Clinical research

Exploring the link between kidney dimensions and anthropometric measurements: insights from a Saudi population study

Mansour Almanaa[1], Haitham Alahmad[1], Mohammad Alarifi[1], Khaled Alenazi[1], Ahmad Abanomy[1], Khalid Alneghaimishi[1], Bashayr Alshamrani[1], Raed Albathi[2]

[1]Radiological Sciences Department, College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia
[2]Radiology Department, Prince Sultan Military Medical City, Riyadh, Saudi Arabia

Submitted: 30 July 2024; **Accepted:** 5 September 2024
Online publication: 25 September 2024

Arch Med Sci Atheroscler Dis 2024; 9: e171–e176
DOI: https://doi.org/10.5114/amsad/192995

Corresponding author:
Mansour Almanaa
Radiological Sciences
Department, College of
Applied Medical Sciences
King Saud University
Riyadh, Saudi Arabia
E-mail: malmanaa@ksu.edu.sa

Abstract

Introduction: Ultrasound (US) measurements of kidney dimensions are essential for correlating with height, weight, and body mass index (BMI), establishing kidney size baselines, and assessing renal health. The global rise in obesity has increased interest in the links between BMI and chronic kidney disease (CKD). This study investigates the relationship between renal dimensions (length, width, and thickness) and anthropometric measures (height, weight, and BMI) in a Saudi population.

Material and methods: A cross-sectional study was conducted at two ultrasound clinics in Riyadh, Saudi Arabia, with 129 participants (73 males and 56 females) aged 18–60 years. Kidney dimensions were measured using ultrasound machines. Spearman correlation assessed relationships between kidney dimensions and age, height, weight, and BMI, while the Mann-Whitney U test investigated sex differences.

Results: Significant correlations were identified between kidney dimensions and anthropometric measures. Age negatively correlated with kidney thickness for both kidneys (right: $r = -0.502$, $p < 0.0001$; left: $r = -0.542$, $p < 0.0001$) and left kidney width ($r = -0.204$, $p = 0.020$). Height positively correlated with all kidney dimensions. Weight also positively correlated with kidney dimensions. BMI showed positive correlations with right kidney length ($r = 0.219$, $p = 0.013$) and width ($r = 0.319$, $p < 0.0001$), and left kidney length ($r = 0.209$, $p = 0.018$). Males had greater kidney thickness and left kidney width compared to females.

Conclusions: This study establishes significant correlations between renal dimensions and anthropometric measures in a Saudi population, highlighting the importance of considering individual characteristics in renal assessments. These findings support the development of personalized clinical guidelines for improved renal condition management.

Key words: kidney dimensions, anthropometric measures, body mass index, renal ultrasound.

Introduction

Ultrasound (US) measurements of kidney dimensions are crucial for establishing correlations with height, weight, and body mass index (BMI) and setting baselines for normal kidney sizes, thus providing insights into healthy parameters for this vital organ [1, 2]. Ultrasound technology is a valuable tool for visualizing internal body structures, offering a safe, cost-effective and noninvasive imaging technique that provides detailed data on the kidneys and other vital organs [3–7]. Kidney dimensions serve as indicators of declining kidney function and tissue loss [8, 9]. Given that many kidney disorders involve size fluctuations, guidelines for measuring kidneys have been established and are widely used in clinical settings. Establishing baseline estimations of typical kidney size under healthy conditions is essential [8, 9].

The global prevalence of overweight and obesity has increased awareness of the connections between various health conditions and BMI, including chronic kidney disease [10–12]. BMI, a simple, low-cost, noninvasive measure of body fat, allows individuals to monitor their BMI regularly, contributing to its utility at the population level [13–15]. BMI is calculated by dividing weight (kg) by height squared (m^2) and is used to classify individuals according to their degree of obesity [14–16]. A BMI of less than 18.5 is classified as underweight; 18.5–24.9 is normal; 25–29.9 is overweight; and 30 or higher is obese [16, 17]. In recent years, the rapid increase in obesity rates worldwide has become strikingly evident [18–22]. Obesity is associated with increased mortality risk and is linked to chronic kidney disease (CKD) [18].

