Original Article

Computed Tomographic Assessment of Renal Length in Correlation to Anthropometric Parameters: A Cross-Sectional Hospital-Based Observational Study from Iraq

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Abstract

Background: Measuring the renal size is an important parameter used in the assessment of patients with renal diseases. There is no conventional nomogram for kidney length in the Iraqi population. **Objectives:** The main objective of our study was to evaluate the ranges of normal renal length in our population. **Material and Methods:** The right and the left kidney lengths were measured by computed tomography (CT) scan in 100 adult individuals without apparent renal condition. Analysis for differences was conducted according to laterality, age, and sex. The correlation of renal length with anthropometrical indices like body weight, height, body mass index (BMI), and body surface area (BSA) was also evaluated. **Results:** The mean length of the right kidney was 11.4 cm for males and 10.2 cm for females, and of the left kidney was 11.5 cm in males and 10.8 cm in females. The mean renal lengths in the Iraqi population were similar to Iranian and American populations. The left kidney was longer than the right. Age-group analysis exhibited a significant decline in renal length beyond the sixth decade. There was a modest positive correlation of renal length with height, weight, and BSA but no correlation with BMI. **Conclusion:** The research supports the knowledge of the standard renal length range in a study population of apparently healthy Iraqi individuals by using CT scan imaging and derives linear regression equations that can be simply used in clinical practice to estimate the renal length according to body indices such as height or weight.

Keywords: CT abdomen, Iraq, renal length

Introduction

Measuring kidney size is a crucial parameter in the evaluation of a patient with kidney disease and other systemic conditions. Clinical examination by palpation is usually difficult, as the kidneys are usually impalpable organs in adults and will be rarely felt unless enlarged; nevertheless, to say that clinical detection of shrunken or small kidneys would be more difficult. Evaluation of renal size is assisted by imaging techniques like ultrasound, computed tomography (CT) scan, and magnetic resonance imaging (MRI); of these, ultrasound imaging is the most commonly used technique; however, it is highly operator dependent compared to CT scan and MRI. We chose CT scan over MRI, as it is of a short study time, less costly, more accessible, and less sensitive to patient motion than MRI.

Renal length is the most straightforward, useful, and reproducible way to quantify renal size, with only a small amount of inter- and intraobserver variability.[1,2]

Numerous physical (anthropometric) factors, including height, weight, body mass index (BMI), and body surface area (BSA), have an impact on renal length.[3-5] It has been found that there is a lack of information in Iraq concerning kidney length and its association with those anthropometric indices. Our study was therefore assigned

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with the objective to detect the anthropometrical indices that best correlated with kidney length in Iraqi individuals and to construct tables and scatterplot figures which could be used as a reference for measuring renal length in healthy Iraqi adults.

Materials and Methods

The study is a cross-sectional observational in design carried out in the department of human anatomy in Al-Mustansiriyah Medical College and the Radiology Department of Al-Yarmouk Teaching Hospital, Baghdad, Iraq. It was approved by the local ethical committee of Al-Mustansiriyah Medical College, and informed consent was taken from the patients.

The study includes 100 adult individuals aged 18 years and older who had undertaken CT examination of the abdomen during the period (January 2023–March 2023) for nonrenal indications, e.g., acute and chronic abdominal pain, weight loss, gastrointestinal tract bleeding, chronic anemia, constipation, vomiting not suggestive of renal diseases, trauma, back pain, and others.

Exclusion criteria were: non-Iraqi nationality, any clinical features suggesting renal diseases, hypertension, diabetes mellitus, and a family history of congenital renal diseases. Additionally, any individual detected to be suffered from any renal pathology on CT imaging was also omitted from the study.

Each individual's age, gender, body weight, height, BMI, and BSA were recorded at the time of the examination. Height and Weight were recorded to the nearest tenth, BMI was calculated by using the formula [BMI = weight in kg/(height in meter)^2], BSA was calculated by using the Mosteller formula [BSA =0.016667 × $H^{0.5}$ × $W^{0.5}$, where H height in meter, W weight in kg].[6,7]

All kidneys were examined by "Siemens SOMATOM Definition AS CT Scanner," and 2D CT scan grayscale pictures were stored in the picture archive system. These pictures were reexamined by an expert radiologist to ensure that they met the inclusion and exclusion criteria. Imaging was executed by a qualified CT technician in the axial and sagittal planes that passed through the hilum of the kidney with the individual lying supine or in the right or left lateral recumbent position. One measure of the maximal renal kidney was taken on the coronal slice parallel to the longitudinal renal axis [Figure 1]. The renal lengths were recorded to the nearest tenth of a centimeter (0.1 cm).

