

Correlation Between eAG Values Calculated from HbA1c Values Obtained from Three Different Techniques and Fasting Plasma Glucose Levels for Diagnosis and Prognosis of Diabetes

Omkar Kadhane^{1*}, Usha Mukundan¹, Shirish Malvankar², Nikhil Ranade²

¹Department of Biotechnology, Ramniranjan Jhunjhunwala College, Ghatkopar (West), Mumbai, Maharashtra, India

²Hematology & Biochemistry Department, Pyramid GroupLab, New Panvel, Maharashtra, India

Abstract

The objective of the present study was to correlate estimated average glucose (eAG) values calculated from HbA1c values obtained from Tosoh TLC-723 G8 based on cation exchange based HPLC, TBA 12 FR enzymatic fructosyl peptide oxidase (FPOX) method and D10 HbA1c analyser Bio Rad Laboratories (USA) with fasting plasma glucose (FPG) levels by hexokinase method for diagnosis and prognosis of diabetes.

A total of 300 randomly selected patient samples were analysed for FPG by hexokinase method and HbA1c values were estimated by using Tosoh TLC-723 G8 analyser based on cation exchange HPLC, enzymatic FPOX (Manufacture by Seikisui Medical Co. Ltd., Japan) programmed on TBA 12 FR biochemistry analyser and D10 HbA1c analyser Bio Rad Laboratories (USA). The eAG values were calculated using Nanthan's regression equation for both HbA1c values. The correlation between FPG, HbA1c and eAG values has been done by Pearson correlation (r) and regression analysis was done by SPSS software.

The correlation was good in entire data and poor in differentiated groups. Male data has shown good correlation between FPG and eAG as compared to female data with higher mean levels of FPG, eAG and HbA1c values. Both HPLC methods have shown closer correlation between eAG values calculated from it and FPG values from which Tosoh HLC-723 G8 has shown closer correlation.

The overall correlation between eAG and FPG was good in entire data but mean value difference was found to be slightly high. So for diabetes diagnosis, HbA1c values along with calculated eAG value along with FPG values are recommended as per the American Diabetes Association (ADA) guidelines. As both the HPLC methods have shown good correlation between eAG and FPG values, we recommend that HbA1c values and eAG values calculated from it has to be used for diagnosis and prognosis of diabetes along with FPG values and other relevant clinical findings of patients. Tosoh HLC-723 G8 HPLC HbA1c analyser could be preferred technique for HbA1c estimation due to closer correlation with FPG values and true separation of labile and stable fraction of HbA1c. The use of HbA1c values alone for diagnosis and prognosis of diabetes still need multicentre studies with large sample size in different population.

Keywords: estimated average glucose (eAG), HbA1c, fasting plasma glucose (FPG), diabetes

*Author for Correspondence E-mail: rkomkar@gmail.com

INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder marked by hyperglycemia with alteration in normal status of carbohydrate, protein and fat metabolism resulting from defects in insulin secretion, insulin action or both. Diabetes mellitus is associated with retinopathy, nephropathy, peripheral

neuropathy, cardiovascular disorder and other lethal complications of organ system [1]. According to the International Diabetes Federation (IDF) 2013, prevalence of type 2 diabetes mellitus is increasing in epidemic proportions worldwide and developing countries like India has alarming situation for this disease. The number of people living with

diabetes is expected to rise from 382 million in 2013 to 592 million by 2035. As per the IDF report, India alone has more than 65 million people living with diabetes and this number is expected to reach 109 million by 2030.

An accurate measurement of blood glucose and evaluation of blood glucose control is helpful to assess the efficiency of particular therapy related to diabetes mellitus. Before 2010, all diabetes societies recommended blood glucose analysis as the exclusive method to diagnose diabetes [3]. But it was year 2009, when an International Expert Committee that included representatives of the American Diabetes Association (ADA), the International Diabetes Federation (IDF), and the European Association for the Study of Diabetes (EASD) recommended the use of the A1C test to diagnose diabetes, with a threshold of $\geq 6.5\%$ (48 mmol/mol), and the ADA adopted this criterion in 2010.

The clinical significance of HbA1c was supported by the Diabetes Control and Complications Trial (DCCT) and the United Kingdom Prospective Diabetes Study (UKPDS) [1]. According to a report published by the ADA in 2010, criteria for diagnosis of diabetes are as follows:

1. **HbA1c $\geq 6.5\%$:** The test should be performed in a laboratory using a method that is NGSP certified and standardized to the DCCT assay.* OR
2. **Fasting plasma glucose (FPG) ≥ 126 mg/dl (7 mmol/l):** Fasting is defined as no caloric intake for at least 8 h.* OR
3. **2-h plasma glucose ≥ 200 mg/dl (11.1 mmol/l) during an oral glucose tolerance test (OGTT):** The test should be performed as described by the World Health Organization, using a glucose load containing the equivalent of 75 g anhydrous glucose dissolved in water.* OR
4. In a patient with classic symptoms of hyperglycemia or hyperglycemic crisis, a random plasma glucose ≥ 200 mg/dl (11.1 mmol/l).

(*In the absence of unequivocal hyperglycemia, criteria 1–3 should be confirmed by repeat testing).

HbA1c is now generally accepted as the single, most prominent and independent

parameter of metabolic control, a risk factor for the development of diabetic complications and is widely used as treatment goal in disease management [2]. The HbA1c value indicates a patient's average blood glucose level during the previous 60–90 days. As recommended by the ADA, HbA1c test can be performed at least two times a year in patient with diabetes who are meeting treatment goals with stable glycemic control and quarterly in patients with diabetes whose therapy has changed or who are not meeting glycemic goals.

Being a 'gold standard' test for diagnosis of diabetes, HbA1c value has prognostic potential also. HbA1c is useful biomarker for long-term glycemic control as well as a good predictor of lipid profile which eventually can predict the risk of cardiovascular complication in diabetes patients. In a study done by Khan *et al.* in 2007, on 1011 type 2 diabetic patients, HbA1c exhibited direct correlations with cholesterol, triglycerides, and low density lipoprotein cholesterol and inverse correlation with high-density lipoprotein cholesterol [4]. There was a linear relationship between HbA1c and dyslipidemia as the levels of serum cholesterol and triglycerides were significantly higher and that of high-density lipoprotein cholesterol were significantly lower in patients with worse glycemic control as compared to patients with good glycemic control.

More than 20 different assay methods based on different physical, chemical or immunological characteristic of the glycated hemoglobin and different analytical principles, such as immunoturbidimetry, cation exchange chromatography, and high-performance liquid chromatography (HPLC) have been used to measure HbA1c. Among all methods, measurement of HbA1c by HPLC became gold standard and has been appointed as the reference method for HbA1c assay by the National Glycohemoglobin Standardization Program (NGSP) in USA [5].

