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Free iron status & insulin resistance in type 2 diabetes mellitus: Analyzing the probable role of a peanut protein

Sir,

South Asian population is known to have an increased predisposition to type 2 diabetes mellitus (T2DM), which turns out to be an important health concern in this Region[1]. As per an earlier report about 11.7 per cent people of Kolkata, West Bengal, suffered from T2DM and the prevalence was on a rise[2]. Anaemia is also present in the Region as a significant public health problem, having a prevalence of greater than 40 per cent in South Asia[3]. However, the actual status of iron remains unclear because of extensive prevalence of haemoglobinopathies, possible genetic mutations contributing to iron overload, indiscriminate over-the-counter use of iron pills and traditional formulations containing undefined concentrations of iron. Higher heme iron intake and increased body iron stores were found to be significantly associated with a greater risk of T2DM[4,5]. Patients suffering from haemoglobinopathies or undergoing repeated blood transfusions also suffer from secondary iron loading disorder[6].

Insulin influences the iron uptake and storage in cells by increasing the cell surface transferrin receptors[7]. Whether a patient with diabetes has excess iron due to increased insulin resistance still remains an unanswered question. Insulin resistance has been shown to have an association with chronic kidney diseases[8,9]. Iron accumulation has been reported in the proximal renal tubules in diabetic nephropathy[10]. Iron in its free form[11,12] *i.e.* in non-transferrin bound form is known to induce oxidation of biomolecules and in the formation of reactive oxygen species. We, therefore, studied the free iron status in patients with T2DM and compared with healthy individuals and to find a suitable biocompatible reagent which can bind the free iron.

A cross-sectional, pilot study was conducted on consecutive patients attending the General Medicine outpatients department of M.R. Bangur Hospital, Kolkata, India, between August 2012 and February 2014. Fasting blood and urine samples (10 ml each) were collected from 111 patients with T2DM (53.7 ± 12.4 yr, M:F 60 : 51) and 30 healthy controls (75.6 ± 2.5 yr, M:F 8:7). Approval of ethical committee of Institute of Post Graduate Medical Education & Research (IPGMER), Kolkata, was obtained prior to the study.

Those *(i)* having anaemia, *(ii)* suffering from any form of haemoglobinopathy, *(iii)* who were on iron therapy within one year, *(iv)* having non-diabetic kidney disease, *(v)* having febrile illness, *(vi)* having benign prostatic hypertrophy or prostatic cancer, *(vii)* having urinary tract infection, or *(viii)* with uncontrolled hypertension, were excluded. The total iron analysis was done by Ferrozine method[13] and free iron by HPLC[14]. Fasting plasma glucose was estimated by glucose oxidase-peroxidase (GOD-POD) method[15], serum insulin by ELISA monobind kit and creatinine analysis was done by a kinetic assay[15] of Jaffe's involving alkaline solution of sodium picrate[16]. The plasma creatinine clearance or estimated glomerular filtration rate (eGFR) were estimated as per Cockroft and Gault formulae in ml/min[17]. Insulin resistance was calculated by homeostatic model assessment - insulin resistance (HOMA-IR) formula[18]. Urinary microalbumin analysis was done by immunoturbidimetry[19].

Conarachin I was extracted from peanut and purified[20], and was used as a complexing agent for free iron. Conarachin I was characterized by molecular weight determination and absorption spectrometry[20]. A 15 per cent resolving sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) gel was used for molecular weight determination and confirmation of protein purification from crude peanut protein[20]. Presence of band at about 18 kD (Figure, lane 1) showed the presence of conarachin I in the

