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CONCORDANT ROLE OF BMI AND SERUM FERRITIN IN DIABETES

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ABSTRACT The current scenario regarding the impact of different variables of nutritional status on serum-ferritin is inconclusive. The present cross sectional study was conducted to explore the role of nutritional status with ferritin level in association with fasting blood glucose (FBG) level and with the HbA1C of ~400 individuals. Presently, FBG was estimated by colorimetric kit method. Parameters were estimated and these were hemoglobin by cyanmethaemoglobin, serum-ferritin by ELISA and HbA1C by immunoturbidimetry methods in this study. Data were analyzed by the ANOVA, Pearson's chi-square test, product moment correlation with the help of SPSS for windows statistical software. Hemoglobin, serum ferritin and HbA1C were found significantly variable in different nutritional status. The overweight group was affected with diabetes and higher HbA1C with increased blood glucose. The overweight group also having elevated hemoglobin and ferritin was less directly associated with glucose metabolism and HbA1C right be a connecting link between Hb level and glycemic status. In association with FBG and HbA1C the role of iron and ferritin in the BMI of an individual and hyperglycemia/diabetes status was found to be facultative in the current investigation. In non diabetic individual TG, TC & LDLC were noticed to be significantly associated with ferritin. These findings suggest a significant role of ferritin in diabetes complication. Thus, serum ferritin in association with nutritional state may be considered as a determinant of diabetes status.

KEYWORDS : Fasting blood glucose, HbA1C, Ferritin, Hb, BMI

INTRODUCTION

Diabetes is a global issue. A large number of people are now in pre-diabetic condition. Different dependent and independent variables are known to be associated with this disorder. Over-nutrition and some vascular disorders are involved with body energy metabolism (1). Abnormal fat metabolism and its extra-amount deposition in the body result in severe metabolic disorder, in the long run. Body mass index (BMI) or several other physiological/metabolic indices are the good predictor for diabetes. Beside fasting glucose level or GTT, chronic glycaemia is well judged from the HbA1C (2). Glycation of Hb is also predicted from the iron metabolism which is related to several other micronutrients plus biological iron transportation and storage capacity (3,4). Nevertheless, serum ferritin and transferrin are the important predictors of Hb status and iron utilization in the body. Regulations of iron pool and its binding protein ferritin are not well studied in relation to diabetic condition predicted by the HbA1C level (5). BMI or the nutrition status of the individuals is also less focussed in relation to iron/ferritin function and HbA1C predicted diabetic outcome (6). In the current study, several of these factors and their relationships have been studied to predict the diabetes status of an individual.The higher prevalence of pre-diabetes among adolescents created a serious public-health issue in India and other several countries. Report reveals that, BMI and sub-scapular skin-fold thickness positively associated with pre-diabetes/diabetes suggesting an important role nutritional status of the individual (7). In relation to the current scenario, obesity and diabetes are main risk factors for COVID-19 and mortality (8). These types of patients are more affected with severe inflammations.

Iron and other transition metals are like two sided knife. Especially iron which is the main cofactor of the hemoglobin can be deposited in different places like brain and this unauthorized deposition may cause several neurological disorders. Physiological metabolism of iron and its carrier protein ferritin may be associated with diabetes. These issues are less focused. The serum ferritin levels of the type 2 DM patients significantly increased with increasing HbA1c levels which is associated with their fasting blood glucose. Moreover, metabolic inflammatory marker CRP level has also been associated with these factors like ferritin and HbA1c (9). Now, hyperglycemic condition has been well known to associate with several anthropometric parameters like waist circumference (WC), waist-hip ratio, (WHR) and waist-to-height ratio (WHtR). A meta-analysis with >15,000 participants suggested that waist-hip related factors are strongly association with T2DM in all adjusted analyses. More critically, obesity defined using waist circumference (OB-WC) and OB-BMI showed the strongest associations with T2DM (10). Obesity associated T2DM is more linked with peripheral artery occlusive disease (PAOD). And in this case also several anthropogenic factors are found to be associated like waist-hip ratio (WHR), body roundness index (BRI), waist-to-height ratio (WHtR), conicity index (CI) and abdominal volume index, visceral adiposity index (VAI), lipid accumulation product (LAP), body adiposity index, body mass index and triglyceride-glucose index (11).

When the issue is related to lipid metabolism status, T2DM was prevalent in 14.2% in normal-weight elderly individuals having strongest association with blood triglyceride (12). In the previous section ferritin has been associated with diabetic status and BMI of an individual but this role may be regarded as the facultative role of ferritin, iron and hemoglobin. These are not some nutrient compounds and they have no direct role in calorie metabolism. So, in non-diabetic patients, TG, TC, and LDL-C were found to be significantly associated with serum ferritin level. But, ferritin is also influenced by diabetes condition (13).

