ORIGINAL ARTICLE NORTH BENGAL MEDICAL COLLEGE JOURNAL [2017], VOL., 3, No. 2 : 6-17

Kidney Screening and Estimation of Glomerular Filtration Rate by CG, MDRD and CKD-EPI Equations in Healthy Adults of Dhaka

*Md. Shariful Haque,[1] Md. Azizul Hoque,[2] Harun Ur Rashid,[3] Muhammad Rafiqul Alam,[4] Md. Shahidul Islam[5]

Received : August 20, 2016 Accepted : September 24, 2016

Abstract

Introduction: *Kidney disease screening should be done to detect kidney disease early. Blood pressure measurement and simple tests like urine examination, blood sugar, creatinine measurement and GFR estimation (eGFR) by creatinine based equations can detect early renal impairment. Among different GFR estimation equations, CG and MDRD are most widely used. The newer CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration) equation by Levey ASin 2009 has claimed superiority in terms of improved precision, accuracy and less bias. This equation has been used in many countries including India and found consistently improved performance. To our knowledge it was the first epidemiologic study applying CKD-EPI equation in Bangladesh.*

Methods: *We have conducted a population based cross-sectional observational study involving these 3 equations among 498 healthy adult volunteers in urban area of Dhaka from May 2010 to December 2010.*

Results: *Mean age of adult population (n-410) was 36.81±12.17. Mean creatinine 89.125± 13.82 µmol/L.CKD-EPI equation yielded highest eGFR. Estimated GFR with CG equation (CG-CCr), BSA adjusted/corrected CG (CG-GFR) equation, MDRD and CKD-EPI equation was 83.13±18.69 ml/min, 86.71±17.60ml/min/1.73^2, 84.80±17.67ml/min/1.73^2, and 89.92 ± 18.69 ml/min/1.73^2 respectively. Groups were significantly different from one another in multivariate analysis of variance (ANOVA) ($p<0.05$). Estimated GFR by CKD EPI equation is similar with measured GFR by DTPA renogram among healthy volunteers in a study conducted in CMH, Dhaka. Despite higher creatinine (92.04±12.75 vs 82.48±13.91 µmol/L in female), males have had higher GFR by all GFR estimation equations. Population having GFR less than 60 ml/min was 10.7% in CG-CCR, and 6.8% and 5.9% by MDRD and CKD-EPI equations respectively.*

Conclusion: *Despite a number of limitations such as purposive sampling, small sample size and single based institution, this study was meant to estimate GFR by different equations. Till now CKD-EPI equations is the best method to estimate GFR.*

Key words*: eGFR, MDRD, CKD-EPI*

*[1.] *Assistant Professor, Nephrology, Shaheed M. Monsur Ali Medical College, Sirajganj*
[2.] *Associate Professor, Endocrinology, Shaheed Ziaur Rahman Medical College,Bogra*
[3.] *Professor of Nephrology Kidney Foundation, Dhaka*
[4.] *Professor of Nephrology, BSMMU, Shahbag, Dhaka*
[5.] *Professor and Chairman, Department of Nephrology, BSMMU, Shahbag, Dhaka*

Correspondence *Md. Shariful Haque, Email: sharifuldr@gmail.com*

Introduction

Evidence from the Western countries is emerging that migrant populations of South Asian origin have a higher risk for chronic kidney disease (CKD) than the native whites.[1–3] Though widely used, creatinine is not a robust marker of kidney damage at early stage. An individual must lose 50% of their kidney function before the serum creatinine will begin to rise.[4] GFR is usually accepted as the best overall index of kidney function. Normal GFR varies according to age, sex, and body size; in young adults it is approximately 120-130 mL/min/1.73 m^2 and declines with age. Normal range of glomerular filtration rate (GFR) is significantly lower in Indian population compared to western population. Apparent low GFR among healthy Indians are physiological and is not are flection of any chronic subclinical subtle renal impairment.[5] Low nephron mass due to genetic predisposition also postulated. Moreover anthropometric measures like body surface area is different in south Asian population. GFR <60 ml/min/1.73 m^2 for at least three months, with or without kidney damage is a criterion for CKD. Decline in GFR precedes creatinine rise, that's why different authorities [The National Kidney Disease Education Program (NKDEP) of the National Institute of Diabetes,Digestive and Kidney Diseases (NIDDK), National Kidney Foundation (NKF) and American Society of Nephrology (ASN)] recommend estimating GFR from serum creatinine based GFR prediction equations.[6] Until now there are no fewer than 46 GFR prediction equations of which CG and MDRD is most widely used.[7] The newer CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration) equation by Levey AS published in 2009 has claimed superiority in terms of improved precision, accuracy and less bias.CG equation over estimate GFR when GFR is actually low, while MDRD under estimate GFR in healthy adult by about 30% and is not applicable below 18 years of age. CKD-EPI equation yield higher GFR, consequently lowers CKD prevalence and applied to all age and race. In NHANES, (National Health and Nutrition Evaluation Survey, USA) the median estimated GFR was 94.5 ml/min/1.73 m^2 vs. 85.0 ml/min/1.73 m^2, and the prevalence of chronic kidney disease was 11.5% versus 13.1% in CKD-EPI and MDRD equations.[8]

