

Early Detection of Renal Impairment Among Patients with Type 2 Diabetes Mellitus Through Evaluation of Serum Cystatin C in Comparison with Serum Creatinine Levels: A Cross-Sectional Study

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Background: The proportion of patients with end-stage renal disease caused by diabetes has progressively increased during the last few decades. Serum creatinine level is the most commonly used biochemical parameter to estimate GFR in routine practice. However, 50% of GFR can be lost before significant elevation of serum creatinine. Cystatin C is found to be a new promising marker for early detection of renal diseases.

Objective of the Study: The aim of this study was to determine the value of serum cystatin C and serum creatinine levels for early detection of renal disease in patients with type 2 diabetes mellitus.

Methodology: A hospital-based comparative cross-sectional study was conducted with a sample size of 120. For early detection of renal disease in patients with type 2 diabetes mellitus, serum creatinine and cystatin C levels were measured and compared.

Result and Discussion: Serum creatinine and cystatin C levels were significantly increased in patients with type 2 diabetes mellitus compared to healthy controls. The mean±SD value of serum creatinine was found to be 0.87±0.44 mg/dL in patients and 0.63±0.27 mg/dL in control. Serum cystatin C level was also found to be significantly ($P=0.0001$) higher in patients (0.92±0.38 mg/L) compared to controls (0.52±0.20 mg/L). The mean±SD of eGFR in three equations (Creatinine Equation, Cystatin C Equation, and Creatinine–Cystatin C Equation) were 105.7±27.5 mL/min/m², 90.4±28.2 mL/min/m², and 100±29.5 mL/min/m², respectively.

Conclusion: Cystatin C-based GFR estimation equations detect renal impairment in patients with type 2 diabetes mellitus earlier than creatinine-based GFR estimation equations.

Keywords: diabetic nephropathy, type 2 diabetes, serum cystatin C, creatinine

Background

Diabetes mellitus is a metabolic disorder resulting from insufficient insulin secretion or inefficient insulin action and covers a wide range of heterogeneous diseases.¹ It is characterized by elevated blood glucose levels. Patients with diabetes are at substantial risk for tissue injury in organs supplied by an end arterial system due to microangiopathy. These microvascular complications include nephropathy, retinopathy, and neuropathy.² Kidney disease is a significant problem in the diabetic population. The

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proportion of patients with end-stage renal disease (ESRD) caused by Type 2 diabetes has progressively increased during the last few decades, and renal disease is now the most common cause of ESRD in the world.³ It has become one of the major killer diseases in the world among Sub-Saharan countries. Approximately 40% of patients with Type 2 diabetes eventually develop End Stage Renal Disease (ESRD).⁴

GFR is considered as the most accurate measurement of kidney disease and is reduced before the onset of clinical symptoms, and it is measured or predicted using different methods.⁵ To estimate the GFR, an endogenous substance in the blood that is cleared by the kidney is used. Serum creatinine is the most widely used metabolite to estimate GFR and for detection of renal disease. But creatinine concentration is influenced by sex, age, diet, and muscle mass and in some cases it is only increased after a 50% reduction in GFR. This leads to limit its usefulness as an ideal marker for early diagnosis of diabetic renal disease.⁶ Hence, other small molecular substances, such as cystatin C, which is not influenced by age, sex, or muscle mass and dietary intake and is being explored for early detection of renal disease.^{7,22} This new marker might reflect the early diminished GFR for early detection of renal impairment compared with traditional markers; and it is a new promising marker for early detection of renal disease. So far, there have been no studies done on cystatin C in patients with diabetes mellitus for early detection of diabetic nephropathy in Ethiopia.

This study was aimed to determine the value of serum cystatin C and serum creatinine levels for early detection of renal disease in patients with type 2 diabetes mellitus.

Methods

Study Design and Patients

An institutional-based Comparative Cross-Sectional Study design was implemented. We enrolled 120 participants (60 T2DM patients and 60 healthy controls). The patients had treatment follow-up at the diabetic center of TikurAnbesa Specialized Hospital. We excluded patients who had urinary tract infections, malignancies, liver disease, thyroid gland dysfunction, congestive heart failure, hypertensive, HIV, and women who were pregnant, because these may affect our outcome variables (serum creatinine and cystatin C).