Statistical analyses were executed using SPSS "Statistical Package for the Social Sciences" version 26 (IBM, USA), and Microsoft Office Excel 2021 (Microsoft Corporation, USA). Continuous data were presented as mean ± SD, and their normality of distribution was tested by the nonparametric test (one sample Kolmogorov–Smirnov). For the normally distributed data, intergroup comparison

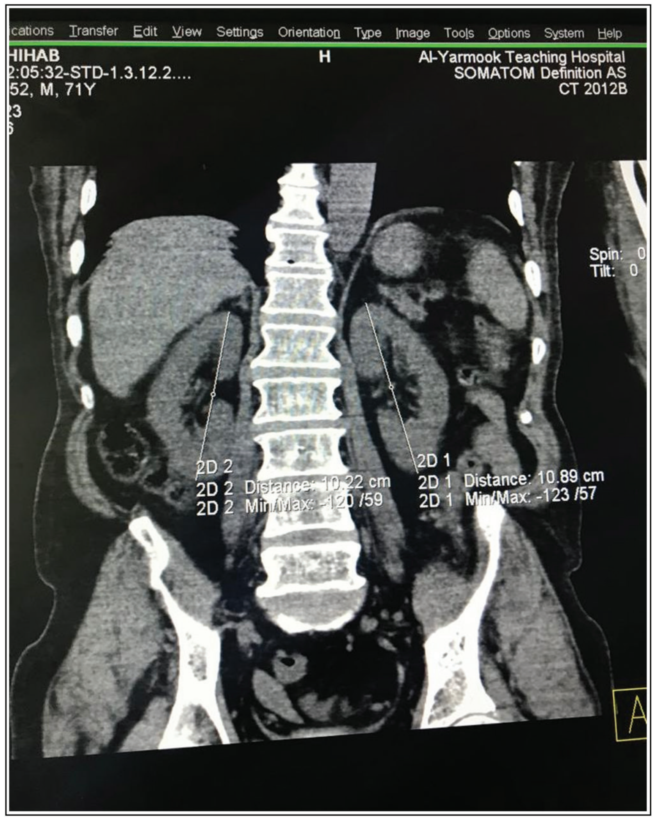

Figure 1: Abdominal CT scan reformatted coronal view, showing vertical right and left renal length measurements

Table 1: Descriptive statistics of the cases

Variables		Count	Min.	Max.	Mean	SD
Age	All	100	18	79	43.04	16.34
	M	66	18	79	41.30	16.44
	F	34	20	69	46.41	15.83
Height	All	100	154	190	168.86	9.74
	M	66	160	190	173.79	7.61
	F	34	154	175	159.29	5.27
Weight	All	100	50	115	78.36	14.03
	M	66	56	115	81.55	13.69
	F	34	50	97	72.18	12.71
BMI	All	100	18.08	37.89	27.47	4.25
	M	66	18.08	35.43	26.98	3.95
	F	34	19.53	37.89	28.41	4.70
BSA	All	100	1.47	2.46	1.91	0.21
	M	66	1.64	2.46	1.98	0.19
	F	34	1.47	2.08	1.78	0.17
RRL	All	100	8.20	14.00	10.95	1.43
	M	66	8.20	14.00	11.35	1.42
	F	34	8.70	12.40	10.19	1.11
LRL	All	100	8.80	13.60	11.24	1.36
	M	66	8.80	13.50	11.49	1.40
	F	34	8.90	13.60	10.75	1.15
MRL	All	100	8.80	13.55	11.10	1.34
	M	66	8.80	13.55	11.42	1.37
	F	34	8.89	12.30	10.47	1.03

was executed using t-test. The correlation between two continuous data was determined by Pearson's correlation coefficient (r). Bivariate regression and the "coefficient of determination" R^2 were determined and were used to predict the relationship (if any) among different data and also for deriving regression equations. A probability value of $P < 0.05$ was considered statistically significant.[8]

Ethical approval

The study was conducted under the ethical principles that have their origin in the WMA Declaration of Helsinki. It was carried out with patients' verbal and analytical approval before the sample was taken and was ethically approved by the local committee of Al-Mustansiriya Medical College.

Results

The total number of participants in this study was one hundred (n = 100). The percentile contribution of males and females was 66% and 34%, respectively. Their age ranged from 18 years to 79 years, with a mean age of 43 ± 16.34 years. The age distribution was as follows: 24 patients (18–30 years), 28 (31–40 years), 16 (41–50 years), 14 (51–60 years), and 18 patients (>60 years).

