

# Morphometric Characteristics of 1200 Normal Kidneys in Cadavers at the Mashhad Forensic Medicine Center

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## Abstract

**Background:** Kidneys play an important role in excretion of bodily waste and the regulation of water and electrolyte. Currently available sources and books are based on anthropometric characteristics from Western countries. Determining national anthropometric measurements is a research priority in Iran. Based on a recent search, no study has been done on the standard data of kidneys in the Iranian population.

**Objectives:** The present study investigated the morphometrical characteristics of the kidney (length, width, thickness, index, and weight) in an Iranian population.

**Methods:** This cross-sectional study was performed on 604 cadavers (122 females/482 males) with a mean age of  $43.86 \pm 19.09$  years in Mashhad Forensic Medicine Center in 2015. After approval of the Ethical Committee, demographic characteristics of cadavers were recorded. Then, length, width, thickness, index and weight of kidney were measured using a vernier caliper. At the end, data were analyzed using SPSS software.

**Results:** The mean length of the kidney was  $11.12 \pm 1.73$  cm, mean width was  $5.09 \pm 2.19$  cm, mean thickness was  $2.60 \pm 1.39$  cm, kidney index was  $2.33 \pm 1.62$ , and mean weight was  $143.03 \pm 52.97$  g. No significant difference was seen in the morphometric values of the kidney between males and females ( $P > 0.05$ ), but a significant correlation was found between the age and body surface area of the cadavers and the length, width, thickness, index, and weight of the studied kidneys ( $P < 0.05$ ).

**Conclusion:** The investigation of the morphologic characteristics of kidney is useful for both surgeons and anatomists. Besides, it provides valuable data on standard kidney sizes in Iranian population.

**Keywords:** Cadaver, Human, Kidney, Macroscopic anatomy, Morphometry

## 1. Background

The kidneys are a pair of bean-shaped organs, brown in color, located on either side of the spinal column parallel to the first and third lumbar vertebrae (1). Several factors such as age, sex, race, physical activity, nutrition, and health status affect the size of the kidney and various other organs (3-8). Studies have identified differences in morphological characteristics of various bodily organs of different races and ethnicities. The weight of certain organs increases with age in some races and decreases with age in others (3-8). There is no significant difference in organ weight between males and females in some races, while in others, organ weight is higher in men than in women (3,5,8-11). Physical activity is a factor that reduces fat and increases muscle mass in the body (2). Malnutrition and disease are also factors that affect organ size (2).

According to Gray's Anatomy, the length of a normal kidney is 11 cm, its width is 6 cm, and its thickness is 3 cm (1). Kidney length was reported in Texas, USA as 12 cm (12), and in Austria's population as 11.4 cm (13). In Brazil, the length, width, and thickness of the kidney were measured as 11.09 cm, 5.96 cm, and 3.29 cm, respectively (14). In

Nigeria, Africa, the length, width, and thickness of the kidney were measured as 11.45 cm, 4.8 cm, and 4.6 cm, respectively (15). On the Asian continent, the ranges of kidney length, width, and thickness were 9-11.08 cm, 4.5-6.25 cm, and 2.04-4.73 cm, respectively (16-21). The weight of a normal kidney ranged from 112 to 172 g on the American continent (22-24) and from 95 to 260 grams in Asian populations (3,4,9,25-28). Currently available sources and books are based on anthropometric characteristics from Western countries. Determining national anthropometric measurements is a research priority in Iran. Based on a recent search, no study has been done on the standard data of kidneys in the Iranian population.

## 2. Objectives

The present study investigated the morphometrical characteristics of the kidney (length, width, thickness, index, and weight) in an Iranian population.

## 3. Methods

This cross-sectional study was performed in 2015 at the Mashhad Forensic Medicine Center on

604 cadavers (122 females and 482 males). After obtaining approval for the study from the Ethics Committee (ethical code: 14759-133711), demographic characteristics including age, sex, and body surface area (BSA) and anthropometric values including weight, height and body mass index (BMI) were recorded for each specimen. To calculate the BSA, the body's weight in kilograms was multiplied by its height in meters and then divided by 3600. Cadaver weight in kilograms was divided by height squared to calculate BMI; the kidney index was calculated by dividing the weight of the kidney by the specimen's body weight. Sample size was determined by census. Samples were taken from former residents of Khorasan province. Causes of death included accident, stab wound, and fall from a height. Cadavers were into 10 age groups: Group 1 (0-9 years), Group 2 (10-19 years), Group 3 (20-29 years), Group 4 (30-39 years), Group 5 (40-49 years), Group 6 (50-59 years), Group 7 (60-69 years), Group 8 (70-79 years), Group 9 (80-89 years), and Group 10 (90-99 years).