In a comprehensive study of renal dimensions, Amirkhanlou *et al.* analyzed kidney lengths in 320 individuals with a mean age of 48.03 ±14.86 years [1]. The results revealed notable differences in kidney size, with the right kidney averaging 113.27 ±8.57 mm in length and the left kidney averaging 111.91 ±9.199 mm. These dimensions were distinct when compared to those reported for Kuwaiti [23], Mexican [24], and Nigerian populations [25], which recorded lengths of 106.7 ±14 mm, 100 ±7 mm, and 103 ±17 mm, respectively. Additionally, Amirkhanlou *et al.* observed gender differences, noting that males had higher BMI, height, and right kidney length than females [1].

El-Reshaid and Abdul-Fattah conducted a study to establish normal renal size parameters via ultrasound in individuals without renal disease [23]. They examined 252 healthy participants (111 males and 141 females) aged 18–80 years, categorized into five age groups. The mean right and left renal lengths in the Kuwaiti population were 10.68 ±1.4 cm and 10.71 ±1.0 cm, respectively. A significant correlation between renal length and body weight was observed, with an increase of 0.23 cm in renal length for every 10 kg increase in body weight within the 60–120 kg range. However, no statistical correlation with height was found. The research further revealed a notable correlation between BMI and renal length, yet found no significant gender-based disparities in overall renal length. Additionally, a reference chart was created for the Kuwaiti population, depicting standard values for renal length and cortical thickness within a 95% confidence interval.

Oyuela-Carrasco *et al.* highlighted the importance of ultrasound-based renal length estimation as a replacement for radiography in evaluating adult patients with kidney disease [24]. In their prospective observational study of 153 healthy volunteers, including 77 males and 76 females with an average age of 46.12 ±15.44 years, significant anthropometric measurements were reported. The study found higher average right and left renal lengths in males, measuring 105.74 ±5.74 mm and 107.16 ±6.97 mm, respectively. A positive correlation was identified between renal length and weight, BMI, and height [24, 25].

This study investigates the potential relationship between renal dimensions and height, weight, and BMI in Saudis, aiming to understand how variations in these parameters influence kidney size.

Material and methods

Design and settings

This observational cross-sectional study was conducted over 9 months, from September 2023 to June 2024, at two ultrasound clinics in Riyadh, Saudi Arabia. The objective was to investigate the relationships between renal dimensions and the anthropometric measures of weight, height, and BMI in individuals aged 18 years and older.

The study cohort comprised 129 participants, including 73 males and 56 females. Height was measured in centimeters and converted to meters, while weight was recorded in kilograms. BMI was calculated using the formula: BMI = weight (kg)/height (m^2).

Ultrasound scans were performed on all participants using SonixTouch and Philips machines, each located at one of the clinics, and equipped with low-frequency curvilinear transducer probes (2–5 MHz). Renal dimensions, including the longest longitudinal diameter (bipolar axis), width, and cortical thickness (defined as the distance from the outer border of the renal cortex to the outer border of the medullary pyramid), were measured in millimeters for both kidneys, as illustrated in Figure 1. The supine position was primarily utilized for these measurements, with right and left lateral decubitus positions adopted when necessary. Data collection was efficiently conducted using a comprehensive data collection sheet.

Statistical analysis

All statistical analyses were conducted using Python (version 3.10) [26] in the Google Colab environment. Normality checks were performed using the Shapiro-Wilk test. Given the non-normal distribution of the data, non-parametric tests were employed. The Spearman correlation coefficient was used to investigate the relationship between each kidney dimension and height, weight, BMI, and age. The Mann-Whitney U test was utilized to compare kidney dimensions between males and females.

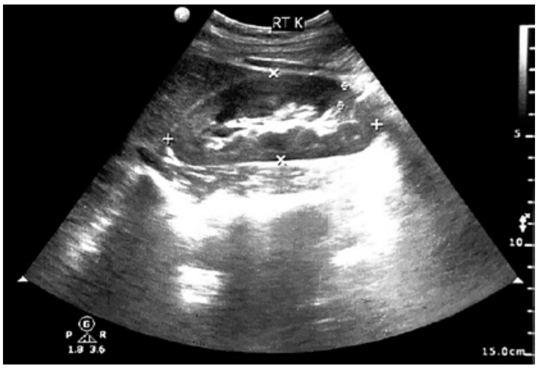

Figure 1. Ultrasound image showing dimensions of the right kidney in a participant

Results

Participants' demographics and characteristics

A total of 129 participants were included in this study, consisting of 73 (57%) males and 56 (43%) females. The age distribution of the participants ranged from 18 to over 60 years, with the majority (65%) falling within the 18-24 age group. Detailed demographic characteristics are presented in Table I.

