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# The relationship between kidney function and cardiometabolic risk factors, anthropometric indices, and dietary inflammatory index in the Iranian general population: a cross-sectional study

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## Abstract

**Background** The prevalence of chronic kidney disease (CKD) is estimated to be about 13.4% worldwide. Studies have shown that CKD accounts for up to 2% of the health cost burden. Various factors, such as genetic polymorphisms, metabolic disorders, and unhealthy lifestyles, can contribute to the occurrence of CKD. Therefore, the present study aimed to investigate the relationship between renal function and cardiometabolic risk factors, anthropometric characteristics, and the dietary inflammatory index (DII) in an Iranian population.

**Methods** This study was conducted on 2472 male and female employees of Shiraz University of Medical Sciences (SUMS), selected through census between 2018 and 2019. In this cross-sectional study, renal function was evaluated using serum creatinine (sCr), blood urea nitrogen (BUN), and estimated glomerular filtration rate (eGFR). Biochemical indices including sCr, BUN, fasting blood sugar (FBS), total cholesterol (TC), low-density lipoprotein (LDL), high-density lipoprotein (HDL), and triglyceride (TG) were measured using standard laboratory methods. eGFR was calculated using the Modification of Diet in Renal Disease formula. Systolic (SBP) and diastolic (DBP) blood pressure as well as anthropometric indices such as height (Ht), weight (Wt), hip circumference (HC), waist circumference (WC), body mass index (BMI), conicity index (C-Index), visceral adiposity index (VAI), abdominal volume index (AVI), body adiposity index (BAI), and body shape index (ABSI) were measured and calculated using standard methods and formulas. Diet was evaluated through a 113-item food frequency questionnaire, and the DII was calculated according to its specific instructions. To predict the factors influencing renal function and to remove the impact of confounders, multivariable linear regression was employed using the backward elimination method.

**Results** There was a significant direct relationship between sCr and FBS, TG, HDL, DBP, Wt, and BAI as well as between BUN and age, TG, HDL, and BAI. In addition, there was a significant inverse relationship between eGFR

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and SBP, Wt, BAI, and VAI. In women compared to men, sCr and BUN values were significantly lower, while eGFR levels were significantly higher.

**Conclusions** It seems that age, gender, lipid profile, glycemic status, BP, BAI, VAI, and Wt can be considered factors associated with renal function.

**Keywords** Kidney function tests, Glomerular filtration rate, Blood urea nitrogen, Dietary inflammatory index, Cardiometabolic risk factors

## Background

Renal diseases are disorders that can significantly impact the structure and function of the kidneys, potentially leading to severe complications or death if not diagnosed or treated [1]. Among the most prevalent renal diseases is chronic kidney disease (CKD), which has a global prevalence estimated at approximately 13.4% [2]. Evaluating renal function typically involves estimating the glomerular filtration rate (eGFR), a pivotal metric calculated using various methods. Among these, the Modification of Diet in Renal Disease (MDRD) formula is widely regarded as one of the most accurate for assessing eGFR [3–6]. Notably, many individuals in the general population may harbor undiagnosed or early-stage CKD, particularly since the disease can often be asymptomatic during its initial phases [7].

Research has shown a significant relationship between several cardiometabolic risk factors (CMRFs) and eGFR, where CMRFs such as hypertension, increased fasting blood sugar (FBS), and dyslipidemia—including elevated low-density lipoprotein (LDL), decreased high-density lipoprotein (HDL), increased total cholesterol (TC), and elevated triglycerides (TG)—can adversely affect kidney function [8–16]. Additionally, obesity and overweight have been linked to impaired renal function. A high percentage of body fat, particularly visceral fat, has been implicated in causing insulin resistance, which adversely affects key indicators of renal function, such as serum creatinine (sCr) and blood urea nitrogen (BUN) levels [17–24].

Moreover, inflammatory processes may contribute to the progressive decline of renal function [25]. Inflammation is a defensive response of the immune system that can be activated by various factors, including dietary components [26–28]. Recent studies have demonstrated that a higher dietary inflammatory index (DII) correlates with increased levels of inflammatory mediators, such as C-reactive protein (CRP), indicating that dietary choices can significantly influence inflammation levels [29]. The DII serves as a useful metric for assessing dietary profiles concerning their inflammatory potential, encompassing both anti-inflammatory and pro-inflammatory components [27, 28].

Given that renal diseases pose significant challenges to public health and entail considerable financial burdens on healthcare systems worldwide, investigating the factors influencing renal function is crucial for reducing the incidence of CKD and associated healthcare costs. In this context, the present cross-sectional study aimed to explore the relationship between kidney function and a range of CMRFs, anthropometric indices, and the DII in the Iranian general population, seeking to identify potential factors associated with CKD.