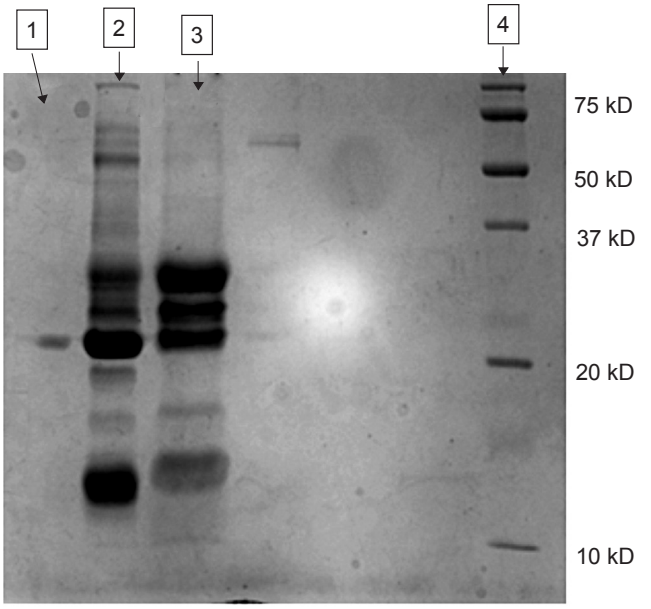

Figure. Purified conarachin I fraction along with its precursors subjected to sodium dodecyl sulphate - polyacrylamide gel electrophoresis (SDS-PAGE). Lane 1, pure conarachin 1; Lanes 2 and 3, protein part before purification; Lane 4, mol.wt.marker.

purified protein fraction as shown earlier[19]. Conarachin I (0.1 ml) was mixed with 0.4 ml of the diluted serum, injected to HPLC column and analyzed to compare the amount of free Fe^{2+} and Fe^{3+} of the same serum samples[20].

Qualitative data were grouped and compared by chi square test. Yates correction was done when the cell frequency was below five[21]. Quantitative data were subjected to comparison by their differences in mean by unpaired t test. A HOMA value of 2.4 was taken as comparator as the value exhibited evidence of diabetic kidney disease in an Indian study[22]. Serum iron value of 150 µg/dl was taken as upper reference limit for both sexes considering 145 and 160 as upper reference limit (URL) for females and males, respectively as per the kit insert.

Insulin resistance was not found to be significantly associated with total iron. Serum total iron values <150 and >150 µg/dl were compared with HOMA values <2.4 and >2.4 for both sexes. No association was seen when the means of total free iron were compared with HOMA<2.4 and HOMA>2.4 (15.7±1.64 vs16.02±2.56 ppm); insulin resistance was not related to Fe^{3+}/Fe^{2+} ratio either in males or in females. Obesity, as body mass index (BMI in kg/m^2) >25[23] was compared with HOMA, the association was significant at (P<0.01). Free iron has been known to cause damage by generation of free radicals. As obesity with raised amount of adipose tissue contributes to more serum iron and serum iron is known to contribute to insulin resistance, we decided to multiply the BMI with the ferric-ferrous ratio, and took the product (BMI×Fe^{3+}/Fe^{2+}) as the index value. The median value of the distribution was around 0.37, the mode was 0.3, and HOMA was compared with values above and below 0.3 in females and males.

Iron contributes to insulin resistance (IR) by hindering its action on liver. It also retards the catabolism of insulin leading to hyperinsulinaemia. Insulin contributes to iron overload by generating more transferrin receptors, more ferritin and entry of iron into the fat cells[24]. So with more number of fat cells, more iron will be present in the body. This will contribute to insulin resistance. A significant difference was obtained in females (P<0.001) but not in males when the index was compared to HOMA of 2.4. Also, concordance of our index values between females and males showed significance (P<0.001) (Table I). Thus, one can assume that the product of free iron ratios and BMI bears a stronger association with IR in females than in males or BMI alone. A mean free iron value of 15.82±1.38 ppm (n=111) was found in patients with diabetes, whereas it was 9.28±1.21 ppm in healthy controls (n=30) (P<0.001).

The stronger relationship with the index in females may be due to lesser amount of iron stores in them[25]. Ferric form contributes more to IR possibly as the origin of free iron is supposed to be from transferrin which contains iron in its ferric form. Ferric form may represent the initial active redox state of iron before being reduced to ferrous form. This led us to hypothesize that with more iron in ferric form, there would be more free iron turnover and hence more damage. Though higher amounts of both free and total iron were found amongst patients with microalbuminuria and lower eGFR, the results were not significant in our population which may be due to the presence of lesser amount of nephropathy in patients.