The HbA1c values are directly proportional to blood sugar value in diabetes mellitus. A diabetic patient with good glucose control has HbA1c level either in the reference range or close to it. Six percent HbA1c value is equals to 135 mg/dl of mean plasma glucose. For

every increase in HbA1c of 1%, mean plasma glucose increases by 35 mg/dl. Many studies have shown that A1C is an index of mean plasma glucose over the preceding weeks to months. Many studies have proved that HbA1c is an index of mean plasma glucose over the preceding weeks to months.

HbA1c does not reflect glycemic control over last three months as it claimed as well as HbA1c value as a sole tool for assessing the diabetic status cannot be used clinically. Since level of HbA1c may get affected due to alteration in red blood cell life span, and presence of different types of hemoglobinopathies, it may give rise to false results [6].

However, combination of FPG, OGTT and HbA1c may be the useful battery of test in diagnosis of diabetes which is also recommended by the WHO. The relationship between the mean blood glucose level and HbA1c value has been investigated in many studies with different equations. Nathan's regression equation which is recommended by the ADA, convert HbA1c values into eAG by the following formula:

$$\begin{aligned} \text{eAG (mg/dl)} &= 28.7 \times \text{HbA1C} - 46.7 \\ \text{(eAG (mmol/l))} &= 1.59 \times \text{HbA1C} - 2.59. \end{aligned}$$

It is in this context that the present study was planned to correlate the performance of HbA1c values obtained from three different techniques as compared to FPG for screening of three different groups of normal, prediabetes and diabetes as defined by FPG values. The technologies involved in the current study are cation exchange HPLC method from Tosoh automated Glycohemoglobin analyser HLC-723 G8 (manufactured in Japan) and with Enzymatic FPOX method from Norudia N HbA1c detection (Manufacture by Seiksui Medical Co. Ltd., Japan) on fully automated TBA 120 FR instrument from Toshiba, Japan.

These two technologies are correlated with values obtained from D10 HbA1c analyser Bio Rad Laboratories (USA) and FPG values obtained by FPG kit based on hexokinase method from Randox Laboratories (USA). This study is essential in understanding the

correlation between HbA1c and diabetes prognosis and diagnosis.

MATERIALS AND METHODS

This study was done at Pyramid GroupLab (PGL), New Panvel, Maharashtra, India. PGL receives clinical specimens from throughout the India from their logistics network in specially designed specimen transport box and Test Requisition Form duly signed by the patient. The timeline of study was from February 2011 to June 2013.

In this study, 300 samples were selected from daily work load at PRL, which came as suspected case of diabetes (1 or 2) and for routine metabolic management of diabetes. For these 300 samples we have chosen patients who have done overnight fasting (at least 8 h) before collecting samples. Patients from all age groups from 23 year to 79 years were included in the study.

Venous blood specimens were collected in vacutainer containing Ethylene Diamine Tetra Acetic Acid (EDTA) as an anticoagulant (BD Vacutainer with purple colour cap). After collection and prior to analysis, these specimens were mixed gently by inversion to ensure homogeneity. The specimens from different parts of country were collected and packed in specially designed, pre barcoded specimen transport box containing cool pack for temperature control.

Once the specimen reach the PGL, preliminary check was done for temperature and nature of sample. After preliminary checks sample information was entered in the Laboratory Management Software, sample was barcoded and forwarded to different sections of the laboratory.

In our study, we have instructed PGL collection centres to measure FPG values by Randox glucose estimation kit by hexokinase method of collected samples at collection site itself. We have collected approximately 2 ml of EDTA whole blood from each individual. Once process of patient data entry and barcoding was done, these samples were aliquoted equally in two tubes.

The first aliquot was sent to satellite laboratory of PGL for HbA1c analysis by HPLC method (i.e., Bio Rad D10 HbA1c analyser). The second aliquot was processed in PGL. We have simultaneously processed sample for two techniques. First samples were processed on Tosoh automated Glycohemoglobin analyser HLC-723 G8. The BD vacutainer containing EDTA whole blood was directly processed by inserting sample tube in sample rack and pushing the start button. The optimum sample volume was 2 ml and minimum was 50 μ l.

For samples having less quantity as well as samples showing "area high" flag was diluted (e.g. 1:100, 1:200 as per requirement) manually with G8 variant dilution solution for further analysis. The values were obtained as SA1c (Stable A1c) in % and were recorded on software as well as printout generated by instrument on thermal paper.

Once samples were processed on Tosoh automated Glycohemoglobin analyser HLC-723 G8, the same samples were further processed for HbA1c detection by Enzymatic FPOX method from Norudia N HbA1c reagents (Manufacture by Seikisui Medical Co. Ltd., Japan) on fully automated TBA 120 FR instrument from Toshiba, Japan. EDTA whole blood sample was centrifuged for 5 min at 800 g and after that from lower layer of blood cells, 25 μ l of red blood cells were taken in 1.5 ml vial. About 500 μ l of Norudia N HbA1c pretreatment solution was added in the vial and mixed well.

This pretreated sample was used for further analysis on fully automated TBA 120 FR instrument from Toshiba, Japan. Remaining samples were stored at 2–8 °C for 14 days. The HbA1c results were expressed in % as well as μ mol/l as per NGSP guidelines. The results were recorded by TBA 120 FR software and printed on paper by dot matrix printer connected to instrument. In both the analytical technologies, erroneous results were repeated and if error remains consistent then patient history and fresh sample was requested.

Before analysing patient samples, both the methods were calibrated using calibrator level 1 and level 2 provided by the manufacturer and the validity of calibration was checked by using control level 1 and level 2 provided by the manufacturer. As per the ADA guidelines for diagnosis of diabetes, FPG value \geq 126 mg/dl is considered to be diabetic range. In view with this guideline, we have categorised obtained values in three groups on the basis of their FPG values—one below 126 mg/dl, second 126–200 mg/dl and third above 200 mg/dl.

As per the ADA guidelines, first group should fall in nondiabetic range, second should fall in pre-diabetic range and third should be in diabetic individuals range. The correlation between FPG, HbA1c and eAG values has been done by Pearson correlation (*r*) and regression analysis was done by SPSS (version 22) software.

RESULTS

Total 300 patients were included in the study, among which four samples were rejected due to gross hemolysis of sample. Hence, 296 samples were analysed for this study among which 116 (39%) patients were female and 180 (61%) patients were male. The mean age of patients included in the study was 51.31 ± 13.40 years (range 23–79).