Iranian cadavers which death had not passed more

than 24 hours were included in the study. Non-Iranian cadavers, pregnant women, and cadavers with a history of hypertension, poisoning, diabetes, alcohol, drug abuse, kidney disease or trauma, or abnormalities in the kidney area were excluded from the study.

After a longitudinal section, the kidneys of each cadaver were removed from the surrounding tissue by a single expert anatomist. Then the length, width, and thickness of each kidney were measured from the upper pole to lower pole using a vernier caliper (Figure 1). Vernier caliper was calibrated according to ISO guidelines. Measurements of each parameter were taken and recorded three times. A digital scale was used for weighing kidneys. Photos were captured with a camera (Canon Inc., Japan).

The collected data were presented as mean  $\pm$  SD. P values less than 0.05 was considered as the significant level. SPSS software was used for data analysis. Kolmogorov-Smirnov test was used to check data normality. The relationship between demographic values and dimensions of kidneys were assessed using Pearson correlation coefficient. ANOVA and post hoc Tuckey test was used to compare groups.



**Figure 1.** Image A shows location of right kidney in right flank part of abdomen \*: gall bladder,  $\triangle$ : liver,  $\nabla$ : kidney (B) Measurement of the kidney length (C) Measurement of the kidney thickness using a vernier caliper (D) comparison between two kidneys. The left is an adult kidney and the right belongs to an infant.

#### 4. Results

As you can see in Table 1, a total of 604 cadaver (122 female and 482 male) with an average age of  $43.86 \pm 19.09$  years, mean height  $167.83 \pm 81.79$  cm (13 to 192 cm), average weight  $65.95 \pm 14.14$  kg (2.5 up to 98 kg), average BMI  $22.20 \pm 36.77$  kg / m<sup>2</sup> and the average BSA  $3.12 \pm 1.98$  cm were enrolled in the study. Overall, the average length of kidney was  $11.12 \pm 1.73$  cm (0.5 to 15 cm), width of  $5.09 \pm 2.19$  cm, thickness of kidney  $2.60 \pm 1.39$  (0.5 to 3.20 cm), kidney index  $2.33 \pm 1.62$  and weight of kidney was obtained  $143.03 \pm 52.97$  g (5 to 360 g).

The lowest values for kidney length and weight were found in the age group <10 years; the highest value was observed in the age group 80-89 years (Table 2). The lowest value for kidney width was in the age group <10 years; the highest value was found in the 30-39 years group. The lowest value for kidney thickness was observed in the age group <10 years; the maximum value was found in the 90s of life

(Table 2). The most kidney index was observed in the age group <10 years; the lowest averages of kidney index was in the 50s of life (Table 2). A significant difference was found between kidney morphometric characteristics (length, width, thickness, index, and weight) of different age groups with age group <10 years. Besides, a significant correlation was found between kidney weights in age group 10-19 years with other age groups (Table 2). Table 3 shows data regarding kidney length, width, thickness, weight, and kidney index in both male and female Iranian cadavers. Although the size and weight of the kidney were higher in men than in women, the difference between the sexes was not significant ( $P > 0.05$ ).

As Table 4 shows, the results of a study using Pearson correlation demonstrated a significant correlation between age of cadaver with kidney length and weight ( $P = 0.01$ ), height of cadaver with kidney length ( $P = 0.01$ ) and BSA values with length and index of kidney ( $P = 0.01$ ). In addition, a