Materials and Methods

This population based cross sectional observational study was done from May 2010 to December 2010 by non-random purposive sampling among healthy volunteers. A total of 498 (Four hundred and ninety eight) adult respondents (18 and above) having no diabetes, hypertension or known acute or chronic illness were included. Study population was selected on two screening programme among morning exercisers in Ramna park, Shahbag, Dhaka. Fresh urine was tested for glucose, blood, protein, nitrite and leucocyte esterase with dipstix using 10 para 'Uric10 CF' reagent strips. About 3 ml of blood was centrifuged at the screening venue and serum was sent for measurement of serum glucose (random) and creatinine at Kidney Research Laboratory, Department of Nephrology, Bangabondhu Sheikh Mujib Medical University, Shahbag, Dhaka.

Serum creatinine was measured by alkaline picrate (Jaffe) kinetic method (without deproteination). A random blood sugar of ≥7.8mmol/L and s.creatinine of >120µmol/L was excluded. Estimated GFR was calculated by different GFR prediction equations namely Cockcroft-Gault (CG) equation, MDRD (Modification of Diet in Renal Disease) study equation and CKD-EPI equation.

GFR estimating equations:

I. Cockcroft-Gault Equation[9]
(140-Age) ×wt. (kg)

GFR CG equation (CG-CCR) = × (0.85 if female) ml/min 72×S.Cr (mg/dl)

After Body surface area (BSA)adjustment (CG-GFR) = (CG-CCR) ml/min ×1.73m^2÷ BSA

II. 4 variable MDRD Study Equation (Levey AS, 2000) [10, 11] eGFR (ml/min/ 1.73m^2 BSA) = 186 × (Scr)$^{-1.154}$ × (Age)x$^{-0.203}$ × (0.742 if female).

III. The 2009 CKD-EPI Equation[8] GFR = *a* × (serum creatinine/*b*) *c* × (0.993) age

The variable *a* takes on the following values on the basis of race and sex:Black (Women = 144, Men = 141); White/other (Women = 166, Men = 163).The variable *b* takes on the following values on the basis of sex:Women = 0.7, Men = 0.9.The variable *c* takes on the following values on the basis of sex and creatinine measurement: Women: Serum creatinine ≤ 0.7 mg/dL = -0.329, Serum creatinine> 0.7 mg/dL = -1.209.Men: Serum creatinine ≤ 0.9 mg/dL = -0.411, Serum creatinine> 0.9 mg/dL = -1.209.

Data was compiled and analyzed using statistical software SPSS-14. P=0.05 was considered as level of significance.

498 adult persons (18 years and above)were enrolled in study. Among them 352 were male and 146 were female. After screening, 88 cases (17.67%) were regarded “not healthy” and excluded from the study due to one or more of hypertension (17), hyperglycaemia (66) or abnormal urinary findings (45). (Table-1).410 (82.33%) eligible respondents were finally enrolled for GFR estimation by CG, MDRD and CKD-EPI equation

Table I: Abnormal results detected in screening of asymptomatic adults. Many have overlaps of abnormalities

Gender		HTN	High blood sugar	Raised creatinine	Abnormal Urine (dipstix test)			
					Alb	Glucose	Nitrite	Blood
M	67	11	55	6	10	17	10	5
F	21	6	11	3	-	-	1	2
n*	88	17	66	9	10	17	11	7

* Multiple responses were elicited.

Results

Among 410 eligible adult respondents 285 (69.50%) were males and 125 (30.50%) were females. Mean age of male and female was almost similar (36.74±12.61 vs 36.98±11.16 respectively). Age range was 18-83. Mean creatinine was higher in males (92.04±12.75 vs. 82.48±13.91). Mean creatinine was 89.125± 13.82 in study population. Mean SBP was 118.34 ±12.66 and mean DBP was 76.27±7.37 mm-Hg. Mean RBS was 5.50±1.03 mmol/L (Table II).

Table II: Demographic and baseline characteristics of the study population

Characteristics	Male (n-285)	Female (n-125)	Total (n-410)
Age	36.74±12.61	36.98±11.16	36.81±12.17
Height	166.38±7.01	157.37± 7.84	163.64 ± 8.37
Weight	62.83±11.42	57.71±10.45	61.273 ± 11.37
BSA(m^2)	1.70±0.15	1.57±0.15	1.657 ± 0.162
Creatinine(µmol/L)	92.04±12.75	82.48±13.91	89.125± 13.82
SBP (mm-Hg)	119.09±12.47	116.64±12.96	118.34±12.66
DBP (mm-Hg)	76.37±7.34	76.04±7.46	76.27±7.37
RBS (mmol/L)	5.46±.99	5.58±1.13	5.50±1.03

Mean eGFR by CG equation i.e. CG-CCr (ml/min) was83.13±18.69. After adjusted with BSA i.e. CG-GFR was 86.71±17.60 (ml/min/ 1.73^2). MDRD-GFR was 84.80±17.67 ml/min/ $1.73^2$and CKD-EPI revealed highest GFR 89.92±18.69 ml/min/1.73m^2 (Table III).