With FPOX method, results were expressed in HbA1c percentage as well as mmol/l as per the IFCC guidelines along with concentration of hemoglobin in μ mol/l and with HPLC methods, results were expressed as SA1c (Stable A1c) in % as well as mmol/l as per the IFCC guidelines. In this study, calibration was done daily before assessing samples and controls. After calibration, validity of calibration was checked by running control level 1 and level 2 for both the methods.

On the successful validation of calibration, samples were processed for HbA1c estimation. Also we have given standard guidelines to inculcate IFCC standard for outsourced samples to satellite laboratory for FPG estimation. The FPG results were

expressed in mg/dl and mmol/l as recommended by the IFCC and ADA.

The eAG values were calculated with HbA1c values obtained from FPOX method and HPLC method by Nathan's regression equation, i.e., 'eAG (mg/dl) = 28.7 × HbA1C - 46.7' (eAG [mmol/l] = 1.59 × HbA1C - 2.59) which is recommended by the ADA.

The data generated in this study were distributed in three groups on the basis of their FPG values—one <126 mg/dl, second 126–200 mg/dl, and third >200 mg/dl. Maximum number of samples, i.e., 118 samples have given values between 126–200 mg/dl, followed by 92 and 86 number of samples has given values <126 mg/dl and >200 mg/dl, respectively. Similar trend was observed in female and male samples involved in the study (Table 1).

In female samples, a total of 36, 55, and 25 number of samples have shown values of <126 mg/dl, 126–200 mg/dl and >200 mg/dl, respectively; whereas in male samples, about 56, 63 and 61 number of samples have shown values of <126 mg/dl, 126–200

mg/dl, and >200 mg/dl, respectively (Figure 1).

In our study we have reported six correlation and regression analysis for each group. HbA1c values obtained from three techniques and eAG values calculated with Nanthan's equation were correlated with FPG values. We have observed that entire data has good correlation values and significant different ($p < 0.05$) as compared to three differentiated groups. All six correlation analysis has shown poor correlation in normal individuals and individuals with higher values of FPG (Table 2).

Both HPLC techniques have shown good correlation in all the groups as compared to FPOX method. Male data has shown good correlation between FPG and HbA1c and corresponding eAG as compared to female data. We observed that mean levels of FPG, eAG, and HbA1c were higher in male than in female. Statistical difference was found significant in male and female eAG, HbA1c values obtained by FPOX method and HPLC method. Overall graphical correlation has been indicated in figure 2 (a-f) to 7 (a-f).

Table 1: Pearson's Correlation Test Data by SPSS Software.

CORRELATION ANALYSIS	Entire data		< 126 mg/dL		126 - 200 mg/dL		>200 mg/dL	
	r	R square	r	R square	r	R square	r	R square
FPG Vs HbA1c % (Tosoh G8 by HPLC method)	0.922	0.850	0.641	0.411	0.852	0.726	0.608	0.370
FPG Vs eAG (mg/dL) (Tosoh G8 by HPLC method)	0.922	0.850	0.641	0.411	0.852	0.726	0.608	0.370
FPG Vs HbA1c % (Seikisui Norudia HbA1c by FPOX method)	0.852	0.726	0.432	0.187	0.565	0.319	0.504	0.254
FPG Vs eAG (Seikisui Norudia HbA1c by FPOX method)	0.852	0.726	0.432	0.187	0.565	0.319	0.504	0.254
FPG Vs HbA1c % (Bio Rad D-10 by HPLC method)	0.925	0.856	0.727	0.529	0.881	0.777	0.597	0.357
FPG Vs eAG (mg/dL) (Bio Rad D-10 by HPLC method)	0.925	0.856	0.727	0.529	0.881	0.777	0.597	0.357
CORRELATION ANALYSIS	Entire Female data		Entire Male data					
	r	R square	r	R square				
FPG Vs HbA1c % (Tosoh G8 by HPLC)	0.896	0.803	0.932	0.868				
FPG Vs eAG (mg/dL) (Tosoh G8 by HPLC)	0.896	0.803	0.932	0.868				
FPG Vs HbA1c % (Seikisui Norudia HbA1c by FPOX method)	0.835	0.698	0.861	0.741				
FPG Vs eAG (Seikisui Norudia HbA1c by FPOX method)	0.835	0.698	0.861	0.741				
FPG Vs HbA1c % (Bio Rad D-10 by HPLC)	0.906	0.821	0.932	0.569				
FPG Vs eAG (mg/dL) (Bio Rad D-10 by HPLC)	0.906	0.821	0.932	0.569				

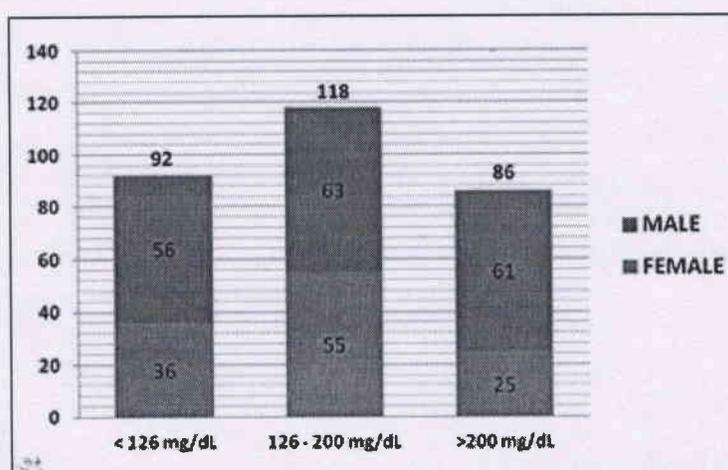


Fig. 1: Number of Samples Distributed in the Defined Groups.

Table 2: Statistical Comparison of Glycemic Parameter Levels in Differentiated Groups with Standard Error Mean (SEM), Standard Deviation (SD) and Minimum–Maximum Range.