So the definitive role of ferritin in diabetes complications has not been clarified. But prominently as a micronutrient function iron and ferritin are linked with increased risk of GDM (14). The dominant role of iron metabolism in female makes them apparently more susceptible to higher ferritin level associated T2DM (15). In obese women this risk is increased further because obesity has a positive relation to higher plasma ferritin level which is associated with the muscle ferritin also (16).

In this background, we were intended to explore the role of nutritional status with the ferritin level in association with fasting glucose levels and especially with the HbA1c level in >400 participants. Extensive statistical analyses were conducted to find the association between different variable to delineate stronger risk factors.

METHODOLOGY

Study Location And Human Participants

The present study was conducted (October 2018 to January 2019) among the non-pregnant and non-lactating women living in the rural areas of the Pachim Medinipur district. The study design was a community based cross-sectional type.

Sample Size:
The minimum estimated sample size was calculated using the standard formula: $n=(z^2pq)/d^2$. The calculation $((1.96^2 \times 0.712 \times 0.288)/(0.05^2))$ was based on 71.2% prevalence (p) of anaemia among the non-pregnant and non-lactating women of West Bengal according to the recent report of the fifth National Family Health Study (NFHS-5)conducted during 2019–2020 in West Bengal (17), where z=1.96, q=p-1 and desired precision (d) was ±5% 18).Thus, the estimated sample size was 315 and with a dropout rate of 20% was 378.

Ethical Consideration
The study is approved by the Institutional Research Ethics Committee. The researcher explained the study to potential participants. The anonymity of the participants is absolutely conserved. The researchers also obtained permission from the administrative authority and before the study oral and written permission was obtained from the participants.

Inclusion/exclusion Criteria
The researchers included all the women who fulfilled the following inclusion criteria:
Age between 18 and 45 years
Non-pregnant and non-lactating women
Women with a past history of chronic illnesses were excluded from this study.

Socio-economic Status
Socioeconomic status was assessed by the modified Kuppuswamy scale updated for 2019 (19). This scale is based on a composite score considering the education, occupation and family's monthly income.

Anthropometric Measurements
All anthropometric measurements were made by trained investigators using the standard techniques (20). All the equipments were checked regularly to minimize random errors. Height was measured to the nearest 0.1 cm using Martin's anthropometer. Body weight of lightly-clothed subjects was recorded to the nearest 0.5 kg on a weighing scale (Doctor Beliram and Sons, New Delhi, India). The weighing scale was set to zero before every measurement. For height and weight, individuals were requested to remove their shoes before taking measurements. Circumference of the head (HeC), mid upper arm (MUAC), breast (BC), waist (WC) and hip (HC) were measured with a rigid measuring tape and recorded to the nearest 0.1 cm. WC was measured at the smallest horizontal circumference between the ribs and iliac crest (the natural waist), or, in case of an indeterminable waist narrowing, halfway between the lower rib and the iliac crest. HC was measured at the largest horizontal expansion of the buttocks. The subjects stood erect with abdomen relaxed, the arms at the side and feet together and breathing normally. Errors of measurements were computed and they were found to be within acceptable limits (21).

Body mass index (BMI), waist hip ratio (WHR), body fat percentage (PBF), waist hip ratio (WHtR), a body shape index (ABSI), conicity index (Cindex), body adiposity index (BAI) were computed using the following standard equations:
BMI (kg/m^2) = Weight (kg) / Height (m)^2(22)
WHR = Waist circumference (cm)/Hip circumference (cm) (23)
PBF= (1.20 x BMI) + (0.23 x Age) - (10.8 x Sex) - 5.4, where, Sex; Female = 0 (24)

WHtR= Waist circumference (cm) / Height circumference (cm) (25)
ABSI= Waist circumference (m)/(BMI (kg/m^2)$^{2/3}$×Height (m) $^{1/2}$) (26)
CIndex = Waist Circumference (m) / [0.109 X /{Body weight (kg) / Height (m)}] (27)

BAI=[Hip circumference (cm) /(Height ×√Height)] -18 (28)

Nutritional status was evaluated using internationally accepted World Health Organization

BMI (kg/m^2) guidelines (22). The following cut-off points were used:
Underweight: BMI < 18.5;
Normal: BMI = 18.5 – 24.9;
Overweight: BMI > 25.0.

Blood Sample Collection And Test Procedure:
Two ml of venous blood were drawn from each subject. An aliquot of the blood was placed immediately in a tube containing Drabkin's solution for haemoglobin estimation. The haemoglobin concentration was measured using cyanmethaemoglobin method (29). Three levels of severity of anaemia are classified: mild anaemia (10.0-10.9 g/dl for pregnant women, 10.0-11.9 g/dl for non-pregnant women), moderate anaemia (7.0-9.9 g/dl for women), and severe anaemia (less than 7.0 g/dl for women) (17).

