

MORPHOMETRIC STUDY OF HUMAN KIDNEY: A CADAVERIC STUDY IN RAJASTHAN POPULATION

Nikhil Sharma^{1*}, Dr. Meghna Bhaumik², Dr. Hina Sharma³

¹Research Scholar, Department of Anatomy, Pacific Medical University, Udaipur, Rajasthan, India. EMAIL ID: nikhilsharma2775@gmail.com, ORCID ID-0009-0009-6472-1564

²Professor, Department of Anatomy, Pacific Medical University, Udaipur, Rajasthan, India. EMAIL ID: drmeghnabhaumik@gmail.com.

³Professor and Head, Department of Anatomy, Pacific Medical University, Udaipur, Rajasthan, India, EMAIL ID: drsharmah@gmail.com , ORCID ID-000-0002-9863-5260

*Corresponding Author: Nikhil Sharma, Email Id: nikhilsharma2775@gmail.com

ABSTRACT

Background: Kidneys are vital organs responsible for maintaining fluid, electrolyte, and metabolic homeostasis. Renal morphometry plays an essential role in clinical diagnosis, radiological evaluation, and surgical planning. Variations in renal dimensions may reflect underlying pathological conditions and population-based differences.

Aims and objectives: To evaluate the morphometric parameters of human kidneys in the Rajasthan population and compare the findings with previously published studies.

Materials and Methods: A cross-sectional cadaveric study was conducted on 100 human kidneys (50 right and 50 left) in the Department of Anatomy, Pacific Medical University, Udaipur. Parameters including weight, length, width (superior pole and inferior pole), and thickness were measured using standard instruments. Data were analyzed using descriptive statistics.

Results: The mean weight of the right and left kidneys was 110.0 ± 2.75 g and 104.6 ± 2.31 g, respectively. The mean length was 9.6 ± 1.1 cm (right) and 10.1 ± 1.2 cm (left). Width and thickness showed minimal variation between sides. The left kidney was found to be longer, while the right kidney showed slightly higher weight.

Conclusions: The present study provides baseline morphometric data for the Rajasthan population. The findings are largely consistent with previous studies, with minor variations likely due to regional and demographic factors.

KEYWORDS: Cadaveric study, Morphometry, Renal parameters, Renal transplantations.

INTRODUCTION

Kidneys are the chief excretory organs which help in maintaining the water and electrolyte balance. They also serve as an important endocrine organ. They are located retroperitoneally in the posterior abdominal wall beside the vertebral column and extend from T12 to L3 vertebra. The average weight of a kidney is about 150 grams in males and 135 grams in females. Each kidney is a bean shaped structure having length of 11 cm, width of 6 cm and thickness of 3 cm. Kidneys have broad thick upper pole & pointed thin lower pole, convex anterior surface, flat posterior surface, convex lateral border and concave medial border. Right kidney is usually slightly inferior to the left, showing its relationship with liver while left kidney is little longer and narrower than the right and lies nearer the median plane.⁽¹⁾

The concept of histogenesis, which refers to the embryonic development and differentiation of kidney tissues, plays an important role in understanding both normal kidney structure and disease conditions.⁽²⁾ During nephrogenesis, a process that is usually completed by around 34–36 weeks of gestation, the kidneys develop through several complex steps such as branching of the ureteric bud, transformation of mesenchymal cells into epithelial cells, and maturation of nephrons⁽³⁾ Any disturbance in these developmental processes can lead to subtle abnormalities that may remain unnoticed during early life but can persist into adulthood and increase the risk of future renal disorders.⁽⁴⁾

Morphometric studies have gained a lot of research attention as they are believed to possess a significant clinical importance in conditions like systemic diseases, urinary tract diseases, congenital anomalies, neoplasia, micro and macrovascular diseases which reported significantly influence kidney sizes.⁽⁵⁾ Evaluations of renal measurements such as length, width, thickness are important for the diagnosis and treatment of renal diseases since there is a strong relationship between renal size and its function. Foetal lobulation persists in adult life to appear longer than normal.⁽⁶⁾

Given the close correlation between renal function and size, evaluations of renal parameters such as length, width, and thickness are critical for the diagnosis and management of renal disorders. In adulthood, fetal lobulation continues to look longer than usual.⁽⁷⁾

There is little data available in literature on renal morphometry which were mainly based on the radiological investigations like ultrasound, CT-scan, MRI but anatomical studies on renal parameters are scarcely lacking.^(8,9)

MATERIALS AND METHODS

The present cross-sectional cadaveric study was conducted in the Department of Anatomy, Pacific Medical University, Udaipur, Rajasthan. A total of Hundred human cadaveric kidneys, comprising fifty from the right-side and fifty from the

left, were obtained from embalmed human kidney specimens. Ethical clearance for the study was granted by the Institutional Ethical Committee (PMU/PMCH/IEC/2023/25).