## Methods

### The study population

In this cross-sectional descriptive-analytical study, data from the employees' health cohort of Shiraz University of Medical Sciences (SUMS) were used. This cohort was launched to identify the most common non-communicable diseases among Iranians and investigate effective methods of prevention, and it is a branch of the PERSIAN (Prospective Epidemiological Research Studies in Iran) cohort [30]. In this study, informed consent was first obtained from 3400 people (both sexes in the age group of 25 to 65 years) who were selected by census. Then, demographic, biochemical, anthropometric, blood pressure (BP), and dietary information were collected through appropriate instruments by trained individuals. Moreover, 928 people were excluded from the study due to meeting the exclusion criteria, and finally, this study was conducted on 2472 participants who entered the study from August 9, 2018 to October 23, 2019. The exclusion criteria were the use of drugs and supplements affecting cardiometabolic disorders, pregnancy, breastfeeding, surgery, infection, smoking, certain diseases such as cancer, and an energy intake of less than 1000 or more than 4000 kcal. This cross-sectional research has been approved by the Medical Ethics Committee of SUMS under the code IR.SUMS.SCHEANUT.REC.1400.039 and was conducted in the year 2023.

### Biochemical indicators and renal function

In the present study, all biochemical evaluations including the measurement of sCr, BUN, FBS, TC, LDL, HDL, and TG were performed according to routine laboratory methods and based on the PERSIAN cohort protocol [30]. eGFR was also calculated using age, race, gender, and sCr through the MDRD formula [6]:

$$\text{eGFR}\left(\text{mL/min/1.73m}^2\right) = (175\times\text{sCr}^{-1.154}\times\text{age}^{-0.203}(\times0.742 \text{ if female; } \times1.21 \text{ if black}))$$

### BP measurement

In order to assess systolic BP (SBP) and diastolic BP (DBP), the participants rested for 15 min before the assessment, and then their BP was measured twice with a time interval of 10 min using a dial sphygmomanometer (N-Precisa Riester) by a physician [30].

### Anthropometric indicators

The anthropometric data in this study, including height (Ht), weight (Wt), hip circumference (HC), and waist circumference (WC), were collected using available routine methods in the PERSIAN cohort protocol [30]. Other anthropometric indices include body mass index (BMI), conicity index (C-Index), visceral adiposity index (VAI), abdominal volume index (AVI), body adiposity index (BAI), and body shape index (ABSI), which were calculated using the formulas in Table 1 [31–33].

### Diet and DII

In the present study, in order to assess the participants' annual food intake, the 113-item Food Frequency Questionnaire (FFQ) was used, which has acceptable validity and reliability in the Iranian population [34]. Then, food intakes were entered into Nutritionist 4 software, and values of energy, macronutrient, and micronutrient intake were obtained. In this study, the DII score for 26 food parameters including energy, carbohydrate, protein, total fat, alcohol, vitamin B12, vitamin B6, vitamin B9, vitamin B3, vitamin B2, vitamin B1, vitamin A, vitamin D, vitamin E, vitamin C, zinc, beta-carotene, caffeine, cholesterol, fiber, iron, magnesium, monounsaturated fatty acid, polyunsaturated fatty acid, saturated fatty acid, and selenium was calculated. In order to calculate the DII score, intake values of the aforementioned food parameters for each person were subtracted from the global average intake. Then, the obtained values were divided by the global standard deviation to obtain the Z score. After that, Z-score values were converted to percentiles. The percentile values were then multiplied by 2 and subtracted by 1. Finally, the numbers obtained from the 26 food parameters were multiplied in the overall inflammatory score, and all the values were added together to calculate the final DII score. The total DII scores can range between -8.87 (the most anti-inflammatory) and + 7.98 (the most pro-inflammatory). In the study by Shivappa et al., 45 food items were introduced to calculate the DII [35], but in the present study, 26 food items were available to calculate the DII. In order to standardize the information and eliminate the error of daily energy intake, all the data were adjusted based on intake in 1000 kcal.

**Table 1** Formulas for calculating anthropometric indices

| Anthropometric indices | Calculation formulas |
|---|---|
| **AVI ($m^2$)** | $[(2\times WC^2)+0.7\,(WC - HC)^2]\,/1000$ |
| **C-Index$(m/kg)^{1/2}$** | $WC\,(m)\,/\,(0.109\times\sqrt{[Wt(kg)/Ht(m)]})$ |
| **BAI ($1/m^{1/2}$)** | $(HC\,[cm]\,/\,Ht\,[m]^{1.5}) - 18$ |
| **ABSI$(m/kg)^{2/3}$** | $WC\,(m)\,/\,(BMI^{2/3}\,(kg/m^2)\times Ht^{1/2}\,(m))$ |
| **BMI$(kg/m^2)$** | $Wt/Ht^2$ |
| **VAI ($m^3$/kg)** | $M=(WC\,/\,(39.68+(1.88\times BMI))\times(TG/1.03)\times(1.31/HDL\,(mmol/l))$<br>$F=(WC/\,(36.58+(1.89\times BMI))\times(TG/0.81)\times(1.52/HDL\,(mmol/l))$ |