Table III: GFR in different equations

Characteristics	Male (n-285)	Female (n-125)	Total (n-410)
CG-CCR (ml/min)	85.72±17.35	77.22±20.31	83.13±18.69
CGGFR(ml/min/1.73^2)	87.59±16.90	84.69±19.0	86.71±17.60
MDRD-GFR	89.0±17.33	75.22±14.34	84.80±17.67
CKD-EPI	93.47±18.31	81.83±17.02	89.92±18.69

Respondents were divided into 6 age groups. Majority of respondents (40.98%) were among 18-30 years age. This age group had lowest creatinine (85.77±12.23 µmol/L) and highest eGFR by all equations (Table IV).

Table IV: Serum Creatinine and eGFR by different equations in different age groups

Age group	Serum Creatinine (µmol/L)	CG-CCR (ml/min)	CG-GFR (ml/min/1.73m^2)	MDRD (ml/ min /1.73m^2)	CK-DEPI (ml/ min/1.73m^2)
18-30	85.77±12.23	87.24±16.09	95.06±17.78	94.61±17.12	101.02±16.34
31-40	87.07±13.40	87.85±20.30	90.03±16.09	84.35±14.50	90.68±15.28
41-50	92.54±13.21	79.82±17.05	79.22±13.60	75.59±12.63	79.59±13.36
51-60	97.97±14.51	69.28±12.04	69.14±08.70	70.08±11.11	71.63±11.43
61-70	96.34±14.51	65.05±16.71	63.83±12.32	70.89±12.54	70.06±12.70
>70	115.50±10.61	35.00±18.38	36.0±12.73	49.50±16.26	46.50±16.26
Total	**85.77±12.23**	**83.13±12.69**	**86.71±17.70**	**84.80±17.67**	**89.92±18.69**

Respondents were divided into 6 groups as follows (Figure1).

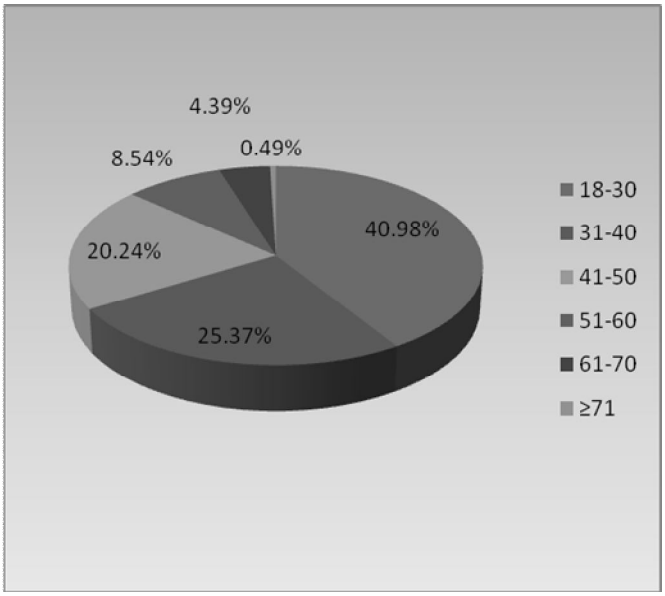


Figure 1: Pie diagram showing distribution of adult population in different age groups

Group 1: (18-30) years: 122 males and 46 females .Total 168(40.98%).
Group 2: (31-40) years: 64 males and 40 females. Total 104 (25.37%).
Group 3: (41-50) years: 56 males and 27 females. Total 83 (20.24).
Group 4: (51-60) years: 27 males and 08 females. Total 35 (8.54%).
Group 5: (61-70) years: 15 males and 03 females. Total 18 (4.39%).
Group 6: (71 and above): 01 male and 01 female. Total 02 (0.49%).

326 (79.51%) were having creatinine between 50-100 µmol/L. This group had higher GFR by all equations. While 84 (20.49%) have had creatinine>101 µmol/L (Table V).