	Entire Data (N = 296)			Values < 126 mg/dL (N=92)		
	Mean (Min - Max)	Mean (± SEM)	SD	Mean (Min - Max)	Mean (± SEM)	SD
Age	51.31 (23-79)	51.31 (±0.78)	13.40	49.76 (23-74)	49.76 (±1.55)	14.86
FPG (mg/dL)	174.95 (71.31-440.12)	174.95 (±4.68)	80.57	100.64 (71.31-124.57)	100.64 (±1.55)	14.82
HbA1c % (Tosoh G8 by HPLC method)	7.94 (4.1-15.8)	7.94 (±0.14)	2.43	5.74 (4.1-7.2)	5.74 (±0.08)	0.75
eAG (mg/dL) (Tosoh G8 by HPLC method)	181.1 (70.97-406.76)	181.1 (±4.06)	69.79	117.98 (70.97-159.94)	117.98 (±2.24)	21.49
HbA1c % (Seikisui Norudia HbA1c by FPOX method)	8.28 (3.93-19.17)	8.28 (±0.15)	2.57	6.12 (3.93-9.48)	6.12 (±0.1)	0.94
eAG (Seikisui Norudia HbA1c by FPOX method)	190.93 (66.09-503.48)	190.93 (±4.28)	73.62	128.87 (66.09-225.38)	128.87 (±2.8)	26.87
HbA1c % (Bio Rad D-10 by HPLC method)	8.1 (4.2-15)	8.1 (±0.14)	2.37	5.96 (4.2-7.1)	5.96 (±0.07)	0.65
eAG (mg/dL) (Bio Rad D-10 by HPLC method)	185.83 (73.84-383.8)	185.83 (±3.95)	68.04	124.38 (73.84-157.07)	124.38 (±1.94)	18.63
	Values 126 - 200 mg/dL (N= 118)			Values 200 mg/dL (N= 86)		
	Mean (Min - Max)	Mean (± SEM)	SD	Mean (Min - Max)	Mean (± SEM)	SD
Age	55.39 (29-77)	55.39 (±1.04)	11.28	47.36 (28-79)	47.36 (±1.41)	13.04
FPG (mg/dL)	153.86 (127-199.56)	153.86 (±1.84)	19.95	283.36 (200.31-440.12)	283.36 (±6.16)	57.12
HbA1c % (Tosoh G8 by HPLC method)	7.38 (5.8-9.8)	7.38 (±0.08)	0.82	11.05 (8.3-15.8)	11.05 (±0.2)	1.88
eAG (mg/dL) (Tosoh G8 by HPLC method)	165.14 (119.76-234.56)	165.14 (±2.15)	23.39	270.5 (191.51-406.76)	270.5 (±5.81)	53.89
HbA1c % (Seikisui Norudia HbA1c by FPOX method)	7.77 (5.24-10.61)	7.77 (±0.09)	0.93	11.29 (6.1-19.17)	11.29 (±0.27)	2.47
eAG (Seikisui Norudia HbA1c by FPOX method)	176.29 (103.69-257.81)	176.29 (±2.47)	26.78	277.42 (128.37-503.48)	277.42 (±7.64)	70.84
HbA1c % (Bio Rad D-10 by HPLC method)	7.54 (6.1-9.7)	7.54 (±0.07)	0.78	11.17 (8.5-15)	11.17 (±0.2)	1.82
eAG (mg/dL) (Bio Rad D-10 by HPLC method)	169.67 (128.37-231.69)	169.67 (±2.05)	22.28	273.74 (197.25-383.8)	273.74 (±5.65)	52.38
	Entire Female Data (N = 116)			Entire Male Data (N = 180)		
	Mean (Min - Max)	Mean (± SEM)	SD	Mean (Min - Max)	Mean (± SEM)	SD
Age	51.01 (25-77)	51.01 (±1.31)	14.13	51.5 (23-79)	51.5 (±0.96)	12.94
FPG (mg/dL)	164.02 (71.31-360.97)	164.02 (±6.5)	69.97	181.99 (74.55-440.12)	181.99 (±6.42)	86.18
HbA1c % (Tosoh G8 by HPLC method)	7.62 (4.1-14.4)	7.62 (±0.2)	2.15	8.14 (4.1-15.8)	8.14 (±0.19)	2.58
eAG (mg/dL) (Tosoh G8 by HPLC method)	171.87 (70.97-366.58)	171.87 (±5.74)	61.81	187.05 (70.97-406.76)	187.05 (±5.52)	74.04
HbA1c % (Seikisui Norudia HbA1c by FPOX method)	8.03 (3.93-19.17)	8.03 (±0.23)	2.43	8.44 (4.46-16.45)	8.44 (±0.2)	2.64
eAG (Seikisui Norudia HbA1c by FPOX method)	183.75 (66.09-503.48)	183.75 (±6.47)	69.69	195.56 (81.3-425.42)	195.56 (±5.66)	75.88
HbA1c % (Bio Rad D-10 by HPLC method)	7.79 (4.2-13.9)	7.79 (±0.2)	2.12	8.3 (4.6-15)	8.3 (±0.19)	2.50
eAG (mg/dL) (Bio Rad D-10 by HPLC method)	176.91 (73.84-352.23)	176.91 (±5.66)	60.95	191.57 (85.32-383.8)	191.57 (±5.35)	71.82