Principles of Ethical Approval

The study was based on the Declaration of Helsinki. The study protocol was approved by Addis Ababa University

Biochemistry Department Ethics and Research Committee (DRERC). The approval was obtained by meeting number DRERC 01/19 and protocol number M.Sc. 09/19. Informed consent was obtained from the participants before sample collection. All the principles of ethics such as confidentiality and privacy were observed.

Study Area and Period

The study was conducted from January 2019 to August 2019 in TikurAnbesa Specialized Hospital (TASH), Addis Ababa, Ethiopia, with the aim of assessing the renal disease status of known T2DM patients who were on regular follow-up at the diabetic clinic, and with no previous documented impaired renal function.

Data Collection Methods and Procedure

By using \ structured questionnaire, we collected the demographic and clinical data. Using aseptic conditions, 5 mL of venous blood sample was drawn before breakfast (minimum of 8 hours of fasting) from each participant by trained and qualified laboratory technicians. Blood was transferred to a clean, dry serum separator tube, centrifuged, and the serum was transferred to nunc tube and preserved at -20°C until testing at the National References Laboratory for Clinical Chemistry analysis, Ethiopian Public Health Institute (EPHI). Serum cystatin C and serum creatinine were analyzed using a COBAS 6000 automated chemistry analyzer at EPHI. Creatinine derived Equation (CKD-EPI 2009), Cystatin C derived Equation (CKD-EPI 2012), and both Creatinine–Cystatin C derived Equation (CKD-EPI mix) for eGFR were calculated and compared for early detection of diabetic-nephropathy.

Statistical Analysis

Categorical data were presented as number and percentage, whereas continuous variables either as mean and standard deviation (SD) after testing for normal distribution. Kappa value calculation was used for agreement test. In addition, between-group differences were assessed by using Student's *t*-test. The relationship between the outcome and several covariates was assessed through uni- and multi-variable linear regression models. All variables reaching a *P*-value

<0.05 were included in the multivariable models. At 95% confidence interval (CI), a *P*-value <0.05 was accepted as statistically significant.²³

Result

The study was conducted among 120 subjects (60 patients with Type2 DM and 60 healthy controls). The mean ages of T2DM patients and healthy controls were 56.5 and 56.2 ±14.9 years, respectively. The detailed basic characteristics of the control group and cases with type 2 diabetes mellitus are described in Table 1.

The mean±SD of the duration of patients with T2DM was 12.3±8.6, years with the maximum and minimum duration of 41 years and 6 months, respectively.

Out of 60 T2DM patients 32 (53.3%) used oral medication, 18 (30%) used insulin injection, and 10 (16.7%) used both oral medication and insulin injection.

Body mass index of the study participants was calculated using their weight and height. Based on the calculation, the mean±SD was found to be 26±4.4 kg/m² for cases and 19.7±2.8 kg/m² for the control group, respectively.

Table 1 Socio-Demographic Characteristics of Study Participants

Variables		Type-2 DM Cases (N=60)	Control Group (N=60)
Age	Mean±SD in years	56.5±14.1	56.2 ± 13.9
Sex	Male	25 (41.7%)	25 (41.7%)
	Female	35 (58.3%)	35 (58.3%)
Residence	Urban	50 (83%)	53 (88%)
	Rural	10 (17%)	7 (12%)
Education al level	Illiterate	8 (13%)	1 (1.7%)
	Read and write	1 (1.7%)	6 (10%)
	Primary school	7 (2%)	5 (8.3%)
	Secondary school	23 (12%)	11 (18.3%)
	College and above	21 (38%)	37 (61.7%)
	Housewife	21 (35%)	11 (18.3%)
Occupation	Farmer	5 (8.3%)	3 (5%)
	Non-Governmental Organization (NGO)	3 (5%)	6 (10%)
	Governmental	14 (23.3%)	18 (30%)
	Private	17 (28.3%)	22 (36.7%)
Alcohol consumption	Yes	17 (28.3%)	5 (8.3%)
	No	43 (71.7%)	55 (91.7%)
Regular Physical exercise	Yes	38 (63.3%)	37 (62%)
	No	22 (36.7%)	23 (38%)

Note: Categorical variables are presented in number and percentage while continuous variables are presented as mean±SD.

Abbreviations: SD, standard deviation; %, percentage.