The average age of the participants was 28 ±11 years. The average height, weight, and BMI were 1.66 ±0.10 m, 72.4 ±19.1 kg, and 26.3 ±6.1 kg/m², respectively.

Table I. Distribution of participants according to gender and age

Gender	Number of participants	Percentage
Female	56	43
Male	73	57
Total	129	100
Age groups	**Number of participants**	**Percentage**
18–24	84	65
25–30	9	7
31–40	16	12
41–50	12	9
51–60	6	5
> 60	2	2
Total	129	100

Kidney dimensions

The average dimensions of the right and left kidneys for all participants are summarized in Table II.

Table II. Average kidney dimensions for all participants

Kidney dimension	Right kidney [mm]	Left kidney [mm]
Length	102.79 ±8.65	104.52 ±11.45
Width	39.71 ±5.97	49.46 ±7.07
Thickness	13.47 ±4.51	15.85 ±5.74

Correlation analysis

Correlation with age

Age showed a significant negative correlation with kidney thickness for both kidneys. Specifically, the Spearman's rank correlation coefficient for the right kidney thickness was –0.502 ($p < 0.0001$), and for the left kidney thickness, it was -0.542 ($p < 0.0001$). Additionally, age had a negative correlation with the left kidney width ($r = –0.204$, $p = 0.020$).

Correlation with height

Height showed a significant positive correlation with all measured kidney dimensions. For the right kidney, the correlation coefficients were 0.190 (length), 0.227 (width), and 0.651 (thickness). For the left kidney, the coefficients were 0.222 (length), 0.249 (width), and 0.635 (thickness). All correlations were statistically significant ($p < 0.05$).

Correlation with weight

Weight was also positively correlated with kidney dimensions. The right kidney dimensions had correlation coefficients of 0.284 (length), 0.389 (width), and 0.395 (thickness), while the left kidney dimensions had coefficients of 0.283 (length), 0.216 (width), and 0.351 (thickness). These correlations were statistically significant ($p < 0.05$).

Correlation with BMI

BMI was positively correlated with kidney dimensions, particularly with length and width. The correlation coefficients for the right kidney were 0.219 (length), 0.319 (width), and 0.090 (thickness). For the left kidney, the coefficients were 0.209 (length), 0.068 (width), and 0.044 (thickness). The correlation between BMI and kidney length and width was significant ($p < 0.05$). Detailed correlation coefficients and p-values are provided in Table III.

Table III. Correlation coefficients (r) and *p*-values of Spearman's rank correlation test

Variable	Right kidney length	Right kidney width	Right kidney thickness	Left kidney length	Left kidney width	Left kidney thickness
Age	0.041 (p = 0.647)	–0.088 (p = 0.321)	–0.502 (p < 0.0001)	0.046 (p = 0.608)	–0.204 (p = 0.020)	–0.542 (p < 0.0001)
Height	0.190 (p = 0.031)	0.227 (p = 0.010)	0.651 (p < 0.0001)	0.222 (p = 0.011)	0.249 (p = 0.004)	0.635 (p < 0.0001)
Weight	0.284 (p = 0.001)	0.389 (p < 0.0001)	0.395 (p < 0.0001)	0.283 (p = 0.001)	0.216 (p = 0.014)	0.351 (p < 0.0001)
BMI	0.219 (p = 0.013)	0.319 (p < 0.0001)	0.090 (p = 0.308)	0.209 (p = 0.018)	0.068 (p = 0.441)	0.044 (p = 0.617)