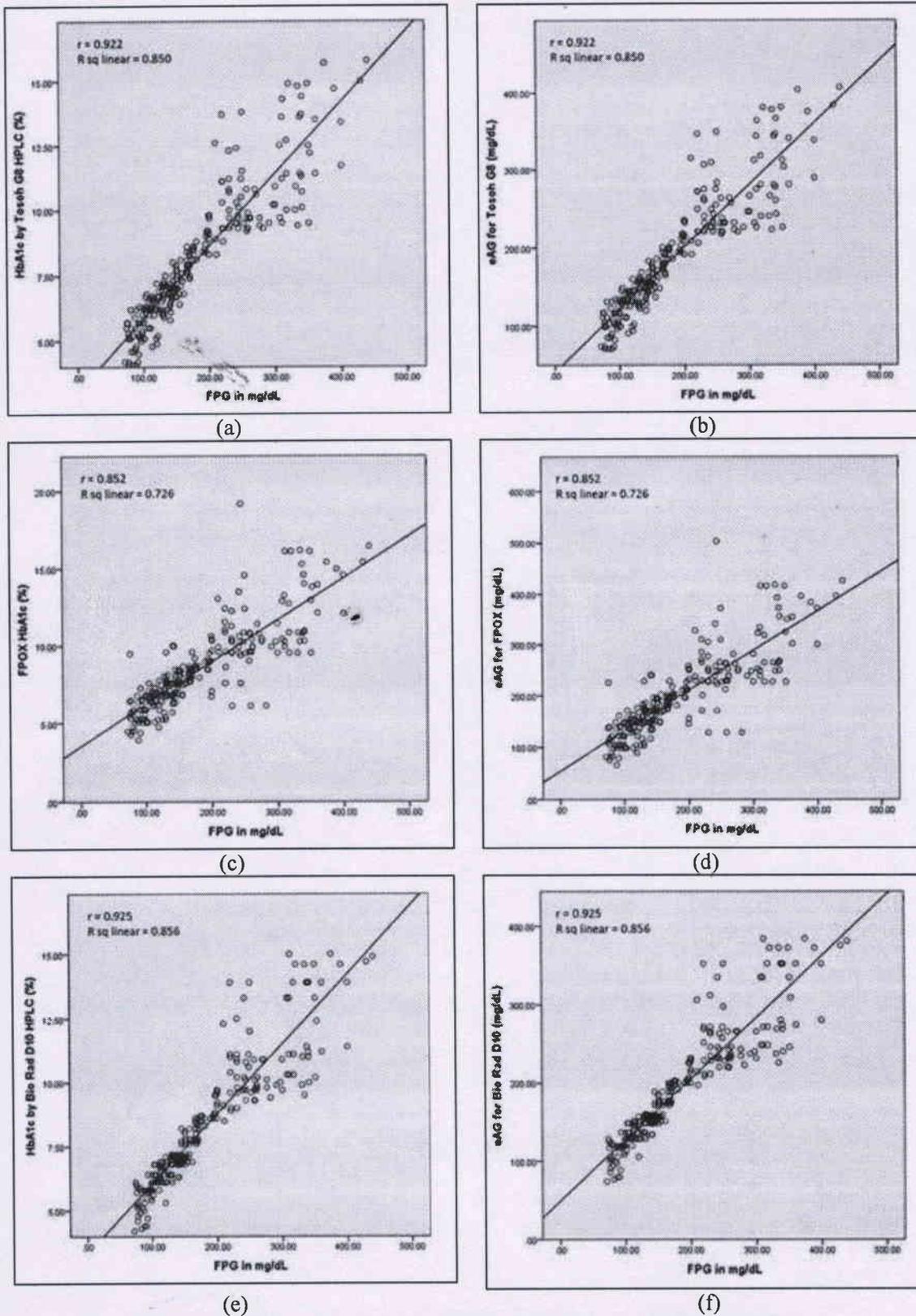


Fig. 2 (a-f): Correlation Plot for "Entire Data" with r and r Square Values.

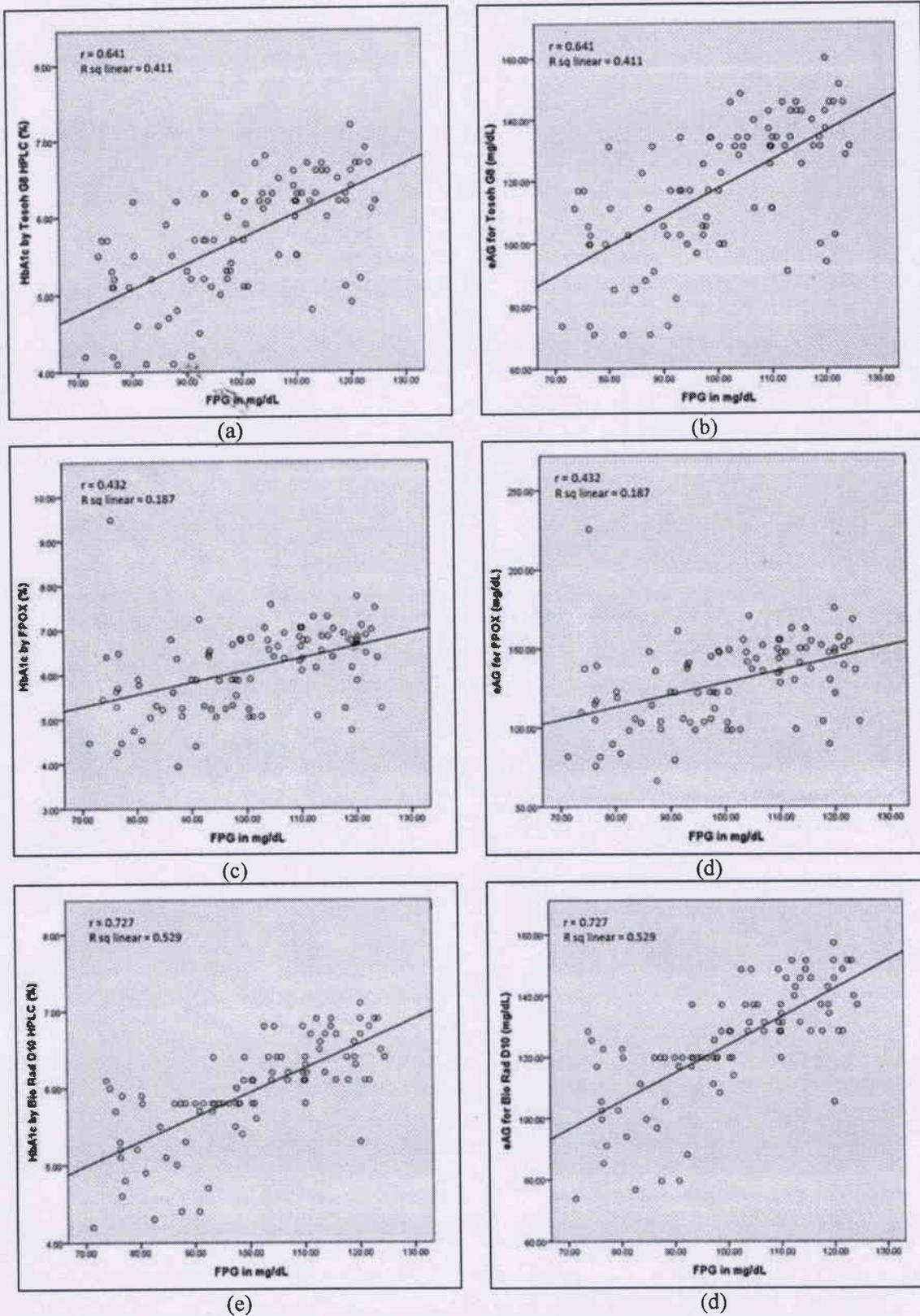


Fig. 3 (a-f): Correlation Plot for Samples having Values “<126 mg/dl” with r and r Square Values.