The minimum and the maximum values of BMI in cases were 19.1 kg/m² and 35.2 kg/m², respectively. The minimum and the maximum values of BMI in the control groups were 15.1 kg/m² and 27.8 kg/m², respectively. In categories, 27 (45%) of the T2DM patients had normal body mass index, 25 (41.7%) were overweight, and eight (13.3%) were obese. Among the patients none were found to be underweight, but among controls 18 (30%) were underweight. Table 2 describes the percentage of study participants in each category of BMI.

The serum creatinine concentration of T2DM patients and healthy controls were examined. The serum creatinine concentration in blood sample was considered as normal when it was in the range 0.5–0.9 mg/dL for females and 0.7–1.2 mg/dL for males, respectively. Out of 35 female T2DM patients, 28 (80%) had a normal creatinine level and seven (20%) had above normal values (above 0.9) but none of the female T2DM patients showed a value below the normal range. Out of 25 male T2DM patients, 22 (88%) showed a creatinine level in a normal range and three (12%) had values above the normal range (above 1.2 mg/dL). In healthy controls, out of 35 females 22 (62.9%) had creatinine levels in the normal range and 13 (37.1%) had values below the normal range. Out of 25 male control groups, 17 (68%) had serum creatinine levels in the normal range and eight (32%) had values below the normal range, but none of the controls had values above the normal range. The mean serum creatinine level was higher among patients compared to controls and it was statistically significant (Table 3).

The serum cystatin C concentration of T2DM patients and healthy controls was compared (Table 3). Its concentration in blood samples was considered as normal when it ranged between 0.61–0.95 mg/L for both sexes. Out of 60 T2DM patients, 40 (66.7%) had a normal serum cystatin C level. Fifteen (25%) had values above the normal range and five (8.3%) of the T2DM patients had values below the normal range. From the apparently health controls, 39 (65%) had a serum cystatin C level in the normal range and 21 (35%)

Table 2 Percentage of Study Participants in Each Category of BMI

BMI Category	T2DM Cases	Health Control Groups
Below 18.5	1 (1.7%)	18 (30%)
18.5–24.9	27 (45%)	40 (66.7%)
25–29.9	24 (40%)	2 (3.3%)
30 and above	8 (13.3%)	0 (0%)

Table 3 Comparison of BMI, Serum Creatinine, and Cystatin C Levels Using Independent Sample *t*-Test Between T2DM Patients and Healthy Controls

Variables	T2DM Patients (N=60, Mean \pm SD)	Control Group (N=60, Mean \pm SD)	P-value (95% CI)
BMI in Kg/m ²	26 \pm 4.4	19.7 \pm 2.8	0.001
Creatinine level (mg/dL)	0.87 \pm 0.44	0.63 \pm 0.27	0.001

Notes: Cystatin C level (mg/L). 0.92 \pm 0.38. 0.52 \pm 0.20. *P*<0.001.

had values below the normal range, but none of the control groups had abnormally higher serum cystatin C level. The mean serum cystatin C level was higher among patients when compared with controls, and the difference was statistically significant (Table 3). The BMI of the participants was also significantly different between cases and control groups (*P*=0.001).

As described in Table 4 the mean value of serum creatinine was significantly higher in males than in females. This may be due to muscle mass variation between males and females. But the mean value of serum cystatin C in males was not significantly higher than females.

As described in Table 5 the level of serum creatinine positively and significantly correlated with age and BMI of T2DM patients but not significantly with duration of DM (Table 5).

Table 4 Comparison of Serum Creatinine and Cystatin C Levels Between Males and Females Using Independent Sample *t*-Test in Patients with T2DM

Variables	Males (n=25, Mean \pm SD)	Females (n=35, Mean \pm SD)	P-value (95% CI)
Serum creatinine level (mg/dL)	1.07 \pm 0.56	0.68 \pm 0.16	<0.001
Serum cystatin C level (mg/L)	1.03 \pm 0.48	0.89 \pm 0.23	0.29

Table 5 Correlation Analysis Between Serum Creatinine and Different Variables of Patients with T2DM

variables	Serum Creatinin	P-value
	r	
Age	0.422	0.001
Duration of DM	0.122	0.353
BMI	0.594	<0.001

The level of serum cystatin C also positively and significantly correlated with the age and BMI of T2DM patients (*r*=0.302, *P*=0.02), (*r*=0.369, *P*=0.021), respectively (Table 6). But, unlike serum creatinine, it correlated weakly with BMI and age of the patients.