Table V: Estimated GFR at creatinine 50-100 µmol/L groups and ≥101 µmol/L

Creatinine	CG-CCr ml/min	CG-GFR(BSA corrected) ml/min/1.73m^2	MDRD ml/min/1.73m^2	CKD-EPI ml/min/1.73m^2
50-100 µmol/L n=326	86.5±17.9	91.0±16.04	89.39±16.2	95.06±16.58
≥101 µmol/L n=84	70.11±15.86	70.02±12.79	67.0±10.35	70.0±11.86
Total n= 410	**83.13±12.69**	**86.71±17.70**	**84.80±17.67**	**89.92±18.69**

279 (68%) respondents were having BSA below 1.73m^2, and 131(32%) having ≥1.73m^2 BSA. In low BSA group highest GFR yielded in CKD-EPI formula (92.65±18.94ml/min/1.73m^2).In high BSA group highest yield was in CG-CCr without BSA adjustment (Table-VI).

Table VI: Level of creatinine and eGFR at Body Surface Area (BSA) below and above 1.73m^2

BSA	Creatinine	CG-CCR	CG-GFR	MDRD	CKD-EPI
<1.73m2	86.89±13.05	79.07±17.22	86.87±17.91	87.05±18.32	92.65±18.94*
≥1.73m^2	93.89±14.25	91.79±18.81	86.35±16.95	80.0±15.16	84.12±16.80**

*n=279 (68%), ** n=131(32%)

In low BSA group highest yield was in CKD-EPI formula (92.65±18.94ml/min/ 1.73m^2).

In high BSA group highest yield was in CG-CCr (actual CCr) without BSA adjustment.

Population was again divided into 2 groups on the basis of eGFR (below 60ml/min and above 60 ml/min). Lowest eGFRbelow 60ml/ minyielded with CG-CCr (10.7%), while BSA adjusted CG-GFR and CKD-EPI revealed almost similar result (5.6% and 5.9% respectively) (Table-VII, VIII).

Table VII: Healthy male and female population having GFR below or above 60 ml/min (despite without markers of kidney damage) by different GFR estimating equations

eGFR (ml/min/1.73m^2)	CG-CCr	CG-GFR	MDRD	CKD-EPI
<60	44(10.7%)	23 (5.6%)	28(6.8%)	24(5.9%)
≥60	366(89.3%)	387(94.4%)	382(93.2%)	386(94.1%)
Total	**410(100%)**	**410(100%)**	**410(100%)**	**410(100%)**

Table VIII: Healthy male and female population having GFR below or above 60 ml/min by different GFR estimating equations

Gender	CG-CCr		CG-GFR (Corrected CCR)		MDRD		CKD-EPI		
	<60	**≥60**	**60**	**≥60**	**60**	**≥60**	**60**	**≥60**	
M	16	269	12	273	9	276	9	276	285
F	28	297	11	114	19	106	15	110	125
Total	**44(10.7%)**	**366(89.3%)**	**23 (5.6%)**	**38 (94.4%)**	**28 (6.8%)**	**382 (93.2)**	**24 (5.9%)**	**386 (94.1%)**	**410**

We observed that creatinine tended to rise and all eGFR tended to fall with age. Though this rise or fall was not strictly linear (Figure 2).

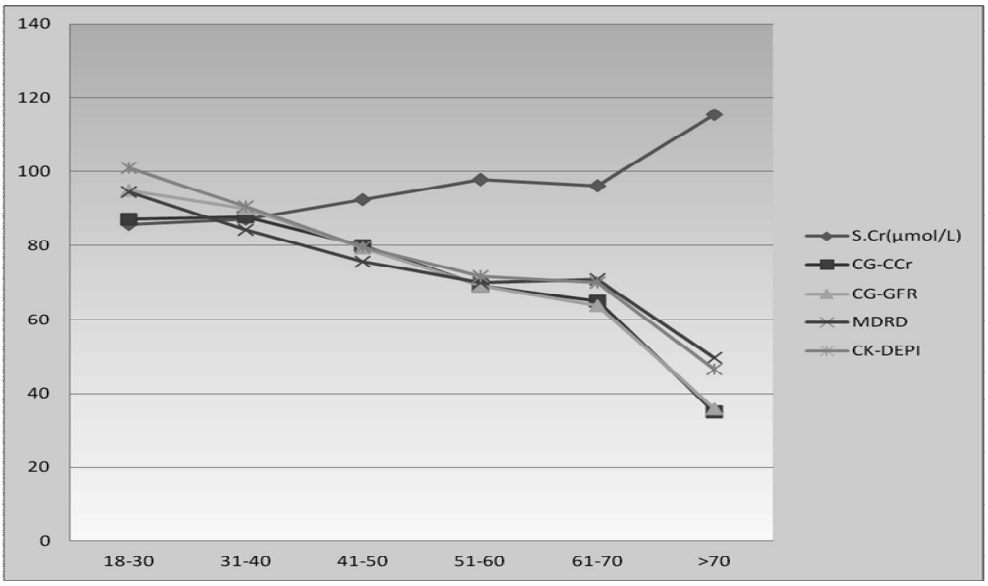


Figure 2: Trend of Creatinine and eGFR by GFR estimating equations in relation to creatinine in different age groups

Estimated GFR by 4 equations were significantly different by multivariate analysis of variance (ANOVA) ($p<.005$) where age, sex and creatinine are fixed factors.