We measured the morphometric parameters: weight, length, width at SP and IP, Thickness at SP and IP. The parameters measured were as follows- Weight was measured by using weighing machine. The length of each kidney was measured from the uppermost edge of the superior pole to the lowest edge of inferior pole. [Fig-1]

The width & thickness at superior and inferior poles medial to lateral and anterior to posterior respectively were also measured at the point of maximum convexity on pole[Fig-2,3]. The results were presented as mean±SD. The obtained values were calculated and mean and standard deviation obtained and tabulated as per Table-1.

Inclusion criteria: All the kidney specimens of cadavers belonging to both sexes available at the Department of Anatomy, irrespective of age, were included in the study.

Exclusion criteria: Damaged kidneys, kidneys showing gross pathological changes, evidence of traumatic injury, prior surgical intervention, or congenital malformations were excluded from the analysis.

Statistical Analysis

Statistical analysis was done by using descriptive and inferential statistics using Student's unpaired t-test, Pearson's correlation coefficient and multiple regression analysis and software used in the analysis were SPSS 17.0 version. The collected data were tabulated and analyzed using appropriate statistical methods. Descriptive statistics such as mean and standard deviation were calculated for all parameters. Comparative analysis between right and left kidneys was performed to assess side-based variations.

RESULTS

In present study. Out of the 100 kidneys studied, 50 were right and 50 were left. All the 100 kidneys were bean shaped. Among the 50 right kidneys, weight ranged from 61-164 gm with an average weight of 110.00 gm. The length of right kidney varied from 8.0 to 12.5 cm with an average length of 9.6 cm. The width of right kidney at superior pole ranged from 4.0 – 5.8 cm with an average width of 4.8 cm and at inferior pole ranged from 3.8 – 5.5 cm with an average width of 4.6 cm. The range of thickness of right kidneys at level of superior pole was observed to be between 2.5 – 3.5 cm with an average thickness of 3.0 cm and at inferior pole was in the range of 2.7 – 3.6 cm with an average being 3.1 cm.

Among the 50 left kidneys, weight ranged from 60-145 gm with an average weight of 104.6 gm. The length of left kidney varied from 8.5 – 13.0 cm with an average length of 10.1 cm. The width of left kidney at superior pole ranged from 4.2 – 6.2 cm with an average width of 5.0 cm and at inferior pole ranged from 4.0 – 6.0 cm with an average width of 5.1 cm. The thickness of left kidneys at superior pole was in between 2.7 – 3.8 cm with an average being 3.1 cm and at inferior pole ranged from 2.8 – 3.8 cm with an average being 3.2 cm [Table-1], [fig. 1-3].

S.No	Measurements	Side	Range	Mean	SD
1	Weight (gm)	Right	61-164	110.0	2.79
		Left	60-145	104.6	2.81
2	Length (cm)	Right	8.0 – 12.5	9.6	1.1
		Left	8.5 – 13.0	10.1	1.2
3	Width at SP (cm) (M-L)	Right	4.0 – 5.8	4.8	0.6
		Left	4.2 – 6.2	5.0	0.7
4	Width at IP (cm) (M-L)	Right	3.8 – 5.5	4.6	0.5
		Left	4.0 – 6.0	5.1	0.6
5	Thickness at SP (cm) (A-P)	Right	2.5 – 3.5	3.0	0.4
		Left	2.7 – 3.8	3.3	0.5
6	Thickness at IP (cm) (A-P)	Right	2.7 – 3.6	3.1	0.4
		Left	2.8 – 3.8	3.2	0.5

Table 1. Morphometric analysis of kidney. (SP- Superior Pole, IP- Inferior Pole, M-L= Medial to Lateral, A-P= Anterior to Posterior



Fig. 1 Weighing of Kidney using Weighing Machine and Measuring Length of Kidney using Vernier caliper.