Table 7 shows the correlation between serum cystatin and serum creatinine. They have strong and positive correlations among T2DM patients (*r*=0.90, *P*<0.0001). This is also graphically depicted using a scatter plot (Figure 1).

All predictor variables were checked by bivariate analysis, and the result showed that sex, age, and BMI of the T2DM participants were found to be significantly related with serum creatinine (Table 8).

Even though the age and BMI of T2DM participants significantly correlated with serum cystatin C level, the relation was not strong like serum creatinine. Unlike serum creatinine, serum cystatin C was not significantly correlated with sex (Table 9).

When we see the outcome variables in T2DM patients, the mean \pm SD of serum creatinine value of the T2DM patients was found to be 0.87 \pm 0.44 mg/dL, the mean \pm SD value of serum cystatin C was 0.92 \pm 0.38 mg/L, the mean \pm SD of eGFR in three equations (Creatinine Equation (CKD-EPI 2009), Cystatin C Equation (CKD-EPI 2012), and Creatinine–Cystatin C Equation (CKD-EPI 2012)) were found to be 105.7 \pm 27.5 mL/min/m², 90.4 \pm 28.2 mL/min/m², and 100 \pm 29.5 mL/min/m², respectively.

Based on the eGFR calculated using serum creatinine, 47 (78.3%) of the T2DM patients had normal or elevated GFR (\geq 90 mL/min/1.73 m²), nine (15%) of the patients were in stage 2 CKD with mild GFR reduction (GFR=60–89 mL/min/1.73 m²), three (5%) of the T2DM

Table 6 Correlation Analysis Between Serum Cystatin C and Different Variables of the Patients with T2DM

variables	Serum Cystatin C	P
	r	
Age	0.302	0.020
Duration of DM	0.175	0.182
BMI	0.369	0.021

Table 7 Correlation Analysis Between Serum Cystatin C and Creatinine Levels Serum Cystatin C