*Abbreviations*: *AVI* Abdominal volume index, *ABSI* A body shape index, *BMI* Body mass index, *BAI* Body adiposity index, *C-index* Conicity index, *F* Female, *HC* Hip circumference, *Ht* Height, *HDL* High-density lipoprotein, *M* Male, *TG* Triglycerides, *VAI* Visceral adiposity index, *WC* Waist circumference, *Wt* Weight

### Statistical analysis

Kolmogorov–Smirnov test was employed to assess the normality of the variables. Quantitative data were described using mean ± standard deviation, median, and interquartile range (IQR). Qualitative data were summarized using counts and frequency percentages. To identify factors affecting renal function, the association between each variable and renal function was initially evaluated using univariate linear regression analysis. Subsequently, to account for confounding variables, those with a $p$-value of less than 0.2 were analyzed using the multivariate linear regression model. In addition, to mitigate the effects of collinearity among the variables, the variance inflation factor (VIF) was calculated. Because of the high VIF of the independent variables, quartiles were created, and the effects of potential confounding factors were adjusted using the backward elimination method. Data analysis was performed using Statistical Package for the Social Sciences (SPSS) version 21 software, and the significance level of the tests was considered to be less than 0.05.

## Results

At the beginning of the study, 3400 people were registered, 928 of whom were excluded (Fig. 1). Finally, the study was conducted on 2472 people with a mean ± standard deviation age of 41.27 ± 6.67 years. Women accounted

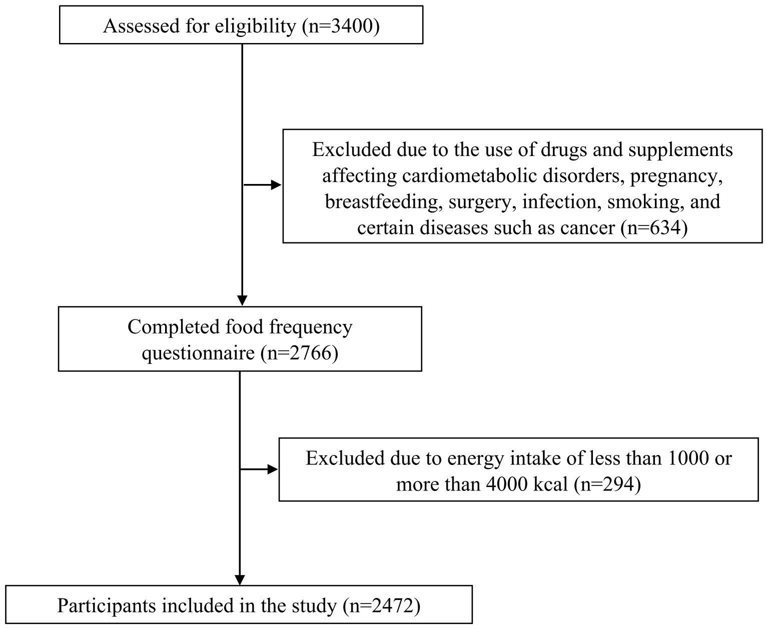


**Fig. 1** Flowchart of the study

**Table 2** Renal, cardiometabolic, anthropometric, and dietary indices of the participants in the study

| Variables | Mean ±SD | Median | IQR |
|---|---|---|---|
| **Glomerular filtration rate (mL/min/1.73m$^2$)** | 72.10 ± 10.51 | 71.51 | 14.05 |
| **Blood urea nitrogen (mg/dL)** | 12.26 ± 3.09 | 11.88 | 4.07 |
| **Serum creatinine (mg/dL)** | 1.00 ± 0.16 | 0.98 | 0.22 |
| **Fasting blood sugar (mg/dL)** | 90.11 ± 11.83 | 88.69 | 11.86 |
| **Triglyceride (mg/dL)** | 133.24 ± 76.23 | 113.77 | 81.70 |
| **Total cholesterol ( mg/dL)** | 175.70 ± 32.80 | 172.88 | 42.41 |
| **High-density lipoprotein (mg/dL)** | 49.39 ± 9.97 | 48.17 | 13.51 |
| **Low-density lipoprotein (mg/dL)** | 99.48 ± 22.84 | 98.00 | 30.92 |
| **Systolic blood pressure (mmHg)** | 109.08 ± 11.94 | 108.00 | 17.00 |
| **Diastolic blood pressure (mmHg)** | 72.56 ± 8.94 | 71.00 | 14.00 |
| **Height (cm)** | 165.29 ± 9.21 | 164.50 | 14.40 |
| **Weight (kg)** | 72.10 ± 12.68 | 71.20 | 17.50 |
| **Waist circumference (cm)** | 93.22 ± 9.35 | 93.00 | 12.00 |
| **Hip circumference (cm)** | 102.00 ± 6.88 | 101.80 | 8.90 |
| **Body mass index (kg/m$^2$)** | 26.33 ± 3.70 | 26.11 | 4.61 |
| **A body shape index$(m/kg)^{2/3}$** | 0.08 ± 0.004 | 0.084 | 0.01 |
| **Abdominal volume index (m$^2$)** | 17.63 ± 3.50 | 17.33 | 4.42 |
| **Conicity index $(m/kg)^{1/2}$** | 1.30 ± 0.07 | 1.29 | 0.09 |
| **Body adiposity index (1/m$^{1/2}$) %** | 30.24 ± 4.74 | 29.83 | 6.55 |
| **Visceral adiposity index (m$^3$/kg)** | 4.78 ± 3.22 | 3.94 | 3.20 |
| **Dietary inflammatory index** | - 0.29 ± 1.73 | - 0.32 | 2.71 |