Table IV. Kidney dimensions by gender

Dependent variable	All participants	Male	Female	*P*-value
Right kidney length [mm]	102.79 ±8.65	103.25 ±8.85	102.18 ±8.44	0.461
Right kidney width [mm]	39.71 ±5.97	40.39 ±6.12	38.82 ±5.69	0.069
Right kidney thickness [mm]	13.47 ±4.51	16.07 ±4.26	10.09 ±1.70	< 0.0001
Left kidney length [mm]	104.52 ±11.45	105.52 ±7.90	103.21 ±14.85	0.732
Left kidney width [mm]	49.46 ±7.07	51.08 ±7.56	47.36 ±5.78	0.0012
Left kidney thickness [mm]	15.85 ±5.74	19.30 ±5.33	11.35 ±1.77	< 0.0001

Gender differences

The Mann-Whitney *U* test was used to compare kidney dimensions between males and females. Significant differences were found in kidney thickness, with males having greater thickness compared to females (p < 0.0001 for both kidneys). There was also a significant difference in the width of the left kidney (p = 0.0012), with males having wider kidneys (Table IV).

Discussion

This study aimed to explore the relationships between renal dimensions (length, width, and thickness) and various anthropometric measures, including height, weight, and BMI, among a Saudi population. The findings highlight significant correlations between these anthropometric variables and renal dimensions, with distinct patterns emerging across different demographic groups (please refer to the heatmap in Figure 2).

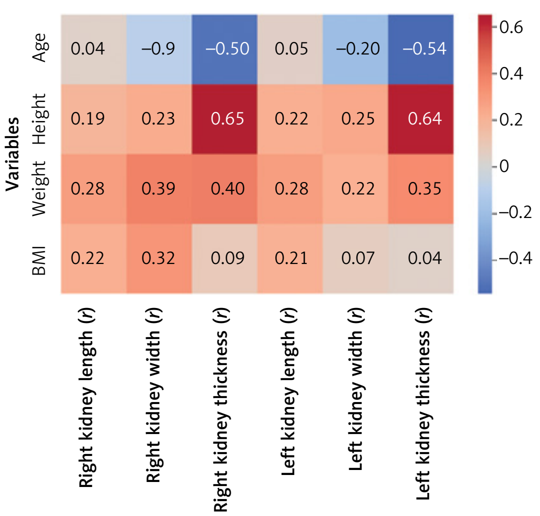

Figure 2. Correlation coefficients (r) between kidney dimensions (length, width, and thickness) and various variables (age, height, weight, and BMI) for both right and left kidneys

Age demonstrated a notable negative correlation with kidney thickness for both kidneys. Specifically, as age increased, the thickness of both the right and left kidneys decreased significantly. This observation aligns with previous studies, such as those by Piras *et al.*, which reported age-related reductions in renal size and cortical thickness, potentially due to age-related nephron loss and renal atrophy [9]. Additionally, the slight decrease in the left kidney's width with age further supports the hypothesis of progressive renal structural changes associated with aging [9].

Height was positively correlated with all measured kidney dimensions. Taller individuals exhibited larger renal dimensions in terms of length, width, and thickness. This finding aligns with the study conducted by Oyuela-Carrasco *et al.*, which also found positive associations between height and kidney size [24]. However, El-Reshaid and Abdul-Fattah found no significant correlation between height and renal length in their Kuwaiti population study [23]. This discrepancy may be due to differences in the populations studied or variations in measurement techniques. While El-Reshaid and Abdul-Fattah did not find a significant correlation between height and renal length, our study observed a positive correlation, which could be attributed to specific demographic and genetic factors present in the Saudi population.

Both weight and BMI were positively correlated with kidney dimensions. Heavier individuals and those with higher BMI had larger renal dimensions, particularly in terms of length and width. This relationship underscores the impact of increased body mass on renal size. Previous research, such as that by García-Carro *et al.* [18], has highlighted the link between obesity and increased kidney size, which may be attributed to hyperfiltration and compensatory hypertrophy in response to increased metabolic demands.

The analysis of gender differences revealed that males generally had greater kidney thickness compared to females. There was also a significant difference in the width of the left kidney, with males having wider kidneys. These findings align with the results of Amirkhanlou *et al.*, who reported that males typically have larger renal dimensions due to differences in body composition and hormonal influences [1]. The greater kidney size in males may reflect higher muscle mass and larger body surface area, necessitating larger renal structures to support metabolic needs.