Variable	r (95% CI)	P-value
Serum creatinine	0.90	<0.001

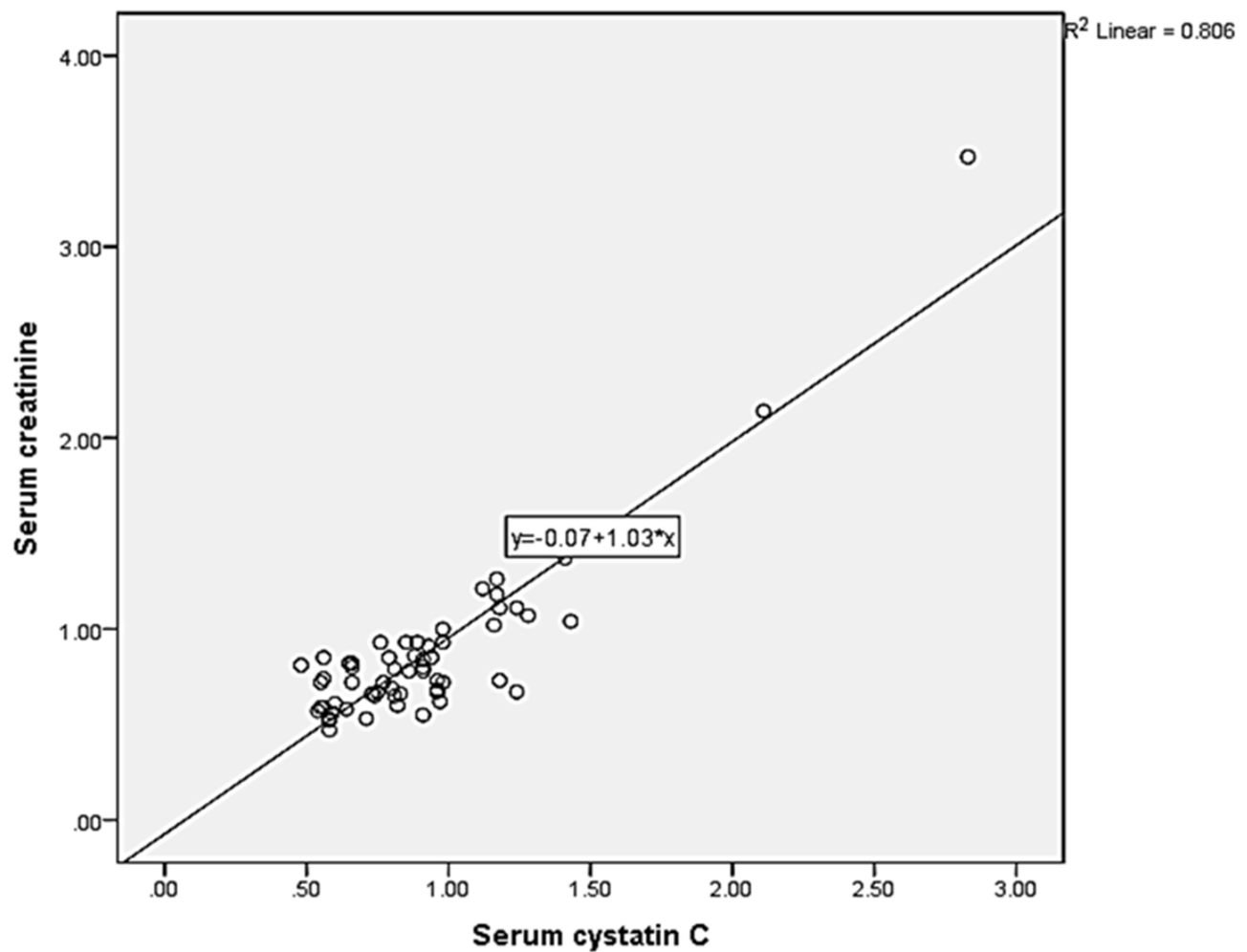


Figure 1 Scatter plot depicting correlation between serum levels of cystatin C and creatinine among T2DM patients.

patients were in stage 3 with moderate decreased GFR (GFR=30–59 mL/min/1.73 m²), and only one T2DM patient was in stage 4 CKD with severe GFR reduction (GFR=15–29 mL/min/1.73 m²) (Figure 2).

On the other hand, the eGFR based on serum cystatin C equation showed that 29 (48.3%) of the

T2DM patients had normal or elevated GFR (≥90 mL/min/1.73 m²), 18 (30%) of the patients were in stage 2 CKD with

mild GFR reduction (GFR=60–89 mL/min/1.73 m²), 11 (18.4%) of the patients were in stage 3 with moderate decreased GFR (GFR=30–59 mL/min/1.73 m²), and two (3.3%) patients were in stage 4 with severe GFR reduction (GFR=15–29 mL/min/1.73 m²) (Figure 2).

Based on eGFR using both serum cystatin C-creatinine Eq, 41 (68.3%) of the T2DM patients had normal or elevated eGFR (≥90 mL/min/1.73 m²), 13 (21.7%) of the patients were

Table 8 Multiple Linear Regression Analysis of Serum Creatinine in Type 2 Diabetic Patients

Variables	Serum Creatinine	
	β (95% CI)	P-value
Sex of participants	-0.388	<0.001
Age of participant	0.013	<0.001
Duration of DM	0.006	0.353
BMI	0.221	<0.001

Table 9 Multiple Linear Regression Analysis of Serum Cystatin C in Type 2 Diabetic Patients

Variables	Serum Cystatin C	
	β (95% CI)	P-value
Sex of participants	-0.061	0.481
Age of participants	0.009	0.015
Duration of DM	0.006	0.303
BMI	0.011	0.013