The values are reported as the mean ± standard deviation (SD), median, and interquartile range (IQR) for 54.40% of the participants, and 1835 people (74.20%) had university education. Table 2 shows the results of renal, cardiometabolic, and anthropometric indicators and the DII score of the participants.

After removing confounding factors, the results of the multivariate linear regression test showed that age, gender (lower in women compared to men), TG, HDL, and BAI were factors associated with BUN, and a significant correlation was observed among these variables and BUN ($P$-value < 0.05). However, no correlation was observed between the DII and the other independent variables with BUN (Table 3).

After removing the effect of confounding factors, the results of the multivariate linear regression test showed that gender (lower in women compared to men), FBS, TG, HDL, DBP, Wt, and BAI were predictive factors of sCr, and there was a significant relationship between these variables and sCr ($P$-value < 0.05). However, no relationship was observed between the DII and the other independent variables with sCr (Table 4).

In addition, the results of the multivariate linear regression test, after removing the effect of confounding factors, showed that gender (higher in women compared to men), SBP, Wt, VAI, and BAI were factors associated with eGFR, and there was a significant relationship among them and eGFR ($P$-value < 0.05). However, no correlation was observed between the DII and the other independent variables with eGFR (Table 5).

## Discussion

The current cross-sectional study investigated the relationship between renal function and CMRFs, anthropometric indices, and DII in SUMS employees. The results of this study indicated a significant relationship between age, gender, TG, HDL, and BAI with BUN.

**Table 3** Univariate and multivariate linear regression models for the evaluation of factors related to blood urea nitrogen

| Independent variables (Q1-Q4) | Univariate model | | | | Multivariate model | | | |
|---|---|---|---|---|---|---|---|---|
| | ß | P1 | 95% CI | | ß | P2 | 95% CI | |
| | | | Lower | Upper | | | Lower | Upper |
| **Fasting blood sugar (mg/dl)** | 0.079 | < 0.001 | 0.044 | 0.114 | - | - | - | - |
| **Triglyceride (mg/dl)** | 0.030 | 0.091 | -0.005 | 0.066 | 0.056 | 0.011 | 0.013 | 0.098 |
| **Total cholesterol (mg/dl)** | 0.033 | 0.068 | -0.002 | 0.068 | 0.041 | 0.051 | 0.000 | 0.083 |
| **High-density lipoprotein (mg/dl)** | -0.029 | 0.110 | -0.064 | 0.006 | 0.047 | 0.027 | 0.005 | 0.089 |
| **Low-density lipoprotein (mg/dl)** | 0.027 | 0.140 | -0.009 | 0.062 | - | - | - | - |
| **Systolic blood pressure (mmHg)** | 0.125 | < 0.001 | 0.091 | 0.160 | - | - | - | - |
| **Diastolic blood pressure (mmHg)** | 0.106 | < 0.001 | 0.071 | 0.141 | -0.036 | 0.071 | -0.075 | 0.003 |
| **Height (cm)** | 0.209 | < 0.001 | 0.174 | 0.243 | - | - | - | - |
| **Weight (kg)** | 0.128 | < 0.001 | 0.094 | 0.163 | 0.037 | 0.083 | -0.005 | 0.079 |
| **Waist circumference (cm)** | 0.057 | 0.002 | 0.021 | 0.092 | - | - | - | - |
| **Hip circumference (cm)** | -0.012 | 0.519 | -0.047 | 0.024 | - | - | - | - |
| **Body mass index (kg/m$^2$)** | -0.014 | 0.435 | -0.049 | 0.021 | - | - | - | - |
| **A body shape index$(m/kg)^{2/3}$** | 0.027 | 0.128 | -0.008 | 0.063 | - | - | - | - |
| **Abdominal volume index (m$^2$)** | 0.057 | 0.002 | 0.022 | 0.092 | - | - | - | - |
| **Conicity index$(m/kg)^{1/2}$** | 0.008 | 0.664 | -0.027 | 0.043 | - | - | - | - |
| **Body adiposity index (1/m$^{1/2}$) %** | 0.203 | < 0.001 | 0.168 | 0.237 | 0.064 | 0.008 | 0.016 | 0.111 |
| **Visceral adiposity index (m$^3$/kg)** | 0.043 | 0.017 | 0.008 | 0.078 | - | - | - | - |
| **Dietary inflammatory index** | 0.098 | < 0.001 | 0.063 | 0.133 | - | - | - | - |
| **Age (year)** | 0.015 | < 0.001 | 0.009 | 0.021 | 0.015 | < 0.001 | 0.009 | 0.021 |
| **Sex** | | | | | | | | |
| **Male** | Ref | - | - | - | Ref | - | - | - |
| **Female** | -0.622 | < 0.001 | -0.697 | -0.547 | -0.603 | < 0.001 | -0.729 | -0.477 |