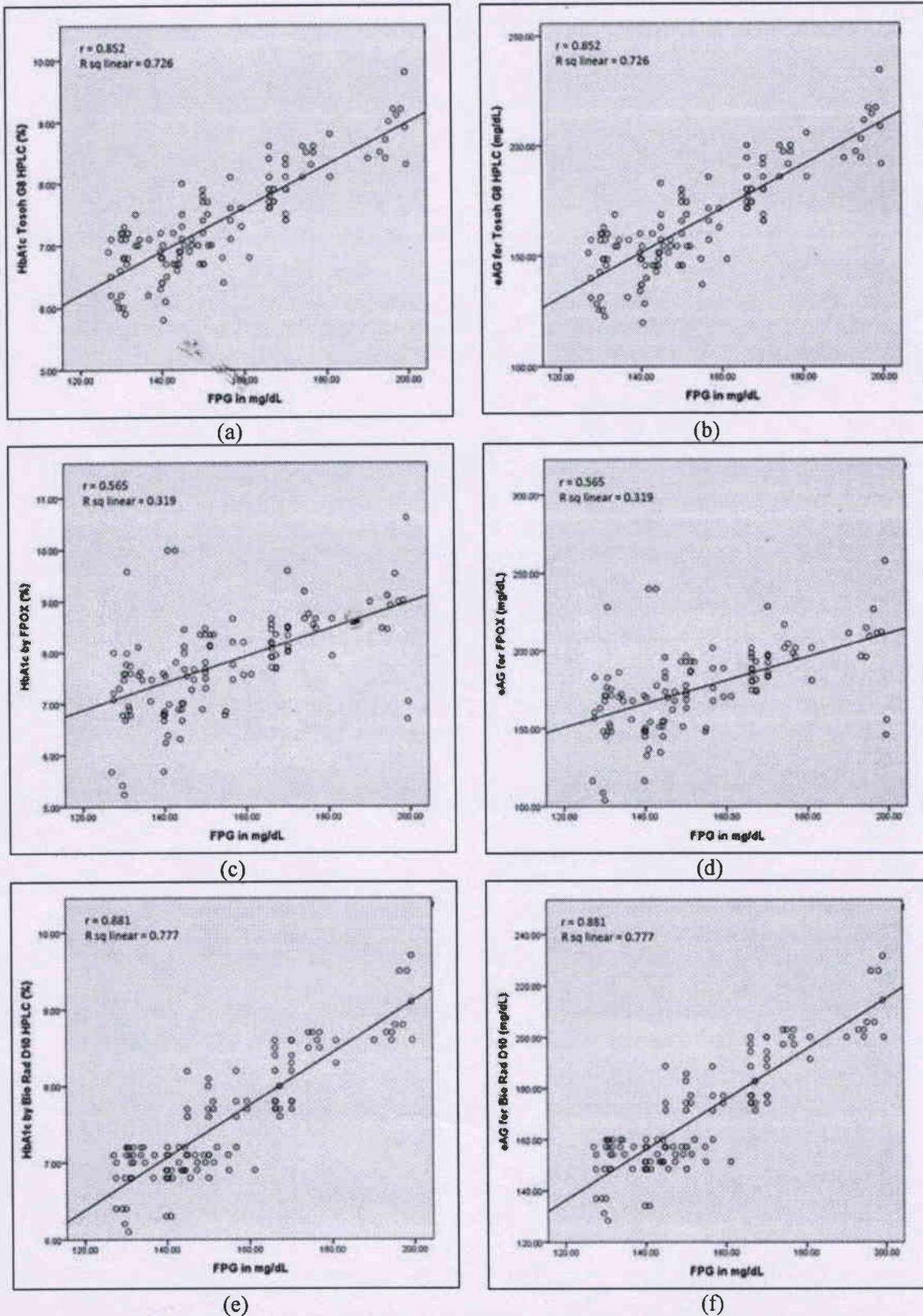


Fig. 4 (a-f): Correlation Plot for Samples having Values Between "126-200 mg/dl" with r and r Square Values.

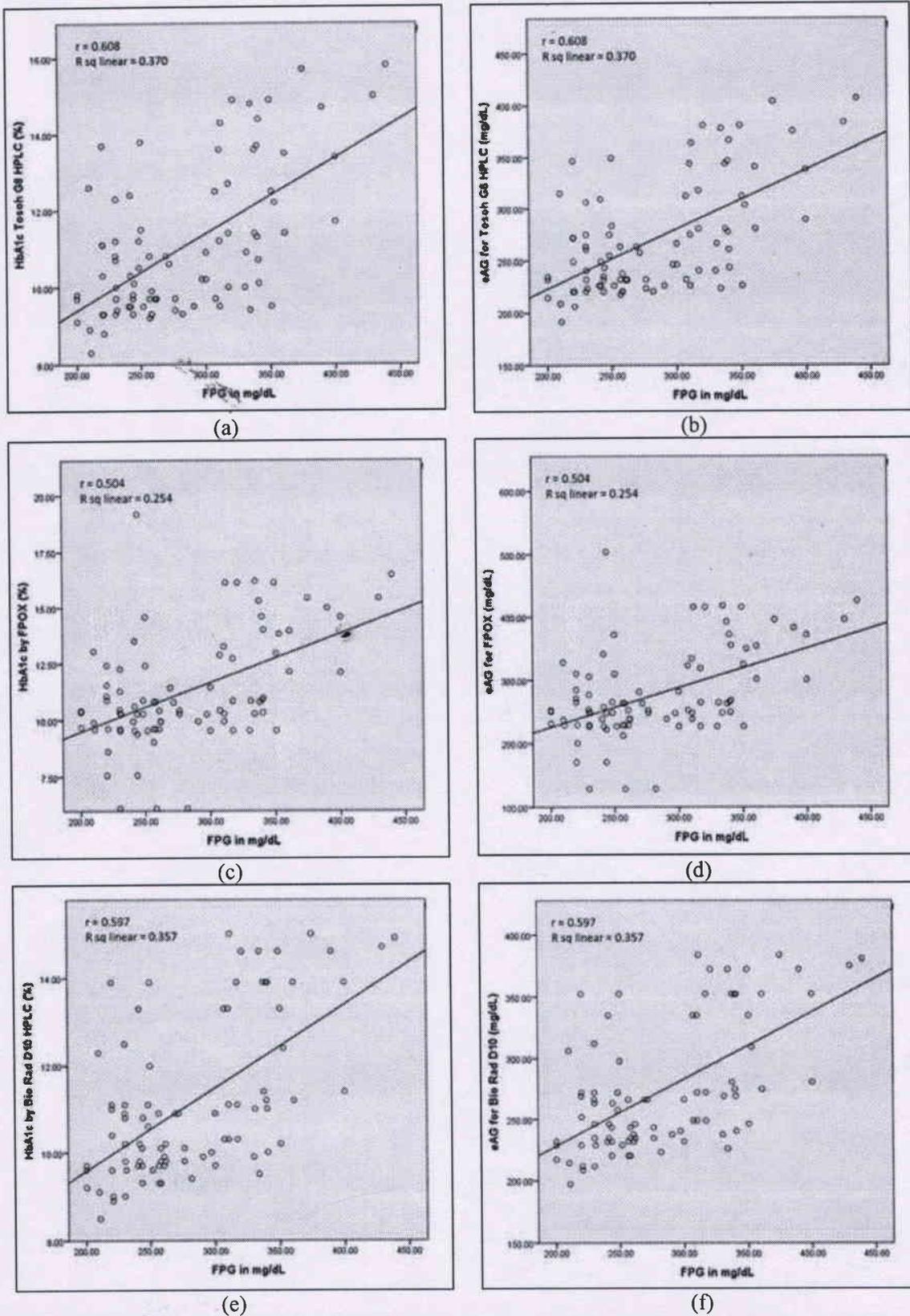


Fig. 5 (a-f): Correlation Plot for Samples having Values ">200 mg/dl" with r and r Square Values.