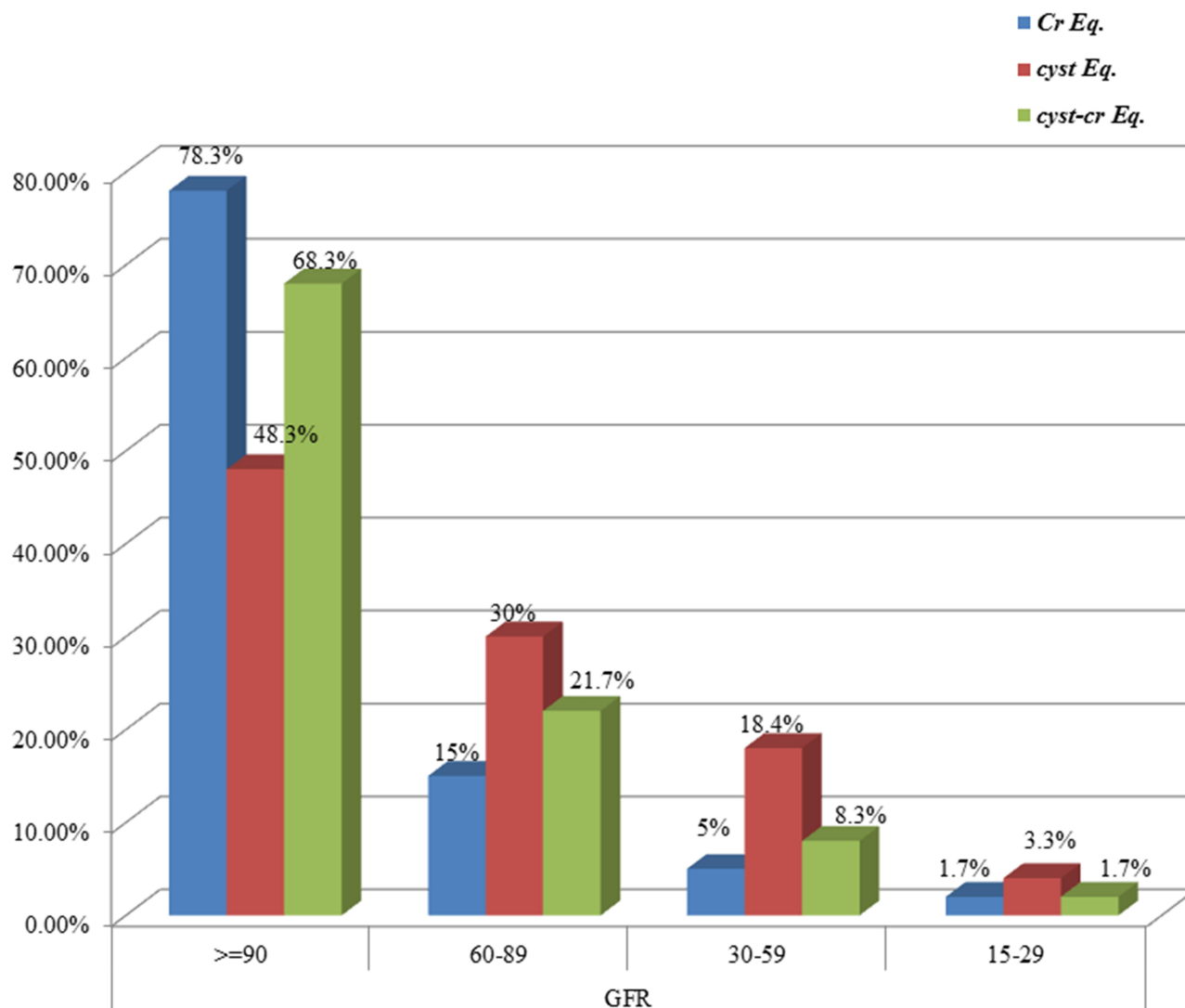


Figure 2 Percentage of participants' vs eGFR category in mL/min/1.73 m² from 15 to 90 calculated with the three equations.

in stage 2 CKD with mild GFR reduction (GFR=60–89 mL/min/1.73 m², five (8.3%) of the patients were in stage 3 with moderate decreased GFR (GFR=30–59 mL/min/1.73 m²), and only one (1.7%) patient was in stage 4 with severe GFR reduction (GFR=15–29 mL/min/1.73 m²) (Figure 2).

We investigated whether there is agreement between the results of estimated GFR-Creatinine based Eq. and estimated GFR-Cystatin C based Eq. by using the Cohen's Kappa statistical analysis. The *P*-value was found to be 0.003 and the kappa result was 0.24, suggesting that there is a poor agreement between the two equations.

In eGFR of 90 mL/1.73 m² and above, the two equations agreed for 29 participants. Eighteen patients were

reclassified to a cystatin C-based eGFR of less than 90 mL per minute per 1.73 m². In terms of 60–89 mL per minute per 1.73 m², the two equations agreed in only two T2DM patients. From the total of 18 T2DM patients who were classified as stage 2 CKD (60–89 mL per minute per 1.73 m²) in estimated GFR-cystatin C based equation, 16 patients were reclassified in 90 mL per minute per 1.73 m² and above in terms of creatinine-based eGFR.