P1: $P$-value based on univariate linear regression

P2: $P$-value based on multivariate linear regression (backward) method

$P$-value > 0.05 was considered significant

In order to remove the confounding effect of independent variables, multivariate linear regression model (backward) method was used

In order to remove the high variance inflation factor (VIF) of independent variables, quartiles were used in multivariate linear regression

Q1-Q4: Quartile 1 to quartile 4

**Table 4** Univariate and multivariate linear regression models for the evaluation of factors related to serum creatinine

| Independent variables (Q1-Q4) | Univariate model | | | | Multivariate model | | | |
|---|---|---|---|---|---|---|---|---|
| | ß | P1 | 95% CI | | ß | P2 | 95% CI | |
| | | | Lower | Upper | | | Lower | Upper |
| **Fasting blood sugar (mg/dl)** | 0.173 | < 0.001 | 0.139 | 0.208 | 0.066 | < 0.001 | 0.037 | 0.096 |
| **Triglyceride (mg/dl)** | 0.200 | < 0.001 | 0.166 | 0.235 | 0.056 | 0.001 | 0.024 | 0.088 |
| **Total cholesterol (mg/dl)** | 0.033 | 0.068 | -0.002 | 0.068 | - | - | - | - |
| **High-density lipoprotein (mg/dl)** | -0.167 | < 0.001 | -0.202 | -0.132 | 0.053 | 0.001 | 0.021 | 0.085 |
| **Low-density lipoprotein (mg/dl)** | 0.038 | 0.033 | 0.003 | 0.074 | - | - | - | - |
| **Systolic blood pressure (mmHg)** | 0.261 | < 0.001 | 0.227 | 0.294 | -0.037 | 0.094 | -0.080 | 0.006 |
| **Diastolic blood pressure (mmHg)** | 0.278 | < 0.001 | 0.244 | 0.312 | 0.045 | 0.042 | 0.002 | 0.089 |
| **Height (cm)** | 0.435 | < 0.001 | 0.404 | 0.466 | - | - | - | - |
| **Weight (kg)** | 0.310 | < 0.001 | 0.277 | 0.343 | 0.075 | < 0.001 | 0.039 | 0.111 |
| **Waist circumference (cm)** | 0.158 | < 0.001 | 0.123 | 0.193 | - | - | - | - |
| **Hip circumference (cm)** | 0.043 | 0.018 | 0.007 | 0.078 | - | - | - | - |
| **Body mass index (kg/m$^2$)** | 0.049 | 0.007 | 0.014 | 0.084 | - | - | - | - |
| **A body shape index$(m/kg)^{2/3}$** | -0.007 | 0.703 | -0.042 | 0.028 | -0.027 | 0.067 | -0.055 | 0.002 |
| **Abdominal volume index (m$^2$)** | 0.156 | < 0.001 | 0.122 | 0.191 | - | - | - | - |
| **Conicity index$(m/kg)^{1/2}$** | 0.005 | 0.784 | -0.030 | 0.040 | - | - | - | - |
| **Body adiposity index (1/m$^{1/2}$) %** | 0.366 | < 0.001 | 0.334 | 0.398 | 0.084 | < 0.001 | 0.044 | 0.123 |
| **Visceral adiposity index (m$^3$/kg)** | 0.075 | < 0.001 | 0.040 | 0.111 | - | - | - | - |
| **Dietary inflammatory index** | 0.155 | < 0.001 | 0.120 | 0.190 | - | - | - | - |
| **Age (year)** | 0.003 | 0.321 | -0.003 | 0.009 | - | - | - | - |
| **Sex** | | | | | | | | |
| **Male** | Ref | - | - | - | Ref | - | - | - |
| **Female** | -1.179 | < 0.001 | -1.243 | -1.115 | -0.954 | < 0.001 | -1.061 | -0.846 |

P1: *P*-value based on univariate linear regression

P2: *P*-value based on multivariate linear regression (backward) method

*P*-value > 0.05 was considered significant

In order to remove the confounding effect of independent variables, multivariate linear regression model (backward) method was used

In order to remove the high variance inflation factor (VIF) of independent variables, quartiles were used in multivariate linear regression

Q1-Q4: Quartile 1 to quartile 4

The findings also showed that gender, FBS, TG, HDL, DBP, Wt, and BAI were significantly related to sCr. In addition, there was a significant relationship between gender, SBP, Wt, BAI, and VAI with eGFR. However, no significant relationship was observed between other studied variables and renal function.