Implications for clinical practice

The observed correlations between anthropometric measures and renal dimensions have several clinical implications. Firstly, understanding these relationships can aid in the development of more accurate reference ranges for kidney size based on patient demographics. This is particularly important for the early detection and monitoring of renal diseases, as deviations from expected renal dimensions may signal underlying pathology.

Additionally, the findings emphasize the importance of considering patient-specific factors, such as age, height, weight, and BMI, when interpreting renal ultrasound measurements. Personalized assessment of kidney size can improve diagnostic accuracy and facilitate early intervention in cases of renal abnormalities.

Limitations

Despite the significant findings, this study has several limitations that should be acknowledged. The cross-sectional design limits the ability to establish causality between anthropometric variables and renal dimensions. Longitudinal studies are needed to confirm the observed associations and to elucidate the underlying mechanisms driving these relationships

Additionally, the reliance on ultrasound measurements, while non-invasive and widely accessible, may introduce variability due to operator dependency and the inherent limitations of ultrasound imaging. Standardizing measurement protocols and employing advanced imaging techniques could mitigate these issues in future studies.

Future research directions

Building on the findings of this study, future research should explore several key areas. Longitudinal studies that track changes in renal dimensions over time in relation to anthropometric changes would provide valuable insights into the dynamic nature of these relationships. Additionally, investigating the impact of other factors, such as diet, physical activity, and genetic predispositions, on kidney size could further elucidate the complex interactions influencing renal dimensions.

Moreover, expanding the study to include diverse populations across different regions and ethnic backgrounds would enhance the understanding of how demographic and environmental factors contribute to variations in kidney size. Such research could inform the development of tailored clinical guidelines for renal assessment in diverse patient populations.

In conclusion, this study establishes significant correlations between renal dimensions and anthropometric measures, underscoring the importance of considering individual patient characteristics in renal assessments. These findings provide a foundation for future research and underscore the potential for personalized clinical guidelines to improve the early detection and management of renal conditions. By advancing our understanding of these relationships, healthcare providers can enhance patient care and outcomes in the context of renal health.

Conclusions

This study aimed to investigate the relationships between renal dimensions and various anthropometric measures, including age, height, weight, and BMI, within a Saudi population. The findings have elucidated significant correlations that provide valuable insights into how these factors influence kidney size.

Age and kidney thickness: There is a significant negative correlation between age and kidney thickness for both the right and left kidneys. As individuals age, the thickness of their kidneys tends to decrease. This finding is consistent with previous research suggesting age-related nephron loss and renal atrophy.

Height and kidney dimensions: Height is positively correlated with all measured kidney dimensions. Taller individuals exhibit larger kidneys in terms of length, width, and thickness. This correlation underscores the physiological necessity for larger organs in taller individuals to maintain metabolic balance.

Weight and BMI: Both weight and BMI show positive correlations with kidney dimensions. Heavier individuals and those with higher BMI have larger kidneys, particularly in length and width. These findings are in line with the understanding that increased body mass imposes greater metabolic demands, leading to compensatory renal hypertrophy.

Gender differences: Significant differences were observed between males and females in terms of kidney thickness and left kidney width. Males generally had thicker and wider kidneys, which can be attributed to differences in body composition and hormonal influences.

Acknowledgments

The authors extend their appreciation to the College of Applied Medical Sciences Research Center and the Deanship of Scientific Research at King Saud University for supporting this work.

Funding

No external funding.

Ethical approval

Approval for the study was obtained from the Institutional Review Board (IRB) at King Saud University (Ref. # 23/0884/IRB). All participants were informed about the study's purpose and potential effects and provided written consent.

Conflict of interest

The authors declare no conflict of interest.