Their heights ranged from 154 to 190 cm, with a mean height of 168.86 ± 9.74 cm. And the weight range is 50–115 kg with a mean weight of 78.36 ± 14.03 kg. The BMI range is 18.08–37.89 kg/m^2, with a mean BMI of 27.47 ± 4.25 kg/m^2. BSA ranged from 1.47 to 2.46 m^2 with a mean BSA of 1.91 ± 0.21 m^2. The mean length of the right kidney (RRL) was 11.35 ± 1.42 cm for males, 10.19 ± 1.11 cm for females, and 10.95 ± 1.43 cm in the combined study group (both males and females). In contrast, the mean left renal length (LRL) was 11.49 ± 1.40 cm in males, 10.75 ± 1.15 cm in females, and 11.24 ± 1.36 cm in the combined study group. The combined mean renal length (the combined right and left renal lengths) (MRL) was 11.42 ± 1.37 cm for males, 10.47 ± 1.03 cm for females, and 11.10 ± 1.34 cm in the combined study group [Table 1].

Table 2: *t*-Test statistics of left vs. right renal lengths

	RRL	LRL
N	100	100
Mean	10.95	11.24
SD	1.44	1.37
t	–3.505	
df	99	
P-value	0.001	

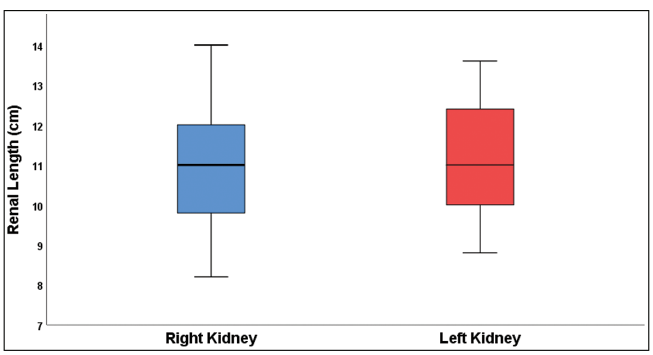

Figure 2: Boxplot presentation for right and left renal lengths

A Student t-test shows that the left renal length was larger than the right renal length (P-value =0.001) [Table 2 and Figure 2].

The analysis of variance and covariance (ANOVA test) confirmed that there was a statistically significant difference in renal lengths between different age groups, where the renal length shows a steady increase toward the late 30s and then a steady decline after the age of 60 (P-values = 0.000 for RRL, 0.000 for LRL and 0.000 for MRL) [Table 3 and Figure 3].

To investigate the effect of gender on renal lengths, an independent t-test was performed; it exposes a significant difference in renal lengths between males and females, where the mean renal lengths are greater in males than in females (P-values = 0.009 for RRL, 0.000 for LRL and 0.001 for MRL) [Table 4 and Figure 4].

A Pearson correlation test was performed to investigate the effect of an individual's height on renal lengths; the test concluded that there was a statistically significant correlation between renal length and height

Table 3: The analysis of variance and covariance of renal lengths in different age groups

		SS	df	MS	*F*	*P*-value
RRL	Between groups	39.797	4	4	5.829	0.000
	Within groups	162.146	95	95		
	Total	201.943	99	99		
LRL	Between groups	41.697	4	10.424	6.975	0.000
	Within groups	141.988	95	1.495		
	Total	183.685	99			
MRL	Between groups	39.251	4	9.813	6.789	0.000
	Within groups	137.312	95	1.445		
	Total	176.563	99			

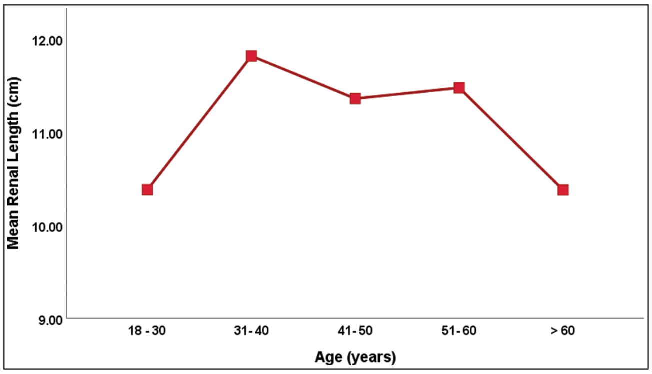

Figure 3: Line graph showing mean renal lengths for various age-groups

Table 4: Independent *t*-test statistics of males versus females

		RRL	LRL	MRL
Mean	Males	11.35	11.49	11.42
	Females	10.19	10.75	10.47
t		2.121	2.661	3.554
df		98	98	98
P-value		0.009	0.000	0.001