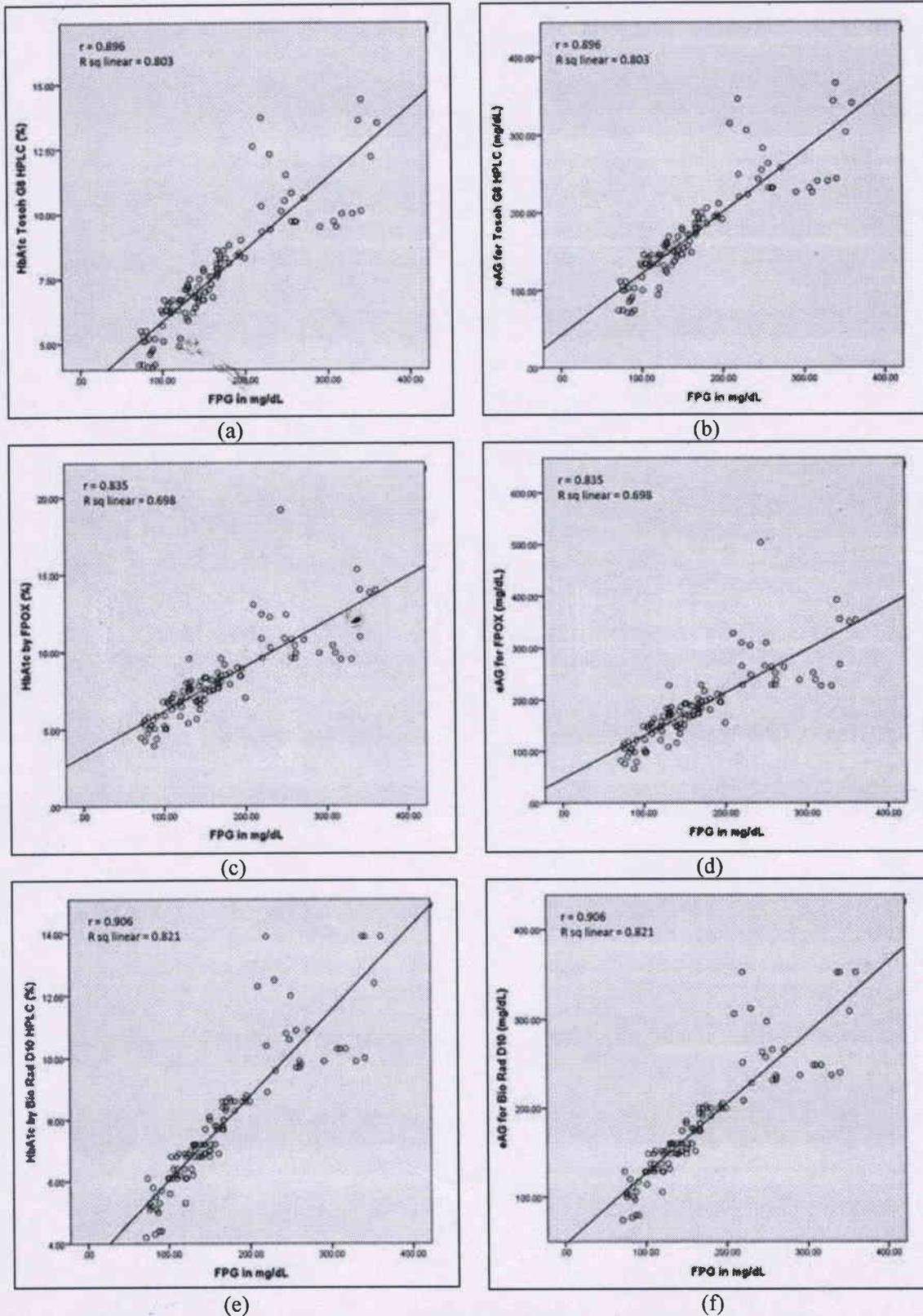


Fig. 6 (a–f): Correlation Plot for “Entire FEMALE Data” with r and r Square Values.