References

1. Amirkhanlou S, Mozafari E, Rashedi A, Hadinejad M, Kordasiabi A, Shahmirzadi A. The relationship between body mass index (BMI) and the kidney size in healthy individuals in Iran. J Med Res 2019; 4: 13-8.
2. Yadav S, Yadav R, Chakradhar S, Karn A. Measurement of renal length and width in healthy adults and their association with various parameters. Int J Curr Res Rev 2017; 9: 29-32.
3. Lucisano G, Comi N, Pelagi E, Cianfrone P, Fuiano L, Fuiano G. Can renal sonography be a reliable diagnostic tool in the assessment of chronic kidney disease? J Ultrasound Med 2015; 34: 299-306.
4. Al Salmi I, Al Hajriy M, Hannawi S. Ultrasound measurement and kidney development: a mini-review for nephrologists. Saudi J Kidney Dis Transpl 2021; 32: 174-182.
5. O'Neill W. Renal relevant radiology: use of ultrasound in kidney disease and nephrology procedures. Clin J Am Soc Nephrol 2014; 9: 373-81.
6. Spatola L, Andrulli S. Doppler ultrasound in kidney diseases: a key parameter in clinical long-term follow-up. J Ultrasound 2016; 19: 243-50.
7. Correas JM, Anglicheau D, Joly D, Gennisson JL, Tanter M, Hélénon O. Ultrasound-based imaging methods of the kidney – recent developments. Kidney Int 2016; 90: 1199-210.
8. Maaji S, Daniel O, Adamu B. Sonographic measurement of renal dimensions of adults in northwestern Nigeria: a preliminary report. Sub-Saharan African J Med 2015; 2: 123-7.
9. Piras D, Masala M, Delitala A, et al. Kidney size in relation to ageing, gender, renal function, birthweight and chronic kidney disease risk factors in a general population. Nephrology Dialysis Transpl 2020l; 35: 640-7.
10. Herrington W, Smith M, Bankhead C, et al. Body-mass index and risk of advanced chronic kidney disease: prospective analyses from a primary care cohort of 1.4 million adults in England. PLoS One 2017; 12: e0173515.
11. Adelman R. Obesity and renal disease. Curr Opinion Nephrol Hypertens 2002; 11: 331-5.
12. Praga M, Morales E. The fatty kidney: obesity and renal disease. Nephron 2017; 136: 273-6.
13. Centers for Disease Control and Prevention. Body mass index: considerations for practitioners. CDC 2011; 1-4.
14. "Obesity and Overweight." World Health Organization. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight (accessed June 30, 2024).
15. Khanna D, Peltzer C, Kahar P, Parmar M. Body mass index (BMI): a screening tool analysis. Cureus 2022; 14: e22119.
16. Assessing Your Weight and Health Risk. National Heart Lung and Blood Institute, U.S. Department of Health and Human Services. https://www.nhlbi.nih.gov/health/educational/lose_wt/risk.htm (accessed July 2, 2024).
17. Katzmarzyk P, Craig C, Bouchard C. Original article underweight, overweight and obesity: relationships with mortality in the 13-year follow-up of the Canada Fitness Survey. J Clin Epidemiol 2001; 54: 916-20.
18. García-Carro C, Vergara A, Bermejo S, Azancot M, Sellarés J, Soler M. A nephrologist perspective on obesity: from kidney injury to clinical management. Front Med 2021; 8: 655871.
19. Mozaffarian D. Perspective: obesity – an unexplained epidemic. Am J Clin Nutrition 2022; 115: 1445-50.
20. Milano W, De Biasio V, Di Munzio W, Foggia G, Capasso A. Obesity: the new global epidemic pharmacological treatment, opportunities and limits for personalized therapy. Endocr Metab Immune Disord Drug Targets 2020; 20: 1232-43.
21. Rubenstein A. Obesity: a modern epidemic. Trans Am Clin Climatol Assoc 2005; 116: 103-13.
22. Villalobos JC. Obesity: the real pandemic of the 21st century. Cirugia Cirujanos 2016; 84: 351-5.
23. El-Reshaid W, Abdul-Fattah H. Sonographic assessment of renal size in healthy adults. Med Principles Pract 2014; 23: 432-6.
24. Oyuela-Carrasco J, Rodriguez-Castellanos F, Kimura E, Delgado-Hernandez R, Herrera-Felix J. Renal length by ultrasound in Mexican adults. Nefrologia 2009; 29: 30-4.
25. Okoye I, Agwu K, Eze C. Relationship between sonographic renal length and renal parenchymal thickness in normal adult southeast Nigerians. West African J Med 2006; 25: 231-4.
26. Python. (2021). Python Software Foundation. [Online]. Available: https://www.python.org/downloads/release/python-3100/