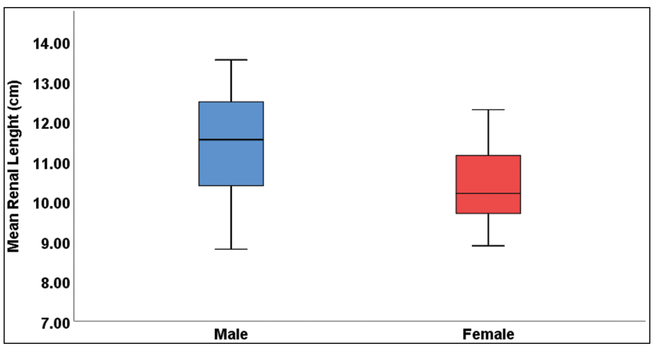

Figure 4: Boxplot presentation of mean renal lengths in males vs. females

Table 5: Pearson correlation—height vs. renal lengths

Descriptives

	Mean	Std. deviation
Height (cm)	168.86	9.74
RRL (cm)	10.95	1.43
LRL (cm)	11.24	1.36
MRL (cm)	168.86	9.74

Correlations

Group	Pearson correlation	*P*-value
RRL-height	0.600	0.000
LRL-height	0.551	0.000
MRL-height	0.602	0.000

(*P*-values = 0.000 for RRL, 0.000 for LRL, and 0.000 for MRL) [Table 5].

Bivariate regression was conducted to see if the height of the individual could predict renal length. Using the Enter method, it was found that the height of the individual explains a modest amount of the variance in renal length. The analysis shows that height significantly predicts renal length [Table 6 andFigure 5]. With the regression equations can be plotted as follow:

Table 6: Linear regression statistics of height vs. renal length

Regression statistics

	RRL	LRL	MRL
R	0.600	0.551	0.602
R^2	0.360	0.304	0.362
Adjusted R^2	0.353	0.297	0.356

ANOVA

	df			*F*			*Sign. F*		
	RRL	LRL	MRL	RRL	LRL	MRL	RRL	LRL	MRL
Regression	1	1	1	55.115	42.813	55.709	0.000	0.000	0.000
Residual	98	98	98						

LRL (cm) = (0.077 × height in cm) – 1.87

RRL (cm) = (0.088 × height in cm) – 3.90

MRL (cm) = (0.083 × height in cm) – 2.84

To explore effect of an individual's weight on renal lengths, a Pearson correlation test was performed; the test displays a statistically significant correlation between renal lengths and weight (*P*-values = 0.000 for RRL, 0.000 for LRL, and 0.000 for MRL) [Table 7].

Moreover, bivariate regression found that the weight of the individual explains a modest amount of the variance in renal length. And it shows that weight significantly predicts renal length [Table 8 andFigure 6]. The regression equations can be plotted as follow:

LRL (cm) = (0.044 × weight in kg) + 7.87

RRL (cm) = (0.057 × weight in kg) + 6.49

MRL (cm) = (0.051 × weight in kg) + 7.12

Regarding the correlation between the BMI of an individual and renal length, a Pearson correlation test was executed, which perceives that there was no statistical connection between an individual's BMI and renal lengths (*P*-values = 0.080 for RRL, 0.471 for LRL and 0.193 for MRL) [Table 9].

Bivariate regression shows that the BMI of the individual can explain a small amount of the variance in renal lengths [Table 10 andFigure 7]. The regression equations can be plotted as follow:

LRL (cm) = (0.023 × BMI) + 10.6

RRL (cm) = (0.059 × BMI + 9.33

MRL (cm) = (0.041 × BMI) + 9.96

Finally, a Pearson correlation test was performed to test the correlation between BSA and renal lengths; it concluded