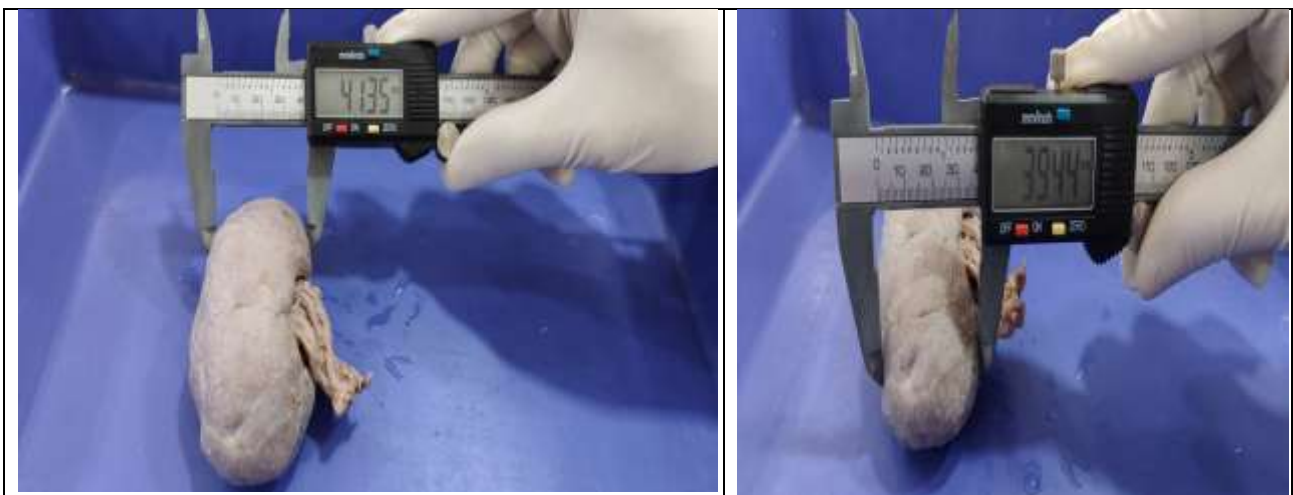


Fig. 2 Measuring Width at Superior pole of Kidney and Measuring Width at Inferior pole of Kidney.

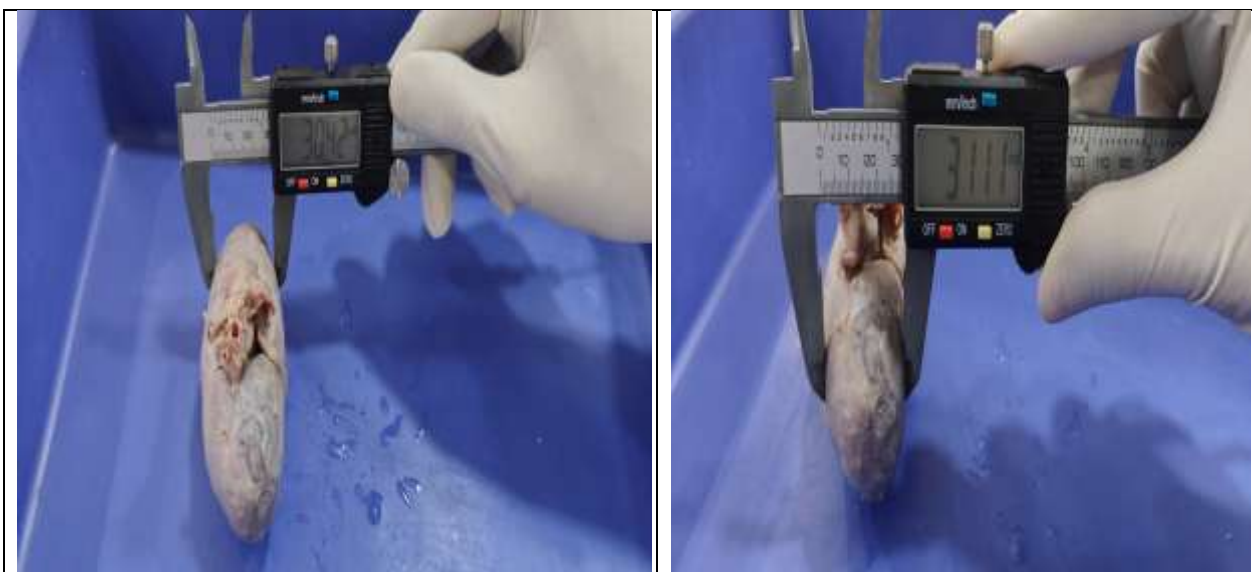


Fig. 3 Measuring Thickness at Superior pole of Kidney and Measuring Thickness at Inferior pole of Kidney.

DISCUSSION

The present cadaveric study provides a comprehensive morphometric evaluation of kidneys in the Rajasthan population and compares the findings with previously published data from different geographical regions. Renal morphometry shows

significant variation due to ethnicity, environmental factors, nutritional status, and methodological differences, making such comparative studies clinically important.