The researchers followed the UNICEF/UNU/WHO of the public health problem of anaemia, based on adult populations worldwide. This classification categorises the prevalence of public health problem according to the prevalence of anaemia, which is as follows.

<5% anaemia signifies no public health problem,

5–19.9% anaemia signifies mild public health problem,

20–39.9% anaemia signifies moderate public health problem and

>40% anaemia signifies severe public health problem.

Determination Of Blood Glucose (Fasting)
Blood glucose of the participants is measured by glucose assay kit employing the glucose oxidase and peroxidises method.

Estimation Of Serum Ferritin By ELISA (Enzyme-Linked Immunosorbent Assay) Method
This immune enzymometric sequential assay is done according to Burtis CA *et al,* (2006), Following were used as study tools: Centrifuge, Spectrophotometer, Water bath, Automated ELISA reader with washer, ELISA reagents, etc. A dose response curve was used to ascertain the concentration of ferritin of unknown specimens by putting the measured absorbance of unknown sample on the best fit line (Fig.2),

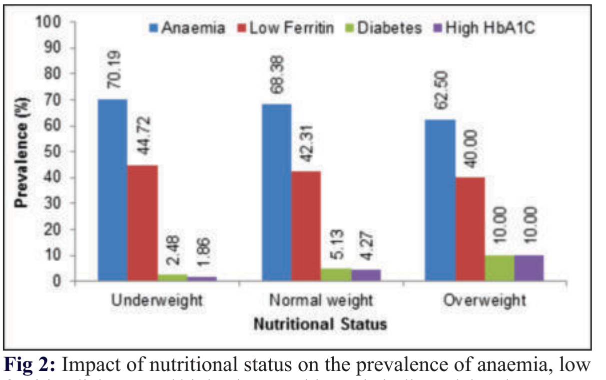

Fig 2: Impact of nutritional status on the prevalence of anaemia, low ferritin, diabetes and high HbA1c. This study indicated that the women belonging to the overweight group were most affected with the diabetes and HbA1C while the underweight group showed the highest percentage in anaemia and low ferritin.

Estimation of Glycated Hemoglobin (HbA1C) by immunoterbidmetric method:
This particle enhanced immunoterbidimetric test was done in whole blood on photometric system. Following study tools were used: incubator, semi auto analyzer, etc. The assay is standardized according to the approved IFCC reference method.

Results are described in mmol/mol (mmol HbA1C/mol Hb), Conversion factor is installed in the analyzer for the conversion of results to % of HbA1C. The concentration of HbA1C in unknown sample is derived from a calibration curve.

Statistical Analysis
Data processing and statistical analyses were done using the SPSS for Windows statistical software package. Data is expressed as means and standard deviations, and group comparison was done using one way ANOVA. Pearson's chi-square test was used to determine significant differences observed within the various categories of nutritional status. Product moment correlation coefficient (r) between haemoglobin level and different anthropometric parameters were determined. Similarly, correlation between intra-parameters of anthropometric measurements was also calculated.

RESULTS
A total of 435 non-pregnant and non-lactating women belonging to low socioeconomic class residing in Paschim Medinipur District

participated in this study.

The mean and sd of the studied anthropometric parameters including weight, height, BMI, HeC, MUAC, BC, WC, HC, WHR, PBF, WHtR, ABSI, Cindex, BAI among the women were 45.71±9.01kg, 151.43±6.81cm, 19.90±3.49kg/m^2, 52.51±3.69cm, 23.20±3.23cm, 79.72±8.92cm, 74.91±11.86cm, 86.67±8.22cm, 0.86±0.09, 23.63±5.44%, 0.49±0.07, 0.14±0.01, 1.25±0.13, 28.59±4.55 respectively. The haemoglobin level of the women was 11.11±1.66 g/dl. The serum ferritin, fasting blood glucose, and HbA1C were 25.81±15.33, 93.95±34.15 mg/dl, 4.91±1.20 respectively.

In this study, it was noted that BMI, WC, WHR, PBF, WHtR, ABSI, Cindex, BAI were significantly (P<0.01 to <0.001) higher with increasing age group. Age associated metabolic changes and increased deregulations in different physiological events especially with calorie (carbohydrate and fat metabolism) consumption are the main factors. The height, weight and BMI SD scores, and c-peptide levels at the time of diagnosis of the overweight/obese group were higher than those with normal weight (30).In the haemoglobin level and serum ferritin no such association was observed. The blood glucose level and HbA1C was increased with the age group except in the age group of 30-39 years (Table 1). This suggests Hb is more associated with iron level because ferritin regulations are more associated with body protein metabolism and regulation. Report reveals that patients with microalbuminuria showed higher ferritin levels compared with patients without microalbuminuria (p < 0.05). Stepwise regression analysis revealed that levels of HbA1c and urinary albumin excretion were independently related to ferritin levels (p < 0.001 for both). Serum ferritin levels are elevated in T1DM, particularly in patients with microvascular complications (31). So somehow protein metabolism has been associated with ferritin related type 2 diabetes.