Discussion

Total 88 cases (67 male and 21 female) have high BP, blood sugar, raised creatinine and abnormalities in urine. It is alarming, even in healthy fit exerciser 17.67% have had risk factors or kidney damage without their knowledge. In this study we have analyzed attributes of rest 410 adult persons of urban Dhaka majority of which were male 285 (69.50%). Females were 125 (30.50%). Mean age was 36.81 years. For male it was 36.74 and for female 36.98 years. Majority of respondents were between 18-30 years age group. 168 (40.98%) of which 122 male and 46 female were among this group.Mean crteatinine in study

population was 89.125± 13.82 µmol/L. In male creatinine was 92.04±12.75 µmol/L and in female- 82.48±13.91 µmol/L.

After estimating GFR in different equations eGFR was 83.13±18.69 ml/min in CG equation (CG-CCr). After correcting with BSA eGFR (CG-GFR) was 86.71±17.60 ml/min/1.73m^2. GFR by MDRD formula was 84.80±17.67 ml/min/1.73m^2.The new CKD-EPI formula reveals even higher GFR estimate. In population, mean GFR with CKD-EPI was 89.92±18.69 ml/min/1.73m^2. In male CKD-EPI eGFR was 93.47±18.31 ml/min/1.73m^2 and in female 81.83±17.02 ml/min/1.73m^2. We have conducted multivariate ANOVA to see difference of means among groups. Fixed factors (independent variables) were age, sex and creatinine (p<0.05) in all equations, groups were significantly different from one another. Post analysis couldn't be done.

Estimated GFR in female is lower than that of males in all equations of our study. Females have 9.95% low CG-CCr, 3.3% low corrected CG-CCr/CG-GFR, 15.48% low GFR in MDRD and 12.45% low GFR by CKD-EPI equation than males' estimated GFR.

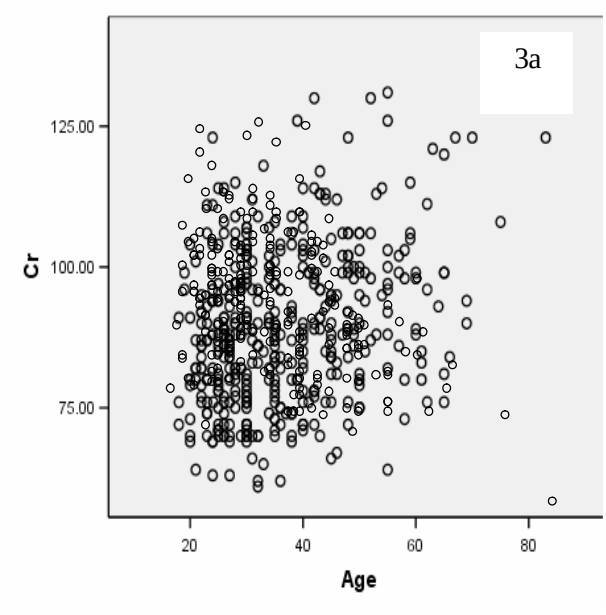
Population was divided into 6 age groups. Least creatinine value and highest eGFR was achieved at lowest age group, i.e, Group 1 (18-30 years) and vice versa. CKD-EPI and MDRD equation yielded highest GFR exception Group 3 (41-50 years) where unadjusted CG equation has the highest yield probably because of higher BSA 1.74m^2.

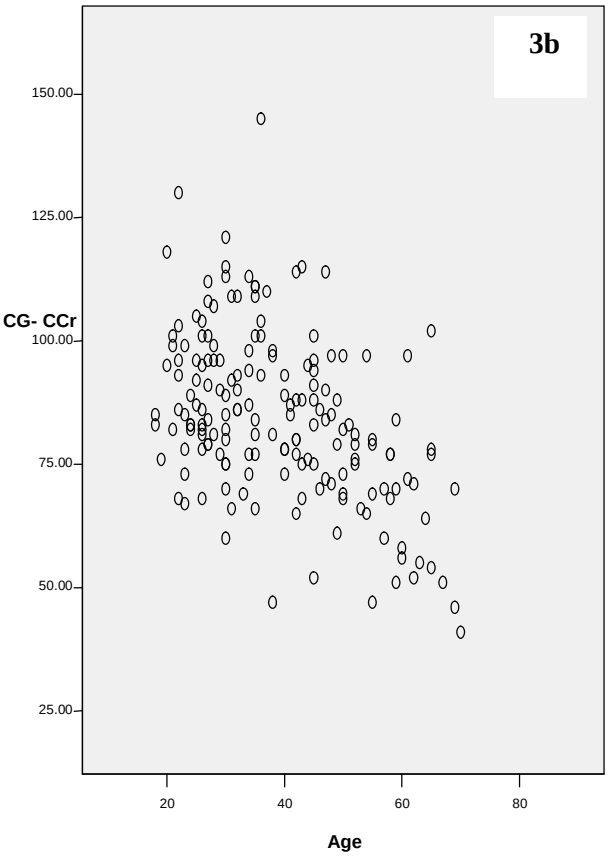
Estimated GFR varied as s. creatinine varies in population. In 50-100 µmol/L groups highest yield was by CKD-EPI equation: 95.06±16.58 ml/min/1.73m^2 followed by corrected CG GFR 91±16.04 ml/min/1.73m^2 and CG-CCr 86.49 ± 17.90 ml/min.