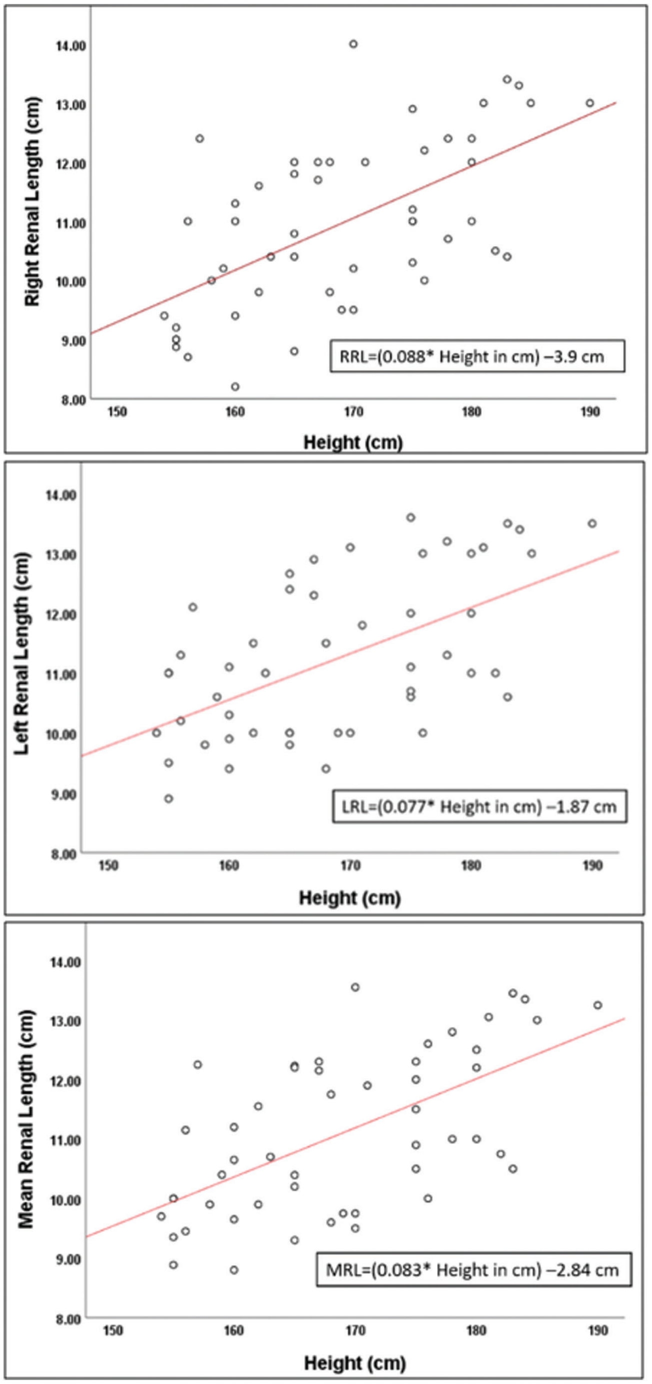

Figure 5: Scatter correlations and linear regressions: height versus RRL (top), height versus LRL (middle), and height versus MRL (bottom)

that there was a statistically significant connection between BSA and renal lengths (P-values = 0.000 for RRL, 0.000 for LRL, and 0.00 for MRL) [Table 11].

The bivariate regression found that the BSA of the individual can explain a modest amount of the variance in renal length. And that BSA can predict renal lengths [Table 12 and Figure 8]. The regression equations are as follows:

Table 7: Pearson correlation—weight vs. renal lengths

Descriptives	Mean	Std. deviation
Weight (kg)	78.36	14.02
RRL (cm)	10.95	1.43
LRL (cm)	11.24	1.36
MRL (cm)	11.10	1.34
	Correlations	
Group	**Pearson correlation**	***P*-value**
RRL-weight	0.562	0.000
LRL-weight	0.455	0.000
MRL-weight	0.532	0.000

Table 8: Linear regression statistics of weight versus renal length

Regression statistics	RRL	LRL	MRL
R	0.562	0.455	0.532
R^2	0.316	0.207	0.283
Adjusted R^2	0.309	0.199	0.276

ANOVA	*df*			*F*			*Sign. F*		
	RRL	LRL	MRL	RRL	LRL	MRL	RRL	LRL	MRL
Regression	1	1	1	25.45	45.25	38.77	0.000	0.000	0.000
Residual	98	98	98						

$$\text{LRL (cm)} = (3.48 \times \text{BSA}) + 4.59$$

$$\text{RRL (cm)} = (4.36 \times \text{BSA}) + 2.62$$

$$\text{MRL (cm)} = (3.92 \times \text{BSA}) + 3.60$$

Discussion

knowing the normal kidney size is very valuable in the assessment, management, and follow-up of patients with renal diseases. While most information available in the literature on renal dimensions related to the pediatric population,[9] there are limited data in adults, and most of these data are mainly derived from studies performed in non-Iraqi populations, where it may not be applicable to the Iraqis. Different kinds of literature have stated relationships between kidney sizes and other body indices.[4] To our knowledge, this research was the first one from Iraq that had investigated the relationship between kidney length and the overall body indices of adult individuals, including sex, age, height, weight, BMI, and BSA, and the only one that tries to make a reference data for the Iraqi population. The mean renal lengths of the right kidney in our study were 11.35 cm for males, 10.19 cm for females, and 10.95 cm for all genders. While the mean left renal lengths were 11.49 cm for males, 10.75 cm for females, and 11.24 cm for all genders. These findings were quite similar to those reported from Iran,[10] the USA,[11]