Renal Weight

In the present study, the mean renal weight was higher on the right side (110.0 ± 2.75 g) than the left (104.6 ± 2.31 g). Higher weights were reported by Deep A et al. (2023)¹⁹ (R: 155.33 g, L: 153.67 g), whereas lower values were observed by Naik SK et al. (2014)¹⁰ (R: 86.88 g, L: 96.32 g). The right-sided higher weight aligns with Deep A et al. (2023)¹⁹ but contrasts with Varalakshmi KL (2017)¹⁵, Dharmadas S et al. (2019)¹⁶, and Nirmala BV et al. (2025)²⁵. Similarly, left-sided higher weight findings agree with Deep A et al. (2023)¹⁹ but differ from studies by More SM et al. (2015)¹³, Ashwini NS et al. (2017)¹⁴, Shilpakala LB et al. (2024)²¹, Singh P (2025)²⁴.

Lowest weight observations were consistent with Naik SK et al. (2014)¹⁰ but differed from several other studies. Overall, findings show partial agreement with previous literature, while variations may be due to differences in sample size, BMI, nutrition, genetics, and measurement techniques. Although classical anatomy suggests minimal side variation, population-based studies show slight asymmetry.

Renal Length

The mean renal length was 9.6 ± 1.1 cm (right) and 10.1 ± 1.2 cm (left), indicating a longer left kidney. This is consistent with classical anatomical descriptions and studies by Murlimanju BV et al. (2014)¹¹, Muthusami P et al. (2014)¹², Ashwini NS et al. (2017)¹⁴, and Bhardwaj S et al. (2024)²². Higher values were reported by More SM et al. (2015)¹³ and Deep A et al. (2023)¹⁹, while lower values were observed by Dharmadas S et al. (2019)¹⁶ and Shilpakala LB et al. (2024)²¹. Alyami AS et al. (2024)²⁰ reported values closer to the present study.

The longer left kidney is anatomically explained by the presence of the liver on the right side, restricting right kidney growth. Overall, the findings fall within the normal reported range, with minor variations due to population and methodological differences.

Renal Width

Renal width ranged from 4.6 cm to 5.1 cm with minimal side variation. Similar findings were reported by Murlimanju BV et al. (2014)¹¹, Muthusami P et al. (2014)¹², and Ashwini NS et al. (2017)¹⁴. Dharmadas S et al. (2019)¹⁶ and Shambharkar S et al. (2020)¹⁷ also reported comparable values, while Shilpakala LB et al. (2024)²¹ observed lower values. Higher values were reported by More SM et al. (2015)¹³, Deep A et al. (2023)¹⁹, and Alyami AS et al. (2024)²⁰.

Renal width shows less variation compared to length and weight, suggesting it is a relatively stable parameter due to anatomical constraints. Overall, the findings are consistent with most studies.

Renal Thickness

Renal thickness ranged from 3.0 ± 0.4 cm to 3.3 ± 0.5 cm, with minimal side variation and slightly higher values on the left. These findings agree with Murlimanju BV et al. (2014)¹¹, Ashwini NS et al. (2017)¹⁴, and Shambharkar S et al. (2020)¹⁷. Lower values were reported by Dharmadas S et al. (2019)¹⁶ and Shilpakala LB et al. (2024)²¹, while higher values were observed by Deep A et al. (2023)¹⁹ and Alyami AS et al. (2024)²⁰.

Comparison with studies from different regions of India (Karnataka, Andhra Pradesh, Maharashtra, North India) and international populations (Saudi Arabia, Pakistan) highlights the role of ethnic and environmental factors in renal morphology. Methodological differences also contribute to variation. Cadaveric studies provide direct measurements but may be affected by embalming, while radiological studies may vary due to imaging and operator factors. Hence, comparisons should be made cautiously.