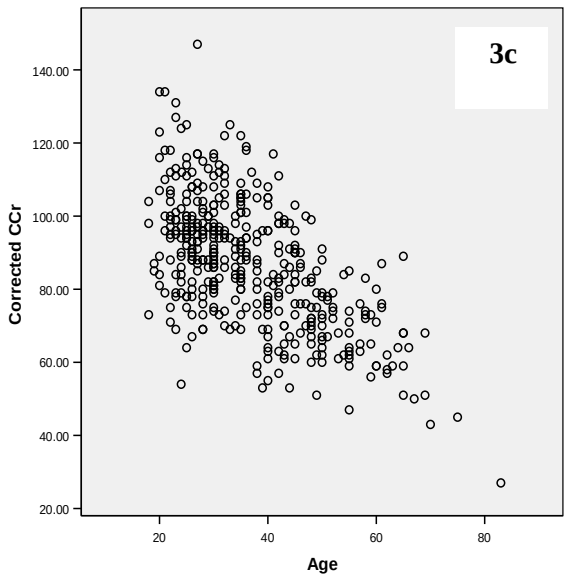
In ≥101 µmol/L creatinine group: CG-CCr and CG-GFR and CKD-EPI equation yielded almost equal mean GFR 70 ml/min. It seems that CG equation has overestimated eGFR in higher creatinine values. It is already known that CKD-EPI produces higher eGFR values in the high GFR range(>60 ml/min/1.73 m^2), and lower eGFR values in the lowest range.[8] In contrast C-G equation overestimate renal function at higher creatinine (lower GFR range).[12] In low BSA group highest yield was 92.65±18.94 ml/min/ 1.73m^2 in CKD-EPI formula. In high BSA group highest yield was by unadjusted CG-CCr. It seems CG equations has been influenced by BSA. MDRD and CKD-EPI equations are already adjusted for BSA, hence not influenced by BSA.

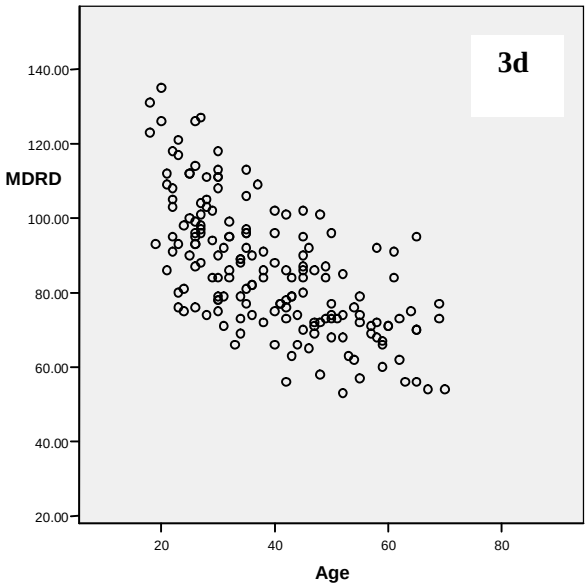
We have documented 10.7% of population having GFR <60 ml/min (i.e. CKD stage 3 range) by C-G equation without surface area correction. After surface area correction (CG-GFR/Corrected CCR) this value falls to 5.6%. By new CKD-EPI equation only 5.6% and with MDRD equation 6.8% of population was found to have GFR <60 ml/min/1.73m^2.

We have plotted scatter diagram for creatinine and all estimated GFR in relation to age to observe correlation. We found creatinine does not have any correlation with age. It signifies, it is not the norm that creatinine will increase or decrease with advanced age. However, we found moderate negative correlation with all form of GFR measured in different equations. This finding matches our understanding that GFR decrease with age (Figure 3).