Free iron was considerably reduced in the serum of most patients with diabetes upon addition of conarachin I with a few showing increase whereas serum samples of healthy subjects showed increase in the free iron concentration upon addition of conarachin I. The difference between the two groups was significant (P<0.001) (Table II). Patients with diabetes (mean fasting plasma glucose = 164.77±16.84 mg/dl) had a

Table I. Comparison of sex concordance to index

Patients	HOMA concordant to index	HOMA discordant to index	Total (N)
Females	48	12	60
Males	21	30	51
Total	69	42	111

HOMA >2.4 and index>0.3 or HOMA<2.4 and index <0.3 are taken as positive concordance
HOMA, homeostatic model assessment

Table II. Comparison between effect of conarachin I in serum of patients with and without diabetes

Subject	Decrease in free iron ($Fe^{3+} + Fe^{2+}$)	Increase in free iron ($Fe^{3+} + Fe^{2+}$)	Total
With diabetes	90	21	111
Without diabetes	0	30	30
Total	90	51	141

$P<0.001$ (χ^2 test)

higher level of free iron than healthy individuals possibly due to more generation of non-transferrin bound iron (NTBI) by glycation of apotransferrin which does not bind iron avidly[26]. It was interesting to observe that the higher plasma glucose level in patients with diabetes renders the medium reducing so as the initial Fe^{3+}/Fe^{2+} equilibrium in plasma is maintained even after being exposed to aerial oxidation for up to 72 h[27]. The serum of patients with diabetes having higher mean fasting plasma glucose levels might enhance the complexing ability of conarachin I and reduce the free iron level. In healthy controls with normal glucose levels, addition of the protein conarachin I from outside probably disturbs the equilibrium of transferrin bound iron and releases some bound iron free thus increasing the free iron level. The results indicate that peanut proteins may serve to design therapeutics to reduce excess free iron in patients with diabetes and hence control sugar levels especially in insulin resistant female patients.

In conclusion, free iron was significantly raised in serum of patients with T2DM when compared with healthy subjects. The calculated index of the product of BMI with the ferric-ferrous ratio may be important in assessing insulin resistance, particularly in females or BMI at any level of glycaemia. A peanut protein, conarachin I binds with the free iron in the serum of patients with diabetes and may contribute to the reduction of insulin resistance. The limitation of the study was that serum ferritin and total iron binding capacity (TIBC) were not measured. As serum ferritin is falsely raised in inflammatory states, thus may contribute as a confounding factor. The use of peanut protein to bind serum free iron is a subject of further investigations in animal models.

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References

1. Jayawardena R, Ranasinghe P, Byrne NM, Soares MJ, Katulanda P, Hills AP. Prevalence and trends of the diabetes epidemic in South Asia: a systematic review and meta-analysis. *BMC Public Health* 2012; *12* : 380.
2. Kaveeshwar SA, Cornwall J. The current state of diabetes mellitus in India. *Australas Med J* 2014; *7* : 45-8.
3. Sireesha G, Kusuma DL. Prevalence of undernutrition and anemia among the child beneficiaries of mid-day meal program. *Int J Adv Nutr Health Sci* 2014; *2* : 52-8.
4. Zhao Z, Li S, Liu G, Yan F, Ma X, Huang Z, *et al.* Body iron stores and heme-iron intake in relation to risk of type 2 diabetes: A systematic review and meta-analysis. *PLoS One* 2012; *7* : e41641.
5. Bao W, Rong Y, Rong S, Liu L. Dietary iron intake, body iron stores, and the risk of type 2 diabetes: a systematic review and meta analysis. *BMC Med* 2012; *10* : 119.
6. Poggiali E, Cassinerio E, Zanaboni L, Cappellini MD. An update on iron chelation therapy. *Blood Transfus* 2012; *10* : 411-22.
7. Yajnik CS. The insulin resistance epidemic in India: fetal origins, later lifestyle, or both? *Nutr Rev* 2001; *59* : 1-9.