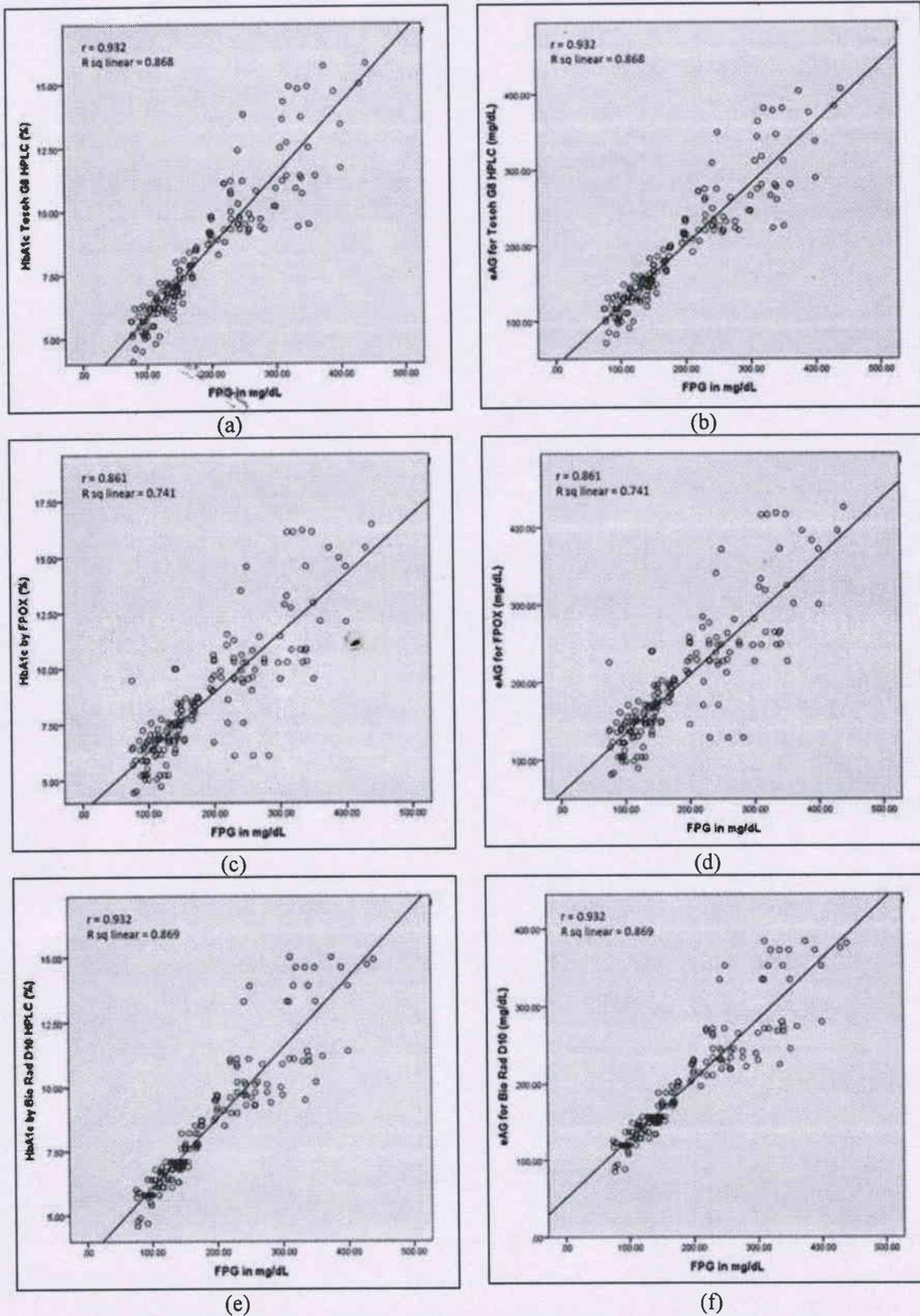


Fig. 7 (a-f): Correlation Plot for "Entire MALE Data" with r and r Square Values.

DISCUSSION

Still one of the remarkable issues with HbA1c measurement is risk of decreasing a patient's glycemic control; when a patient's HbA1c measurement is lower than those previous results, he/she might become confused and lead treatment to change diet which could negatively impact patient's metabolic control [7]. The diabetes diagnostic guidelines fixed by the ADA which is derived from reports of Diabetes Control and Complications Trial (DCCT) and the U.K. Prospective Diabetes Study (UKPDS) has shown acceptance worldwide.

The Nanthan's equation describing relationship between HbA1c and eAG is used by healthcare providers and their patients in interpreting HbA1c values in units similar to those that the patients see regularly through self-monitoring worldwide [8]. In our study we used the same mathematical relationship equation and found the eAG values obtained in entire data by both HPLC techniques (i.e., $r = 0.922$ [Tosoh G8] and $r = 0.925$ [Bio Rad D10]). The eAG values obtained from HbA1c values by both HPLC methods have shown closer mean levels with FPG values. Tosoh HLC-723 G8 has shown closer correlation amongst all three compared techniques.

The eAG values were slightly higher than FPG values in all the groups, and interchangeability of eAG values obtained from both HPLC methods and FPG were significant as per study. Still we recommend that similar study has to be done with multicentre analysis and bigger sample size to obtain clinically meaningful data. Overall, the data analysed in this study showed good correlation and significant difference between eAG and FPG. The correlation between eAG and FPG level in the entire group disappeared when samples were differentiated in subgroups as per their FPG level.

As patient's level of glucose control worsened, good correlation was observed. In this study we also differentiated same data on the basis of gender. Both female and male data has shown higher eAG values as compared to FPG values. Females had lower eAG and FPG levels than males.

In diabetes diagnosis and prognosis, both the values play an important role and interchangeability of these values still has to make a clinically meaningful mark with strong studies. It is recommended strategy to use eAG level together with HbA1c values but clinical usefulness of eAG is not clear [9]. So for diabetes diagnosis, HbA1c values along with calculated eAG value along with FPG values are recommended as per the ADA guidelines.

As both HPLC methods have shown good correlation between eAG and FPG values, we recommend HbA1c values and eAG values calculated from it has to be used for diagnosis and prognosis of diabetes along with FPG values and other relevant clinical findings of patients. Recently introduced Tosoh HLC-723 G8 HPLC HbA1c analyser could be preferred technique for HbA1c estimation due to closer correlation with FPG values and true separation of labile and stable fraction of HbA1c. The use of HbA1c values alone for diagnosis and prognosis of diabetes still need multicentric studies with large sample size in different population.

REFERENCES

1. Sarmah D, Sharma B. Importance and Status of HBA1C in T2DM and its Indian Perspective. *Asian J Biomed Pharma Sci.* 2012; 2(12): 1-10p.
2. Farzana Yasmeen, Asim Mumtaz, Saleem-Uz-Zaman Adha Mi and sajid a. Qureshi. Comparison of cation exchange hplc and immunoturbidimetric Method for determination of hba1c; *Biomedica* . 2011; 27 (Jul. - Dec): 161-165p.
3. Sacks DB, Brunz DE, Goldstein DE, *et al.* Guidelines and recommendations for laboratory analysis in the diagnosis and management of diabetes mellitus. *Clin Chem.* 2002; 48: 436-72p.
4. Khan HA, Sobki SH, Khan SA. Association between glycaemic control and serum lipids profile in type 2 diabetic patients: HbA1c predicts dyslipidaemia. *Clin Exp Med.* 2007; 7: 24-9p.
5. Sema Genc,1 Beyhan Omer,1 Esra Aycan-Ustyol,1 Nurhan Ince,2 Fatih Bal,1 and Figen Gurdoll; Evaluation of Turbidimetric Inhibition Immunoassay

- (TINIA) and HPLC Methods for Glycated Haemoglobin Determination; *Journal of Clinical Laboratory Analysis*. 2012; 26: 481–485p.
6. Sultanpur CM, Deepa K, Kumar SV. Comprehensive review on hba1c in diagnosis of diabetes mellitus. *Int J Pharma Sci Rev Res*. 2010; 3(2): 119–22p.
 7. R. Hanas and W. G. John. 2013 update on the worldwide standardization of the HbA1c measurement. *DIABETIC Medicine*. 2013; 30: 885–886p.
 8. Nathan DM, Turgeon H, Regan S. Relationship between glycated haemoglobin levels and mean glucose levels over time. *Diabetologica*. 2007; 50: 2239–44p.
 9. Leslie RD, Kilpatrick ES. Translating the A1C assay into estimated average glucose values: response to Nathan et al. *Diabetes Care*. 2009; 32: e11.

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