**Table 1.** Demographic values of Iranian cadavers (N=604) in RazaviKhorasan province, Iran

Age groups	Mean age (years)	Sex (female/male)	Height (cm)	Weight (kg)	BSA (cm <sup>2</sup> )	BMI (kg/m <sup>2</sup> )
<10 years	4.50±2.72	6/11	103.88±31.51	17.08±14.68	0.57±0.63	14.21±7.86
10-19	15.61±2.80	11/31	160.59±15.65	56.92±17.33	2.57±0.86	22.01±5.97
20-29	24.78±2.84	25/68	166.31±7.25	68.11±8.54	3.14±0.42	24.74±3.64
30-39	34.61±2.77	24/85	165.57±6.51	68.11±10.17	3.13±0.47	24.98±4.37
40-49	43.89±2.91	18/89	164.32±16.12	68.28±10.03	3.11±0.56	27.80±4.43
50-59	54.17±2.80	17/79	166.62±7.24	69.00±9.15	3.19±0.43	24.99±3.98
60-69	64.41±2.59	12/69	163.06±20.42	66.23±13.64	3.00±0.70	24.84±3.28
70-79	74.31±2.97	7/34	166.80±7.24	68.26±10.20	3.83±4.34	24.03±5.31
80-89	82.80±2.78	1/14	164.23±7.69	73.53±10.48	5.70±9.27	24.93±7.78
90-99	92.33±0.57	1/2	158.33±3.21	65.33±10.69	2.86±0.42	26.17±5.17

Values are presented as mean± SD. body mass index (BMI), body surface area (BSA)

**Table 2.** Length, width, and thickness, weight, and index of the kidney of Iranian cadavers in different age groups

Age groups	Length (cm)	Width (cm)	Thickness (cm)	Weight (cm)	Kidney Index
<10 years	5.61±2.41	3.05±1.44	1.50±1.00	50.29±27.37	4.17±2.82
10-19	10.77±1.56**	4.82±0.75	2.32±0.53	116.95±39.90**	2.32±1.37*
20-29	11.49±1.29**	5.09±0.82##	2.63±0.70	152.03±54.80##	2.26±0.85**
30-39	11.29±1.26**	5.63±0.78**	2.95±2.91*	143.66±48.94**	2.15±0.82**
40-49	11.22±1.60**	4.96±0.75##	2.53±0.60	153.93±55.26**	2.27±0.83**
50-59	11.30±1.24**	5.18±0.78*	2.61±0.73	143.37±44.65**	2.12±0.73**
60-69	11.17±1.66**	5.07±0.87##	2.58±0.64	139.67±50.74**	2.59±3.54*
70-79	11.54±1.32**	4.85±0.74	2.52±0.48	157.14±47.21**	2.36±0.84*
80-89	11.63±1.24**	5.43±0.84	2.53±0.66	157.40±66.24**	2.22±1.14##
90-99	11.00±1.00**	5.16±0.28	3.00±0.00	157.33±32.57##	2.40±0.29

Values are presented as mean± SD. Comparison between groups was made using ANOVA and Tukey test.

\*\*P=0.000 compared to group <10 years within column

\*P=0.003 compared to group <10 years within column

#P=0.003 compared to group 10-19 years within column

##P=0.01 compared to group <10 years within column

**Table 3.** Length, width, thickness, weight, and index of the kidney of Iranian cadavers in different sex groups

Morphometric parameters	Gender		P value
	Female	Male	
Length (cm)	10.93±1.88	11.17±1.68	0.16
Width (cm)	4.87±0.92	5.15±2.41	0.21
Thickness (cm)	2.65±0.82	2.59±1.50	0.64
Weight (g)	135.57±53.33	144.91±52.77	0.08
Kidney index	2.46±2.90	2.29±1.08	0.53

Values are presented as mean± SD. Comparison between groups was made using t- test.

**Table 4.** Correlation (r) between morphological parameters of kidney and demographic characteristics

	Age (year)	Weight (kg)	Height (cm)	BSA (cm <sup>2</sup> )	BMI (kg/m <sup>2</sup> )
<b>Length (cm)</b>	.229**	.448**	.137**	.042	.200**
<b>Width (cm)</b>	.045	.138**	.033	.005	.056
<b>Thickness (cm)</b>	.038	.084*	.044	-.008	.056
<b>Weight (g)</b>	.161**	.242**	.016	.025	0.059
<b>Kidney index</b>	-.056	-.470**	-.066	-.014	-.186**

Correlations were assessed using Pearson correlation coefficients.

\*\* Significant in P value 0.01

\* Significant in P value 0.05

significant correlation was observed between body weight with kidney index ( $P = 0.01$ ), length ( $P = 0.01$ ), width ( $P = 0.01$ ), weight ( $P = 0.01$ ) and thickness of kidney ( $P = 0.05$ ).