## Age and gender

The present study showed that BUN increases significantly with age, but sCr and eGFR do not change significantly. This result is almost consistent with the findings of previous studies [36, 37]. Considering that no significant relationship was found between age and sCr and eGFR levels, it seems that the cause of the BUN increase is not the usual age-related decrease in renal function. Studies have shown that aging leads to increased expression of vasopressin receptors in the kidney and bladder [38]. Therefore, the increase in BUN can be caused by the increased effect of tubular vasopressin on urea reabsorption, which causes an increase in BUN without changes in sCr and eGFR. Additionally, it is important to consider that dehydration, which is more prevalent in older adults due to diminished kidney function, reduced thirst perception, and changes in body composition, can further elevate BUN concentrations. This dehydration creates a relative decrease in plasma volume, leading to an increased concentration of urea produced during protein metabolism, thereby contributing to the rise in BUN with age [37]. In the present study, BUN and sCr values were related to gender and were significantly lower in women than in men. The results of the present study are consistent with the study by Liu et al. [36], but they are inconsistent with the results of the study by Zahir et al. [39]. Zahir et al. reported that there is no significant relationship between gender and BUN and sCr [39]. This difference could be due to the small and insufficient sample

**Table 5** Univariate and multivariate linear regression models for the evaluation of factors related to estimated glomerular filtration rate

| Independent variables (Q1-Q4) | Univariate model | | | | Multivariate model | | | |
|---|---|---|---|---|---|---|---|---|
| | ß | P1 | 95% CI | | ß | P2 | 95% CI | |
| | | | Lower | Upper | | | Lower | Upper |
| **Fasting blood sugar (mg/dl)** | -0.033 | 0.069 | -0.068 | 0.003 | -0.033 | 0.075 | -0.069 | 0.003 |
| **Triglyceride (mg/dl)** | 0.026 | 0.149 | -0.009 | 0.061 | - | - | - | - |
| **Total cholesterol (mg/dl)** | -0.006 | 0.728 | -0.042 | 0.029 | - | - | - | - |
| **High-density lipoprotein (mg/dl)** | 0.040 | 0.026 | 0.005 | 0.075 | - | - | - | - |
| **Low-density lipoprotein (mg/dl)** | 0.008 | 0.660 | -0.027 | 0.043 | - | - | - | - |
| **Systolic blood pressure (mmHg)** | -0.040 | 0.027 | -0.075 | -0.004 | -0.052 | 0.013 | -0.092 | -0.011 |
| **Diastolic blood pressure (mmHg)** | -0.040 | 0.028 | -0.075 | -0.004 | - | - | - | - |
| **Height (cm)** | -0.003 | 0.878 | -0.038 | 0.033 | 0.062 | 0.095 | -0.011 | 0.134 |
| **Weight (kg)** | -0.017 | 0.347 | -0.052 | 0.018 | -0.062 | 0.024 | -0.117 | -0.008 |
| **Waist circumference (cm)** | 0.002 | 0.924 | -0.034 | 0.037 | - | - | - | - |
| **Hip circumference (cm)** | 0.006 | 0.759 | -0.030 | 0.041 | - | - | - | - |
| **Body mass index (kg/m$^2$)** | -0.005 | 0.789 | -0.040 | 0.030 | - | - | - | - |
| **A body shape index** $(m/kg)^{2/3}$ | 0.001 | 0.992 | -0.035 | 0.035 | - | - | - | - |
| **Abdominal volume index (m$^2$)** | 0.002 | 0.924 | -0.034 | 0.037 | - | - | - | - |
| **Conicity index** $(m/kg)^{1/2}$ | 0.007 | 0.682 | -0.028 | 0.043 | - | - | - | - |
| **Body adiposity index (1/m$^{1/2}$) %** | 0.020 | 0.266 | -0.015 | 0.055 | -0.083 | 0.009 | -0.146 | -0.021 |
| **Visceral adiposity index (m$^3$/kg)** | 0.041 | 0.024 | 0.005 | 0.076 | -0.056 | 0.003 | -0.093 | -0.020 |
| **Dietary inflammatory index** | 0.010 | 0.580 | -0.025 | 0.045 | - | - | - | - |
| **Age (year)** | 0.000 | 0.924 | -0.006 | 0.006 | - | - | - | - |
| **Sex** | | | | | | | | |
| **Male** | Ref | - | - | - | Ref | - | - | - |
| **Female** | 0.000 | 0.099 | -0.079 | 0.079 | 0.145 | 0.037 | 0.009 | 0.281 |

P1: *P*-value based on univariate linear regression

P2: *P*-value based on multivariate linear regression (backward) method

*P*-value > 0.05 was considered significant

In order to remove the confounding effect of independent variables, multivariate linear regression model (backward) method was used

In order to remove the high variance inflation factor (VIF) of independent variables, quartiles were used in multivariate linear regression

Q1-Q4: Quartile 1 to quartile 4

size of their study ($n=131$) [39]. It seems that the lower levels of BUN and sCr in women compared to men can be attributed to differences in muscle mass and hormonal influences. Men typically have greater muscle mass due to higher levels of testosterone, which promotes muscle growth and results in elevated creatinine production [36]. In addition, the results of the present study showed that eGFR values were related to gender and were significantly higher in women than in men. Considering the inverse relationship between sCr and eGFR and lower sCr levels in women compared to men, it is logical and reasonable to have higher eGFR in women than in men.