8. De Vinuesa SG, Goicoechea M, Kanter J, Puerta M, Cachofeiro V, Lahera V, *et al*. Insulin resistance, inflammatory biomarkers, and adipokines in patients with chronic kidney disease: effects of angiotensin II blockade. *J Am Soc Nephrol* 2006*; 17* (12 Suppl 3): S206-S12.
9. Milman N, Pedersen P, á Steig T, Byg KE, Graudal N, Fenger K. Clinically overt hereditary hemochromatosis in Denmark 1948-1985: epidemiology, factors of significance for long-term survival, and causes of death in 179 patients. *Ann Hematol* 2001; *80* : 737-44.
10. Guyader D, Jacquelinet C, Moirand R, Turlin B, Mendler MH, Chaperon J, *et al*. Noninvasive prediction of fibrosis in C282Y homozygous hemochromatosis. *Gastroenterology* 1998; *115* : 929-36.
11. Cabantchik ZI, Sohn YS, Breuer W, Espósito BP. The molecular and cellular basis of iron toxicity in iron overload (IO) disorders. Diagnostic and therapeutic approaches. *Thalassemia Rep* 2013; *3*(s1) : e3.
12. Gohel M, Sirajwala HB, Chacko A. Serum free iron concentration in patients with type 2 diabetes mellitus with good and poor control and its correlation with glycemic control. *Int J Diab Res* 2013; *2* : 33-8.
13. Fernandez V, Winkelmann G. The determination of ferric iron in plants by HPLC using the microbial iron chelator desferrioxamine E. *Biometals* 2005; *18* : 53-62.
14. Juaristi E, Cuevas G. *The anomeric effect*. Boca Raton, FL, USA: CRC Press; 1995. p. 9- 10.
15. Henry JB, editor. *Clinical diagnosis and management by laboratory methods*, 16th ed. Philadelphia: WB Saunders; 1974. p. 263.
16. Cockcroft DW, Gault MH. Prediction of creatinine clearance from serum creatinine. *Nephron* 1976; *16* : 31-41.
17. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia* 1985; *28* : 412-9.
18. Comper WD, Jerums G, Osicka TM. Deficiency in the detection of microalbuminuria by urinary dipstick in diabetic patients. *Diabetes Care* 2003; *26* : 3195-6.
19. Gigli G, Altomonte F, Bocca B, Colombano M, De Grandi R, Ponte M, *et al*. Evaluation of a new immunoturbidimetry technique for measuring microalbuminuria. *Boll Soc Ital Biol Sper* 1991; *67* : 273-8.
20. Ghatak SK, Majumdar D, Singha A, Sen S, Das D, Chakrabarti A, *et al*. Peanut protein sensitivity towards trace iron: a novel mode to ebb allergic response. *Food Chem* 2015; *176* : 308-13.
21. Mahajan BK. *Methods in biostatistics*: *for medical students and research workers*. New Delhi : Jaypee Brothers Medical Publishers; 1997.
22. Viswanathan V, Tilak P, Meerza R, Kumpatla S. Insulin resistance at different stages of diabetic kidney disease in India. *J Assoc Physicians India* 2010; *58* : 612-5.
23. Aziz N, Kallur SD, Nirmalan PK. Implications of the revised Consensus body mass indices for Asian Indians on clinical obstetric practice. *J Clin Diagn Res* 2014; *8* : OC01-3.
24. Escobar-Morreale HF, Luque-Ramírez M, Álvarez-Blasco F, Botella-Carretero JI, Sancho J, San Millán JL. Body iron stores are increased in overweight and obese women with polycystic ovary syndrome. *Diabetes Care* 2005; *28* : 2042-4.
25. Congo DL, Fauci AS, Kasper DL, Hauser SL, Jameson JL, Loscalzo J, editors. *Harrison's principles of internal medicine*, 18th ed. New York: McGraw Hill; 2012. p. 847-8.
26. Goodarzi MT, Rashidi M, Rezaei M. Study of nonenzymatic glycation of transferrin and its effect on iron - binding antioxidant capacity. *Iran J Basic Med Sci* 2010; *13* : 194-9.
27. Pratt CW, Cornely K. *Essential biochemistry*, 3rd ed. New Jersey, USA: John Wiley & Sons, Inc.; 2013. p. 626-7.