Within the category of a cystatin C-based eGFR Eq. of 30–59 mL per minute per 1.73 m², nine T2DM patients were reclassified above 60 mL per minute per 1.73 m² by creatinine-based eGFR Eq. In two patients of stage 4 CKD (15–29 mL per minute per 1.73 m²) based on cystatin C-eGFR equation, one patient was reclassified as above 30 mL per minute per 1.73 m² in creatinine-based eGFR Eq.

In general accurate detection and staging of chronic kidney disease is an integral component of clinical medicine, since such evaluations have a major effect on disease labeling, interventions, drug doses, and risk stratification for clinical procedures.

Discussion

This study reaffirms the use of cystatin C as a plausible marker for early detection of diabetic renal disease. The study showed a significant increase in serum creatinine level in type 2 diabetics compared to controls. The serum creatinine was found to be significantly ($P=0.001$) higher in patients (0.87 ± 0.44) compared to controls (0.63 ± 0.27). The serum cystatin C was also found to be significantly ($P=0.0001$) higher in patients (0.92 ± 0.38) compared to controls (0.52 ± 0.20). These findings are similar to studies conducted earlier.^{8,9}

Much evidence suggests that serum cystatin C may not be influenced by age, sex, muscle mass, or dietary intake and, as a result, its level rises faster than creatinine after a fall in GFR and is a reliable endogenous marker for assessing renal function in type 2 diabetic patients. In one study that enrolled 52 Type 2 diabetic patients, an early and more significantly increased level of serum cystatin C than serum creatinine was observed as GFR decreases, which indicated that serum cystatin C might be a useful marker for detecting early renal impairment in diabetic patients.¹⁰

To confirm this, we have done the correlation and regression analysis for serum creatinine and cystatin C. The result showed that the serum creatinine level of the participants was significantly affected by age, BMI, and sex; similar to another study.¹¹ But, unlike our study, the correlation between age and serum creatinine was insignificant in this previous study. This may be due to different age distributions in the studies.

We also conducted the Pearson's correlation analysis of serum cystatin C with age and BMI of the T2DM patients and found that the level of serum cystatin C positively and significantly correlated with the age and BMI of T2DM patients ($r=0.302$, $P=0.02$ and $r=0.369$, $P=0.021$, respectively). But serum creatinine weakly correlated with BMI and age of the patients. This was in line with another study.¹¹ However; regression analysis showed that even though the age and BMI of T2DM participants significantly correlated with serum cystatin C level, the correlation was not as strong as serum creatinine. Unlike serum creatinine serum, cystatin C was not significantly affected by sex.

These findings agreed with many reports.^{12,13} The correlation analysis also showed that there was a strong and positive correlation between serum cystatin C and serum creatinine among T2DM patients ($r=0.90$, $P<0.0001$). These findings agreed with a previous study.¹⁴

For estimating GFR, we also used the three equations (Creatinine Equation (CKD-EPI 2009), Cystatin C Equation (CKD-EPI 2012), and both Creatinine–Cystatin C Equation (CKD-EPI 2012)). After determination of serum creatinine and cystatin C levels, the means \pm SD of eGFR in the three equations were found to be 105.7 ± 27.5 mL/min/m², 90.4 ± 28.2 mL/min/m², and 100 ± 29.5 mL/min/m², respectively. This finding was consistent with the cohort study.¹⁵

Concerning the variation due to gender, we found the mean serum creatinine level was significantly higher in males compared to females ($P<0.0001$). This is an expected finding and agrees with many previous studies. However, in the case of mean value of serum cystatin C, we did not find significant differences between males and females. In contrast to this, Finney et al¹⁶ and Wang et al¹⁷ Wang found significant differences in cystatin C levels, which were higher in men compared to women.