3a
Cr
125.00
100.00
75.00
20
40
60
80
Age


3b
CG- CCr
150.00
125.00
100.00
75.00
50.00
25.00
20
40
60
80
Age


3c
Corrected CCr
140.00
120.00
100.00
80.00
60.00
40.00
20.00
20
40
60
80
Age


3d
MDRD
140.00
120.00
100.00
80.00
60.00
40.00
20.00
20
40
60
80
Age

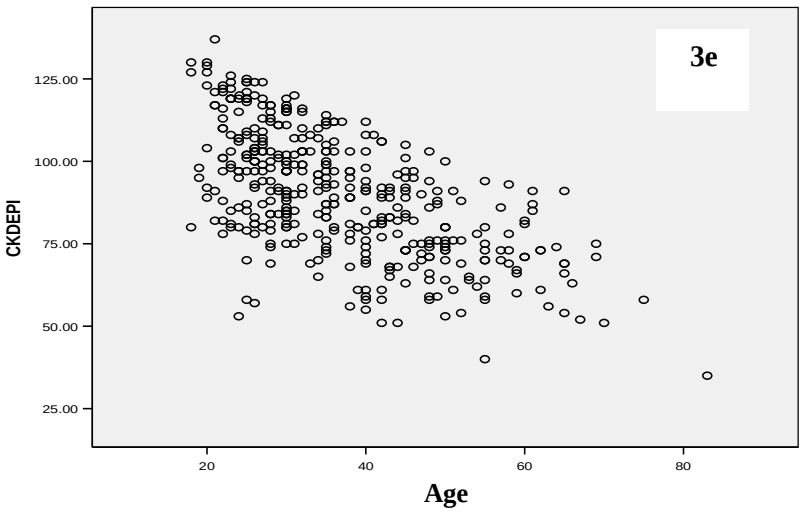


Figure 3: Scatter diagram showing correlation of creatinine and GFR with age

3a. No correlation is observed for creatinine, but moderate negative correlation is noted with age and all GFR prediction equations. **3b, 3c, 3d, 3e.** Moderate negative correlation is noted with age and all GER prediction equations.

Since creatinine does not linearly increase with age as we see in scatter diagram, we can say that somewhat linear decrease in GFR is not due to rise of creatinine; particularly age and other factors and exponentials inherent in the equations might have operating.

On histogram, distribution of creatinine was normal in male but somewhat right skewed in females (Figure 4).

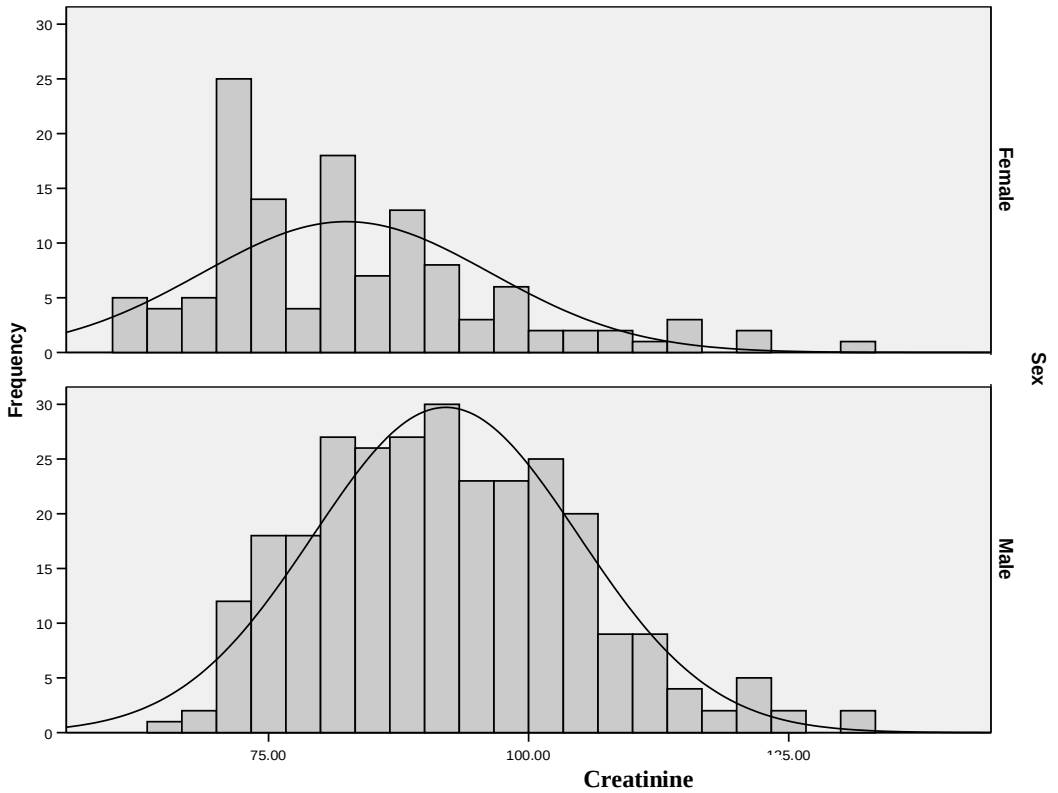


Figure 4: Histogram showing gender variations in creatinine level

Distribution is normal in male but somewhat right skewed in females.