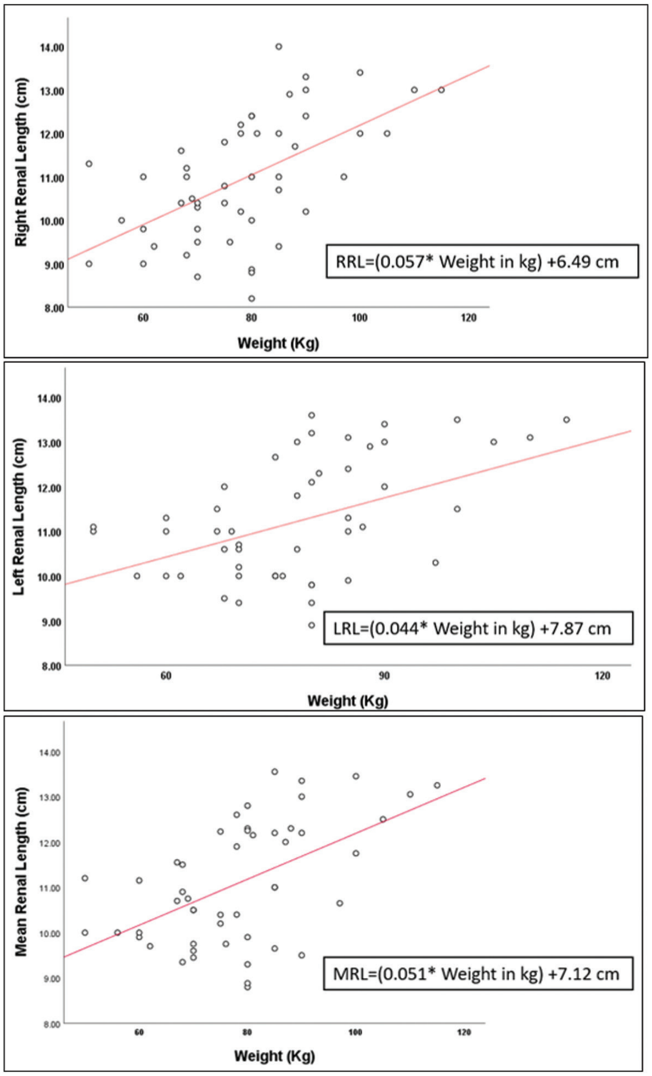

Figure 6: Scatter correlations and linear regressions: weight versus RRL (top), weight versus LRL (middle), and weight versus MRL (bottom)

Table 9: Pearson correlation—BMI versus renal lengths

	Descriptives	
	Mean	**Std. deviation**
BMI (kg/m²)	27.47	4.25
RRL (cm)	10.95	1.43
LRL (cm)	11.24	1.36
MRL (cm)	11.10	1.34
	Correlations	
Group	**Pearson correlation**	***P*-value**
RRL-BMI	0.176	0.080
LRL-BMI	0.073	0.471
MRL-BMI	0.131	0.193

and Denmark.[12] Larger than those reported from India,[13] Pakistan,[14] South Korea,[15] Malaysia,[16] and Jamaica,[17] slightly smaller than those reported from Japan[18] [Table 13].

Table 10 : Linear regression statistics of BMI versus renal length

Regression statistics	RRL	LRL	MRL
R	0.176	0.073	0.131
R^2	0.031	0.005	0.017
Adjusted R^2	0.021	–0.005	0.007

ANOVA	***df***			***F***			***Sign. F***		
	RRL	**LRL**	**MRL**	**RRL**	**LRL**	**MRL**	**RRL**	**LRL**	**MRL**
Regression	1	1	1	3.125	0.525	1.717	0.080	0.471	0.193