Based on the eGFR calculated using the serum creatinine, we found that 47 (78.3%) of the T2DM patients were normal or elevated GFR (≥ 90 mL/min/1.73 m²), and nine (15%) of the patients were in stage 2 CKD with mild GFR reduction (GFR=60–89 mL/min/1.73 m²). While three (5%) of the T2DM patients were in stage 3 with moderate decreased GFR (GFR=30–59 mL/min/1.73 m²), and only one T2DM patient was in stage 4 CKD with severe GFR reduction (GFR=15–29 mL/min/1.73 m²). Our finding was similar to other studies.^{10,18}

We also calculated the serum cystatin C derived eGFR equation and found that, 29 (48.3%) of the

T2DM patients were normal or elevated GFR (≥ 90 mL/min/1.73 m²), 18 (30%) of the patients were in stage 2 CKD with mild GFR reduction (GFR=60–89 mL/min/1.73 m²), 11 (18.4%) of the patients were in stage 3 with moderate decreased GFR (GFR=30–59 mL/min/1.73 m²), and two (3.3%) patients were in stage 4 with severe GFR reduction (GFR=15–29 mL/min/1.73 m²). Based on eGFR using both serum cystatin C-creatinine Eq, 41 (68.3%) of the T2DM patients were in stage 1 CKD with normal or elevated eGFR (≥ 90 mL/min/1.73 m²), 13 (21.7%) of the patients were in stage 2 CKD with mild GFR reduction (GFR=60–89 mL/min/1.73 m²), five (8.3%) of the patients were in stage 3 with moderate decreased GFR

(GFR=30–59 mL/min/1.73 m²) and we found only one (1.7%) patient was in stage 4 with severe GFR reduction (GFR=15–29 mL/min/1.73 m²). This was consistent with other studies.^{10,15}

Based on eGFR using both serum cystatin C-creatinine Eq. we found that 41 (68.3%) of the T2DM patients were normal or elevated eGFR (≥ 90 mL/min/1.73 m²), 13 (21.7%) of the patients were in stage 2 CKD with mild GFR reduction (GFR=60–89 mL/min/1.73 m²), five (8.3%) of the patients were in stage 3 with moderately decreased GFR (GFR=30–59 mL/min/1.73 m²), and only one (1.7%) patient was in stage 4 with severe GFR reduction (GFR=15–29 mL/min/1.73 m²). This finding was consistent with another study.¹⁰

We also investigated whether there is an agreement between the results of estimated GFR-Creatinine based Eq. and estimated GFR-Cystatin C based Eq. by using the Cohen's Kappa statistical analysis. We found that the *P*-value of 0.003 and the kappa value of 0.24 which indicates the overall agreement between these two equations were poor. This finding was similar to other studies.^{15,19} The consistently lower cystatin C-based eGFR-value in T2DM patients might also indicate that a significant number of them suffer from shrunken pore syndrome, which is a common disorder among T2DM patients contributing both to morbidity and mortality.^{20,21}

Strength and Limitation of the Study

As strength, this study was attempted for the first time in Ethiopia. Therefore, this will give the baseline information for further studies. Relative to many international researches the sample size for this study was large enough.

As a limitation, the study was cross-sectional based and we measured the serum parameters only once for each participant which could overestimate or underestimate the results. We did not have a “gold standard” marker due to performing inulin or iothalamate clearance that needs invasive and tedious procedures and not suitable for study subjects. We did not include other parameters like albuminuria in this study due to the limitation of reagent availability.

Conclusion

From our study, we concluded that Cystatin C-based GFR estimation equations detect renal impairment in patients with type 2 diabetes mellitus earlier than creatinine based

GFR estimation equations, because unlike serum creatinine its serum concentration is not that much influenced by sex, muscle mass, and age. The results of this study suggest that serum cystatin C can detect mild-to-moderate decreases of GFR that may not be detected with serum creatinine-based measurements. To compare the performance of eGFR equations based on cystatin C and creatinine, we confirmed discrepancies in eGFR using equations for serum creatinine and cystatin C based biomarkers and found that most T2DM patients in cystatin C based equation, compared with creatinine-based equation, gave lower eGFR values.

Abbreviations

BMI, body mass index; CI, confidence interval; CKD-EPI, chronic kidney disease epidemiology collaboration; DM, diabetes mellitus; DN, diabetic nephropathy; DRERC, Department of Ethics and Research Committee; ESRD, end-stage renal disease; eGFR, estimated glomerular filtration rate; EPHI, Ethiopian Public Health Institute, SPSS, Statistical Package for Social Sciences; T2DM, type 2 diabetes mellitus.

Data Sharing Statement

The datasets used during the current study are available from the corresponding author on reasonable request.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests.

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