We have compared our study with the study of Kabir E, Rahman M[13] conducted at rural village of Chakulia, Savar, Dhaka involving CG and MDRD equations only. Despite higher mean creatinine (89.125 vs 86.44 μmol/L in Chakulia) we have yielded higher mean GFR in all prediction equations. Probably this resulted from lower mean age (36.81±12.17 vs 41.37±14.85 in Chakulia), male dominance (69.50% male vs56.8% female in Chakulia) and anthropometric variables like BSA (1.657 vs 1.55 for Chakulia) in our study.

In a study, among 100 potential kidney donors mean GFR measured by DTPA, renogram was 89.05±10.96 ml/min/1.73m^2, MDRD GFR 88.81±10.47 ml/min/ 1.73m^2, CG-CCr 90.80± z13.43 ml/min, and CG-GFR was 93.55±11.23 ml/min/1.73m^2 done in Combined military hospital, Dhaka.[14] In that study, MDRD equation was not significantly different from measured GFR (p=0.671) so proved valid for healthy Bangladeshi adult. While CG CCR and CGGFR was significantly different (p<0.05 and <0.001) respectively from measured GFR by DTPA, so was proved not valid for healthy Bangladeshi adult. Our CKD EPI eGFR 89.92±18.69 is similar to measured GFR of CMH study.

Conclusion

Kidney screening test should be done to detect kidney disease early, and is cost effective. This study was meant to estimate GFR by different equations, not to see the prevalence of CKD. It requires repeated assessment of same populations at least after 3 months and document their eGFR to label as CKD. Large scale multicenter study involving newer CKD-EPI equations can be useful to see prevalence of CKD and status of renal function across the country. Moderate negative correlation is noted with age and all GFR prediction equations.

Acknowledgement

I would like to thank Kidney Research Laboratory, Department of Nephrology, BSMMU for full laboratory support.

Contribution of the Authors

First author was the principal researcher. Third and fourth were guide and co-guide respectively. Others helped in data collection and analysis.

References

1. Chandie Shaw PK, Vandenbroucke JP, Tjandra YI, et al.: Increased end stage diabeticnephropathy in Indo-Asian immigrants living in the Netherlands. Diabetologia. 2002; 45: 337–341.
2. Fischbacher CM, Bhopal R, Rutter MK et al.: Microalbuminuria is more frequent in South Asian than in European origin populations: A comparative study in Newcastle, UK. Diabet Med. 2003; 20: 31–36.
3. Trehan A, Winterbottom J, Lane B et al.: End-stage renal disease in Indo-Asians in the North-West of England. QJM. 2003; 96: 499–504.
4. Thomas L, Huber AR. Renal function--estimation of glomerular filtration rate. Clin Chem Lab Med. 2006; 44(11):1295-302.
5. Prasad N, Barai S, Sharma RK, et al. Levels of GFR and renal reserve capacity in living kidney donors in India. Indian Journal of nephrology. 2007; 17(3): 99-100
6. National Kidney Foundation. K/DOQI clinical practice guidelines for chronic kidney disease: Evaluation, classification and stratification. Am J Kidney Dis. 2002; 39 (1): S1-S266.

7. Diamandopoulos A, Goudas P, Arvanitis A: Comparison of estimated creatinine clearance among five formulae (Cockroft–Gault, Jelliffe, Sanaka, simplified 4 variable MDRD and DAF) and the 24hours-urine-collection creatinine clearance; HIPPOKR-ATIA. 2010, 14(2): 98-104.
8. Levey AS, Stevens LA, Schmid CH et al. Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI): A new equation to estimate glomerular filtration rate. Ann Intern Med. 2009; 150 : 604-612.
9. Cockcroft DW, Gault MH. Prediction of creatinine clearance from serum creatinine. Nephron. 1976 ; 16 (1): 31-41.
10. Levey AS, Bosch JP, Lewis JB, Greene T, Rogers N, Roth D for the Modification of Diet in Renal Disease Study Group. A more accurate method to estimate glomerular filtration rate from serum creatinine: A new prediction equation. Ann Intern Med. 1996; 130(6): 461-470.
11. Levey AS, Greene T, Kusek JW, Beck GJ, MDRD Study Group. A simplified equation to predict glomerular filtration rate from serum creatinine. J Am Soc Nephrol. 2000; 11: 8-28.
12. Lin J, Knight EL, Hogan ML, Singh AK: A comparison of prediction equations for estimating glomerular filtration rate in adults without kidney disease. J Am Soc Nephrol. 2003; 14: 2573-2580.
13. Kabir E, Rahman M. Estimated GFR in healthy adults in a village in Savar, Dhaka [MD Thesis]. [Dhaka]: Dhaka University; 2010.
14. Bhuyian AQ. Validation of predictive equations for estimation of glomerular filtration rate in a selective section of Bangladeshi population. [MD Thesis]. [Dhaka]: Bangabandhu Sheikh Mujib Medical University; 2011.