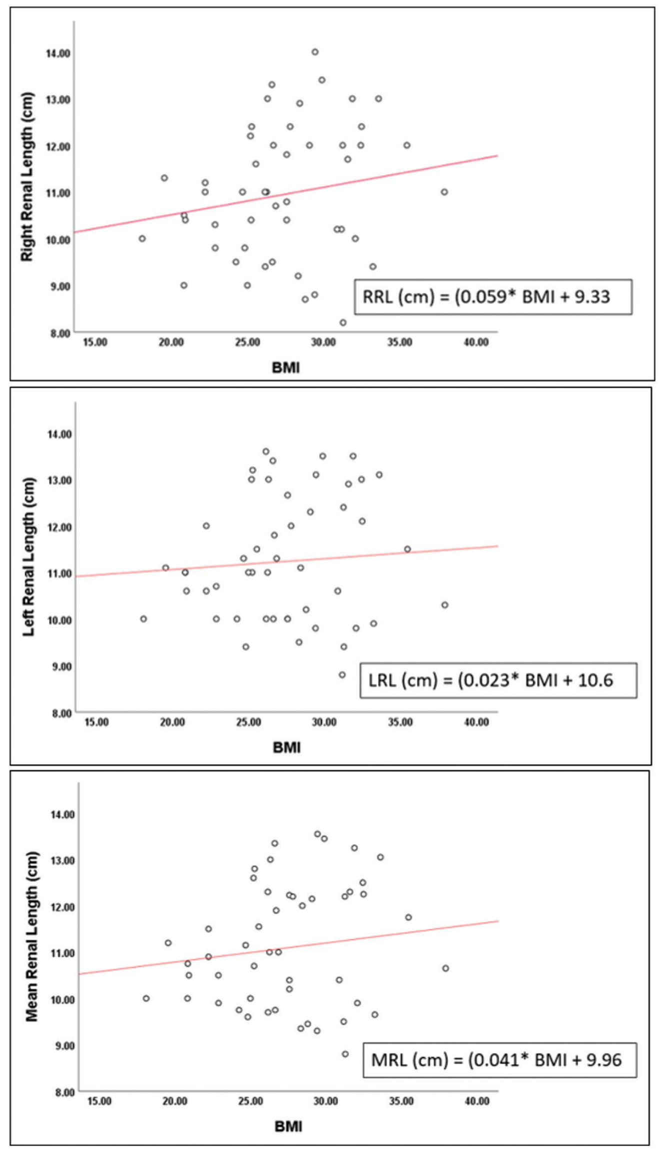

Figure 7: Scatter correlations and linear regressions: BMI versus RRL (top), BMI versus LRL (middle), and BMI versus MRL (bottom)

The study found that the left renal length was longer than the right renal length. The likely explanation for this is the presence of spleen on the left abdominal side, which

Table 11: Pearson correlation—BSA versus renal lengths

Descriptives	Mean	Std. deviation
BSA (m^2)	11.24	1.36
RRL (cm)	1.91	0.21
LRL (cm)	10.95	1.43
MRL (cm)	11.10	1.34
Correlations		
Group	**Pearson correlation**	***P*-value**
RRL-BSA	0.628	0.000
LRL-BSA	0.526	0.000
MRL-BSA	0.604	0.000

Table 12 : Linear regression statistics of BSA versus renal length

Regression statistics	*RRL*	*LRL*	*MRL*
R	0.628	0.526	0.604
R^2	0.395	0.276	0.365
Adjusted R^2	0.389	0.269	0.358

ANOVA	*df*			*F*			*Sign. F*		
	RRL	**LRL**	**MRL**	**RRL**	**LRL**	**MRL**	**RRL**	**LRL**	**MRL**
Regression	1	1	1	63.91	37.391	56.28	0.000	0.000	0.000
Residual	98	98	98						

possess a lesser size than liver on the right abdomen therefore providing greater space for the left kidney to grow.[19] In addition, the left renal artery is shorter than the right one; hence, the blood flowing in the left is higher, and this leads to a relatively larger left renal volume.[5,20] This finding is in accord with most of the findings reported by previous literatures.[5,19,21-24] On the other hand, some researchers conveyed that there were no significant differences in between left and right kidney sizes.[21-23]

A significant argument in our study was the congruity of renal length that was noticed across age groups in adults, with a substantial decline in mean renal length beyond the sixth decade of life. Some other literatures have also revealed that renal length steadily declines with the rising age, and this decline is found to be accelerated beyond the age of seventy.[9,25] This conclusion has a vital allegation in medical decision-making and may make the correction of renal lengths for age in adults unnecessary till the age of 60.