## 5. Discussion

Overall, the average length, width, and thickness of kidneys were 11.18 cm, 5.13 cm, and 2.61 cm, respectively. According to Gray's Anatomy, the length of a normal kidney is 11 cm, its width is 6 cm, and its thickness is 3 cm (1). The kidney dimensions noted in the textbook of Moore's Anatomy were 10 cm, 5 cm, and 2.5 cm (28).

Kidney length in men from Texas was 12.4 cm and in women was 11.6 cm. In Austrian adults, this measurement was 10.99 cm (12,13). The length, width, and thickness of the kidney in 100 autopsies in the Brazilian population were 11.09 cm, 5.96 cm, and 3.29 cm, respectively (14). In Nigeria, kidney length measured 11.45 cm, its width was 4.8 cm, and its thickness was 4.6 cm (15). A significant correlation was found between kidney dimensions and height, weight, and BMI. Similarly, the present study also found a significant relationship between the size of the kidney and the demographic characteristics of the studied cadavers.

In studies in Asia, Kang et al. investigated kidneys from donors in South Korea. Their results showed that kidney length was 11.08 cm, width was 6.25 cm, and thickness was 4.73 cm. The dimensions of the kidneys from Korean male donors were greater than those of kidneys from Korean female donors (16). In the present study, all measured parameters were higher in men than in women, but the difference was not statistically significant. In another study conducted in Pakistan, the average kidney length was found to be 10.4 cm and width was 4.5 cm (17). Kidney dimensions in adults of the Philippines were 10.35 cm, 5.22 cm, and 3.96 cm, respectively (19). The length, width, and thickness of adult kidneys in the Indian population were 9 cm, 4.8 cm, and 3.1 cm, respectively (18). There was no remarkable difference in kidney size between males and females, but in specimens over the age of 70, kidney size was reduced (20). Results of the current study are consistent with these results in that kidney size was not significantly different between males and females; however, this study observed no change in

the kidneys of cadavers over 70 years of age.

In 2012, Otiye et al. investigated the kidneys of children from India aged 1 month to 12 years. Their results showed a kidney length of 4.3 cm during the first months of life, 5.7 cm in infants 9 months old, and 8.6 cm in 12-year-old children (29). In the current study, the length of the kidney was 5.61 cm in specimens <10 years and 12.25 cm in specimens 12 years old.

At birth, both kidneys weigh 20-35 g; the average weight of an adult kidney is 10 to 14 times greater than that (30). In this study, the average weight of the kidney was 143.03 g. Kidney weight in American men and women was 133 g and 112 g, respectively (23,24). Another study in Brazil reported kidney weights of 182.25 g in male donors and 165.20 g in female donors. Similarly, there was no significant difference in kidney weight between males and females, but kidney weight correlated with body weight and BMI (22).

A study in India investigated 109 cadavers (86 males and 23 females). Their results showed that the weight of the kidney was 135.65 g in men and 132.42 g in women. Organ weight was found to be directly related to the body weight of the cadavers. Moreover, in both males and females, kidney weight was lower than in Western populations. Organ weight decreases with age (3).

In a forensic medicine center in Thailand, autopsy results for 499 cadavers (269 men and 230 women) showed that the kidney weight for men was 109 g and for women, it was 97.5 g. The weight of organs in men increased with age (4). In a study in Korea, kidney weight was found to be 157.97 g in men and 129.27 g in women. There was a significant relationship between height, body weight, and kidney weight (5). Caglar et al. reported an adult kidney weight of 89-309 g in Turkey (25). In Korea, the kidney weight was found to be 5.87 g in males and 8.86 g in females (31). Hasini et al. examined adult Indian cadavers and reported a kidney weight of 97.74 g (21). In 206 autopsies performed in Thailand, kidney weight was found to be 260 g for men and 230 g for women (27).

## 6. Conclusion

The investigation of the morphologic characteristics of kidneys is useful for surgeons, urologists, and anthropologists. To the best of the



authors' knowledge, this study is the first to report standard data regarding the kidney in an Iranian population. That is the strength of this study. The weakness of the current study was the lack of investigation into variations among vessels and kidney volume. It is suggested that these areas be examined in future studies.

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## Conflicts of interest

None.

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