### Lipid profile

In the current study, BUN and sCr values were directly and significantly related to TG and HDL levels. This result is consistent with the results of some previous studies and inconsistent with others [40–44]. For instance, in a 5-year prospective cohort study in the Japanese population, Shimizu et al. observed that 224 of 1824 participants developed CKD, and high TG was an independent factor associated with CKD [40]. Moreover, in the study by Liang et al., a direct and significant relationship was reported between BUN and sCr values with TG levels in the Chinese general population [41]. The study by Ong et al. also showed that the increase in HDL may lead to the deterioration of renal function [42]. This problem may be due to the fact that HDL can sometimes lose its vascular protective, anti-inflammatory, and antioxidant properties and become ineffective, or it may be due to the difference in the function of HDL subtypes, including HDL-2 and HDL-3 [45]. Tolonen et al. also showed that dyslipidemia is significantly associated with renal dysfunction in patients with diabetes [43]. Nevertheless, Aliviameita et al. reported a significant negative correlation between BUN and TG and a significant positive correlation between sCr and TG in 50 diabetic patients [44]. This contradiction in the results could be due to the fact that the sample size of the study by Aliviameita et al. was collected from the hospital, and studies have shown that about 60% of diabetic patients referred to hospitals have malnutrition [44, 46]. Furthermore, BUN levels decrease in people with renal dysfunction who are malnourished [47]. Therefore, the presence of a significant negative correlation between BUN and TG in the study of Aliviameita et al. is justified. The mechanism of the effect of dyslipidemia on the development of CKD is being investigated; however, based on the available evidence, it seems that ectopic lipids are accumulated and deposited in all types of mesangial cells, podocytes, and renal proximal tubules. Then, lipid-dependent mitochondrial destruction causes the death of renal proximal tubule cells [41].

### FBS and BP

In the present study, a significant positive relationship was observed between sCr and FBS, which is consistent with the results of previous studies [48–51]. A cross-sectional analysis of 22,363 individuals from the Dongfeng-Tongji cohort in China showed that increased sCr levels are associated with increased FBS values [48]. A positive correlation between sCr and FBS has also been shown in several studies, especially in diabetic patients [49–51]. Studies have shown that high levels of blood glucose lead to an additional burden on the kidneys and their damage in the long term [49]. Therefore, the presence of a significant direct relationship between sCr and FBS may be due to the increase in kidney function to filter excess glucose from the blood [51].

In this study, there was a significant relationship between sCr and eGFR values with BP. This result was almost in line with the results of previous studies [52–54]. In the study by Youssef et al., an increase of 10 mmHg in SBP and DBP increased sCr by about 0.03 and 0.04 mg/dL, respectively. Interestingly, in their study, the role of DBP in increasing sCr was stronger than that of SBP [52]. In the study by Coresh et al., a significant direct relationship was found between sCr and hypertension [53]. Ji et al. also reported a significant inverse relationship between eGFR and SBP [54]. In general, the increase in BP leads to damage to small blood vessels in the kidney, impairs their ability to remove waste products, and increases the levels of sCr [55]. In addition, structural and hemodynamic changes in nephrons following an increase in BP lead to defective sodium excretion, an increase in peripheral vascular resistance, and a decrease in eGFR [56].

### Anthropometric indices

In the present study, BUN and sCr were directly and significantly related to BAI, and eGFR was inversely and significantly related to BAI and VAI. BAI is a practical anthropometric index for estimating body fat percentage, and VAI is an index for measuring visceral adiposity and insulin resistance in humans [57]. It seems that the results of the present study in this field are in line with the results of previous studies [58–61]. For instance, the results of a prospective cohort showed that increased body fat over 5 years was independently associated with decreased eGFR in a relatively healthy Korean population [58]. A cross-sectional study conducted on the National Health and Nutrition Examination Survey (NHANES) data also showed that increased VAI was associated with decreased renal function [59]. Another study showed that higher VAI was associated with an increased risk of CKD [60]. In a meta-analysis published in 2023, the diagnostic value of VAI in predicting the incidence of CKD was confirmed [61]. By increasing body fat mass, especially visceral fat, the production and secretion of pro-inflammatory cytokines increase. These cytokines can have a negative effect on renal function, and as a result, increase BUN and sCr while decreasing eGFR. Moreover, insulin resistance shown by a high VAI and BAI can promote glomerular hyperfiltration and increase intraglomerular pressure, contributing to nephron damage over time [62].