There are some incongruities in regard to the correlation between gender and renal size. Some literatures proposed that males possess larger kidneys than females,[5,11,13,26,27] whereas others have shown no differences in kidney size between males and females.[22,28] In our study, we found that there was a statistically significant difference in renal

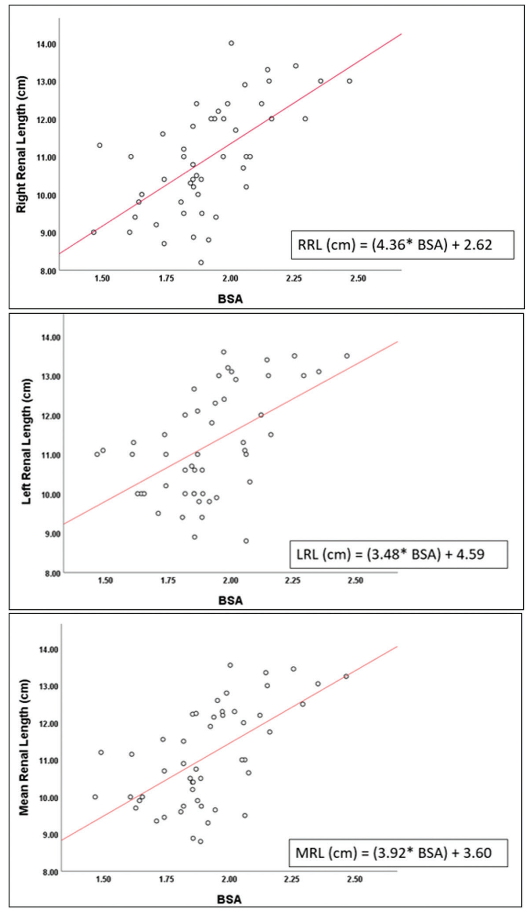

Figure 8: Scatter correlation and linear regression: BSA versus RRL (top), BSA versus LRL (middle), and BSA versus MRL (bottom)

length between males and females, where the mean renal lengths are greater in males than in females.

Our study reveals a positive correlation between the height of the individual and the renal length. This goes well with most of the published literatures.[14,26,29] Although some studies describe no significant differences.[16,30]

Our study detected a significant positive linear correlation between an individual's weight, BMI, BSA, and kidney length in a combined group comprising both males and females. This finding is in agreement with the studies performed by most of the investigators.[4,5,23,26,31,32]

Our research fortifies the knowledge of the standard renal length range in a study population of apparently healthy Iraqi individuals by using CT scan imaging. In clinical practice, body parameters such as height and weight can be simply used to estimate the kidney length in an adult individual by the use of the regression equations that had been derived in our study.

Our study had some limitations, it involved 100 healthy individuals, and this number may consider a small sample size as compared to a large Iraqi population. Even though the sample was nonrandomly selected from different cities

Table 13: Comparisons of kidney lengths described among different countries

Country	Technique	No.		M	F	Both genders
Iraq (present study)	CT scan	100	RRL	11.4	10.2	11.0
			LRL	11.5	10.8	11.3
Iran	Ultrasound	400	RRL	11.0	10.7	10.9
			LRL	11.3	10.9	11.1
USA	Ultrasound	–	RRL	–	–	10.7
			LRL	–	–	11.1
Denmark	Ultrasound	665	RRL	–	–	10.9
			LRL	–	–	11.2
India	Autopsies	239	RRL	9.9	9.1	9.7
			LRL	10.0	9.2	9.7
Pakistan	Ultrasound	194	RRL	10.6	10.3	10.5
			LRL	10.6	10.3	10.5
Malaysia	Ultrasound	205	RRL	10.2	9.8	–
			LRL	10.5	10.0	–
South Korea	Ultrasound	125	RRL	–	–	10.2
			LRL	–	–	10.5
Jamaica	Ultrasound	49	RRL	–	–	9.7
			LRL	–	–	10.0
Japan	Autopsies	5600	RRL	11.3	11.2	–
			LRL	11.5	11.4	–

in Iraq, but our hospital is a referral hospital in Baghdad, and so the findings might be generalizable. Moreover, the individuals involved in this study were supposed to be apparently unaffected by renal diseases, but still, a few of them may possess subclinical renal disorders, which were not evident during the time of the assessment. An additional limitation of this study was that it focused on the measurement of kidney length and did not include the assessment of kidney volume.

Conclusion

Our research supports the knowledge of the standard renal length range in a study population of apparently healthy Iraqi individuals by using CT scan imaging. The present study derives linear regression equations that can be simply used in clinical practice to calculate kidney length based on body indices like height and weight.

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Conflicts of interest

There are no conflicts of interest.

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