Authors	Population	N		Weight (gm)	Length(cm)	Width(cm)		Thickness(cm)	
Naik SK et al.(2014) ⁽¹⁰⁾	Karnataka	36	R	86.88	8.02	4.56		2.51	
			L	96.32	8.56	4.52		2.54	
Murlimanju BV et al (2014) ⁽¹¹⁾	Manipal	151	R	-	8.9±0.9	SP	4.9±0.6	S	3±0.4
						IP	4.8±0.6	P	3.1±0.4
			L	-	9.1±0.9	SP	5±0.7	S	3.2±0.5
						IP	4.5±0.7	P	3.2±0.5
Muthusami P et al.(2014) ⁽¹²⁾	Puducherry	300	R		9.6±0.97	4.5±0.7		1.99±0.30	
			L		9.7±0.89	4.54±0.63		2.09±0.29	
More SM et al (2015) ⁽¹³⁾	Karnataka	80	R	102.48	11.5	5.32		3.32	
			L	122.15	12.71	6.07		3.64	
Ashwini NS et al (2017) ⁽¹⁴⁾	Karnataka	90	R	107.37±28.1	9.22±0.89	SP	4.89±0.91	3.85±0.48	
						IP	4.91±0.64		
			L	105.18±27.5	9.29±0.9	SP	4.91±0.59	3.57±0.45	
						IP	4.57±0.6		
	Karnataka	64	R	120.8±28	8.9±1.58	SP	3.5±0.7	SP	2.92±0.52

Varalakshmi KL (2017) ⁽¹⁵⁾			L	123.45±30.7	9.01±0.88	IP	3.06±0.72	IP	2.06±0.49
						SP	3.55±0.62	SP	2.13±0.51
						IP	3.09±0.53	IP	2.39±0.79
Dharmadas S et al (2019) ⁽¹⁶⁾	Andhra pradesh	50	R	126.92±24.3	7.63±1.039	3.93±0.431		2.62±0.373	
			L	131±24.36	7.68±1.004	3.96±0.426		2.58±0.396	
Shambharkar S et al (2020) ⁽¹⁷⁾	Western Maharashtra	100	R	104.8±34.53	8.69±1.34	4.085±0.55		3.32±0.66	
			L	103.6±30.45	8.8±1.88	4.08±0.57		3.3±0.59	
Chaudhary P et al (2023) ⁽¹⁸⁾	bathinda	209	R	-	10.65±1.343	4.8±1.56		0.915±0.163	
			L	-	10.7±1.69	4.78±1.26		0.76±0.40	
Deep A et al(2023) ⁽¹⁹⁾	kanpur	30	R	155.33±6.38	12.66±1.76	6.40±2.06		3.56±0.93	
			L	153.67±18.8	10.66±1.71	5.93±1.53		4.12±1.22	
Alyami A S et al (2024) ⁽²⁰⁾	saudi	95	R	-	9.79±1.03	5.09±0.96		4.10±0.80	
			L	-	10.1±1.02	5.56±4.48		4.61±0.60	
Shilpakala LB et al (2024) ⁽²¹⁾	tumakuru	50	R	110±25	8.80±1.04	SP	3.32±0.49	SP	2.35±0.21
						IP	3.08±0.38	IP	2.0±0.28
			L	115±27	8.55±0.82	SP	3.53±0.27	SP	2.06±0.36
						IP	3.29±0.40	IP	2.17±0.41
Bhardwaj S et al (2024) ⁽²²⁾	North Indian	511	R	-	9.56±0.7	4.8±0.6		4.75±0.6	
			L	-	9.95±0.7	4.25±0.6		4.3±0.6	
Asgar MR et al (2025) ⁽²³⁾	Pakistan	96	R	-	103.4±7.2	45.6±5.0		-	
			L	-	104.7±7.4	50.0±5.2		-	
Singh P (2025) ⁽²⁴⁾	Akola, India	40	R	104.51	8.39	4.86		3.6	
			L	125.6	9.25	4.7		4.02	
Nirmala BV et al (2025) ⁽²⁵⁾	Vijayawada, Machilipatnam	100	R	142±18	9.5±1.1	5.6±0.7		2.4±0.6	
			L	138±22	8.9±1.4	5.2±0.9		2.8±0.8	
Present study	Rajasthan	100	R	110.0±2.79	9.6±1.1	SP	4.8±0.6	SP	3.0±0.4
						IP	4.6±0.5	IP	3.1±0.4
			L	104.6±2.81	10.1±1.2	SP	5.0±0.7	SP	3.3±0.5
						IP	5.1±0.6	IP	3.2±0.5

Table 2. Comparison of renal parameters with other authors. [R- Right, L- left, SP- superior pole, IP- Inferior pole.

LIMITATIONS

Small sample size, Lack of sex-wise and age-wise analysis, Cadaveric study (may differ from radiological findings), Regional limitation (only Rajasthan population) and histological scope: lack of immunohistochemistry restricts molecular insights.

CONCLUSION

The present study demonstrates that renal morphometric parameters in the Rajasthan population largely align with established anatomical patterns, particularly the longer left kidney and relatively stable width. Variations observed across studies can be attributed to ethnic, environmental, nutritional, and methodological differences. These findings contribute to the development of reliable population-specific reference standards for clinical practice.

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