In the current study, there was a significant direct relationship between sCr and Wt values and a significant inverse relationship between eGFR levels and Wt; however, there was no significant relationship between BMI and sCr, BUN, and eGFR. In previous studies, there was a significant relationship between Wt and BMI with the risk of renal dysfunction [63–66]. It seems that overweight and obesity, through the release of free radicals and the creation of oxidative stress, the activation of the sympathetic system, and the increase in the secretion of leptin from adipose tissue, can lead to changes in the structure and function of nephrons, an increase in arterial pressure, and ultimately damage to renal function [55, 67]. It is worth noting that the reason for the non-significance of the relationship between BMI and renal function indices in the present study is probably the small standard deviation of BMI in the population (Table 2).

### DII

In the current study, no significant relationship was observed between DII and renal function indices. Also, in the study by Rouhani et al., there was no significant relationship between DII and BUN, sCr, and eGFR [68]. However, in some other studies, the increase in DII was significantly associated with a decrease in eGFR [69–71]. In the study by Bondonno et al., for each unit increase in

DII score, eGFR decreased by 0.55 mL/min/1.73 $m^2$ in elderly women [72]. The reason for the conflicting results might be due to the difference in the studied population. For example, in Huang et al.'s study, the relationship between DII and eGFR was significant only in patients with hypertension [70]. Moreover, the lack of access to all 45 food items to calculate the DII in different studies could be a possible reason for the differences in the results.

### Strengths and limitations

The strengths of the present study include a large sample size, the use of trained individuals to collect information and complete the questionnaires with minimal errors, and the use of standard tools with high accuracy and precise laboratory methods to measure variables. The limitations of the study consist of its cross-sectional nature, which reflects associations rather than causations; the lack of measurement of inflammatory biomarkers such as interleukin-6, CRP, and tumor necrosis factor-alpha; and the calculation of DII using 26 items out of the 45 suggested food items. Moreover, only sCr was used to assess renal function, which may not fully capture renal impairment compared to newer biomarkers such as cystatin C. Furthermore, eGFR was calculated using the MDRD equation, as recommended by an Iranian nephrologist; however, using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation in conjunction with MDRD might provide a more comprehensive assessment of renal function in this population.

### Generalizability of findings

Our findings are generalizable to the Iranian population and populations with similar genetic backgrounds and lifestyles, particularly in countries with comparable sociocultural and dietary practices. However, the applicability of these results to populations significantly different in lifestyle, environment, or genetic predispositions may be limited, and further investigation would be necessary to understand how these findings could translate to such groups.

## Conclusion

In conclusion, the findings of this study indicate that age, gender, lipid profile, glycemic status, BP, Wt, and novel anthropometric indices such as BAI and VAI are determinative factors associated with renal function in the Iranian population. Specifically, a direct relationship was observed between sCr and BUN levels and BAI, and an inverse association was identified between eGFR and both BAI and VAI. Importantly, no significant relationships were found between renal function and DII or other studied variables. These findings suggest that routine monitoring of the aforementioned indicators, particularly the cost-effective and accessible anthropometric indices (i.e., BAI and VAI), may provide clinicians with valuable tools for assessing renal health and identifying individuals at risk for kidney dysfunction.

#### Abbreviations

| | |
|---|---|
| AVI | Abdominal volume index |
| ABSI | A body shape index |
| BUN | Blood urea nitrogen |
| BMI | Body mass index |
| BAI | Body Adiposity Index |
| BP | Blood pressure |
| sCr | Serum Creatinine |
| CKD | Chronic kidney disease |
| CKD-EPI | Chronic Kidney Disease Epidemiology Collaboration |
| CMRFs | Cardiometabolic risk factors |
| C-Index | Conicity index |
| CRP | C-reactive protein |
| DII | Dietary inflammatory index |
| DBP | Diastolic blood pressure |
| eGFR | Estimated Glomerular Filtration Rate |
| FBS | Fasting blood sugar |
| FFQ | Food frequency questionnaire |
| HC | Hip circumference |
| Ht | Height |
| HDL | High-density lipoprotein |
| IQR | Interquartile range |
| LDL | Low-density lipoprotein |
| MDRD | Modification of Diet in Renal Disease |
| TC | Total cholesterol |
| TG | Triglyceride |
| SBP | Systolic blood pressure |
| SUMS | Shiraz University of Medical Sciences |
| SPSS | Statistical Package for the Social Sciences |
| VAI | Visceral adiposity index |
| Wt | Weight |
| WC | Waist circumference |

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#### Authors' contributions

The authors' contributions to the preparation of this manuscript are as follows: S.M. and A.A. participated in the study design, data collection and analysis, and writing the manuscript. S.J.M. participated in the data collection. M.Z. participated in the study design and data analysis. N.H. participated in the study design. S.F. participated in the critical revision and editing of the manuscript. All authors read and approved the content of the submitted manuscript.

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#### Data availability

Data is available from the corresponding author upon reasonable request.

## Declarations

#### Ethics approval and consent to participate

This study was done in accordance with the Declaration of Helsinki and its later amendments. It has been approved by the Ethics Committee of

Shiraz University of Medical Sciences with the code IR.SUMS.SCHEANUT.REC.1400.039. Written informed consent was obtained from all participants.

### Consent for publication
Not applicable.

### Competing interests
The authors declare no competing interests.

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