements between healthy-weight and overweight individuals.

In summary, our study corroborates earlier research regarding the relative stability of certain brainstem dimensions with age, while adding further evidence for the influence of gender and BMI on cervicomedullary junction dimensions. These normative reference values can be utilized in future studies and in clinical practice for detecting subtle morphometric changes associated with neurodegenerative, vascular, or other pathological conditions of the brainstem.

5. CONCLUSION

This study demonstrates that basic linear measurements of the brainstem can be effectively and noninvasively obtained using magnetic resonance imaging (MRI), making it a valuable tool in clinical assessment. The findings reveal a statistically significant difference in the anteroposterior (AP) diameters of brainstem structures between males and females, indicating the importance of considering gender-specific reference values. Furthermore, variations in BMI across healthy and overweight ranges also differed by gender, suggesting a potential influence on brainstem morphology. The normative data established in this study can be reliably used for evaluating physiological changes in the brainstem. Additionally, age-related differences in AP diameters were observed between males and females, emphasizing the relevance of age- and gender-specific evaluation in neuroimaging assessments.

LIMITATIONS OF THE STUDY

- Our study's limitation is the absence of volumetric investigation of brainstem structures ,which could have improved the accuracy of the brainstem morphometry and BMI. We suggest conducting volumetric analysis study on this topic in the future.
- Subjects with the age of less than 18 year and more than 60 years may be included in this for the measurement variation.
- Larger sample size allow for the possibility of even the smallest measurement error , which could produce minute variations in the result.
- The male contenders were smaller than the female candidates, which might have affected the study's conclusions.

- In comparison with linear measurements, volumetric measurements might provide more information.

SCOPE FOR FUTURE STUDY

- It can be used in neurological investigations using MRI brain scan to quantify the brainstem morphometric measurement.
- This study has the potential to be utilized to establish normative values based on age, gender and BMI's structural changes in the brainstem.

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