Table 1: Impact Of Age On The Anthropometric And Biochemical Parameters

Parameters	<20 years	20-29 years	30-39 years	40-49 years	ANOVA
	N=56	N=146	N=116	N=117	
Weight	40.90±5.78	45.10±8.63	47.50±9.66	47.01±9.26	8.28***
Height	150.32±6.74	151.77±6.17	152.33±7.35	150.64±6.97	1.835
BMI	18.08±2.19	19.54±3.22	20.40±3.65	20.71±3.81	8.926***
HeC	52.59±5.99	52.29±2.00	52.53±3.20	52.73±4.30	0.315
MUAC	21.32±2.51	23.19±2.65	23.68±2.99	23.64±4.02	8.305***
BC	75.20±6.33	78.99±8.51	81.38±9.19	81.13±9.46	7.785***
WC	67.77±7.71	73.31±10.25	77.32±12.46	77.95±13.03	12.761***
HC	81.42±5.48	85.80±7.32	88.77±8.09	88.20±9.24	13.041***
WHR	0.83±0.07	0.85±0.08	0.87±0.08	0.88±0.10	5.219**
PBF	18.84±3.11	22.02±4.55	24.76±5.14	26.83±5.31	43.858***
WHtR	0.45±0.05	0.48±0.06	0.51±0.08	0.52±0.08	13.71***
ABSI	0.13±0.01	0.13±0.01	0.14±0.01	0.14±0.02	4.259**
Cindex	1.19±0.10	1.24±0.12	1.27±0.12	1.28±0.15	7.428***
BAI	26.27±3.37	27.94±3.94	29.29±4.27	29.82±5.41	10.237***
Hb	11.19±1.51	11.18±1.68	10.88±1.49	11.23±1.84	1.069
Ferritin	26.67±11.46	26.01±11.80	23.56±9.82	27.39±23.22	1.321
BG	87.46±14.32	90.46±33.94	88.37±12.90	106.93±49.24	8.244***
HbA1C	4.67±0.50	4.81±1.20	4.71±0.45	5.35±1.71	7.991***
Significance level at *P<0.05; **P<0.01; ***P<0.001					

The present study indicated that the prevalence of underweight and overweight among the participants were 37.01% and 9.20% respectively while 53.79% of the participants belonging to the normal weight group. This study clearly indicated that haemoglobin (F=3.065; P<0.05), Ferritin (F=4.960; P<0.01), and HbA1C (F=3.603; P<0.05) were significantly different in varied nutritional status. While haemoglobin and ferritin is less directly associated with glucose metabolism but more related to the protein regulations but HbA1c may act the connecting link between the Hb level and the glycemia status of the individuals. Ferritin level might affect the association between glucose and HbA1c, which should be taken into account when using HbA1c as a diagnosis criterion for diabetes and pre-diabetes (32).

The overweight group has the highest mean of the three bio-chemicals /pathological parameters (Table 2).So overweight initiates some metabolic deregulations that hamper glucose metabolism as well as iron-ferritin regulations. Report suggests that the overweight/obese group had higher BMI and c-peptide and lower HDL values in the disorder of insulin resistance syndrome can accompany T1DM (30). Lower HDL and higher metabolic inflammatory marker CRP is an adverse combination to initiate diabetes and related vascular disorder. So it is hypothesized over nutrition may result both T1 and T2 diabetes mellitus.

Table 2: Impact Of Nutritional Status On The Anthropometric And Biochemical Parameters

Parameters	Underweight	Normal weight	Overweight	ANOVA
	N=161	N=234	N=40	
Weight	39.03±5.00	47.44±6.38	62.49±8.18	256.961***
Height	152.06±6.92	151.17±6.64	150.42±7.24	1.292
BMI	16.83±1.39	20.69±1.85	27.54±2.20	670.213***
HeC	51.89±1.96	52.86±4.68	53.01±1.45	3.774*
MUAC	21.21±1.95	23.90±3.10	27.14±2.70	94.698***
BC	74.24±5.46	80.89±7.59	94.92±7.10	154.148***
WC	67.14±7.65	77.32±10.47	92.09±9.10	129.633***
HC	81.40±5.40	88.15±7.13	99.25±6.16	135.822***
WHR	0.82±0.08	0.88±0.08	0.93±0.08	34.164***
PBF	19.25±2.50	24.72±3.54	34.89±3.55	413.248***
WHtR	0.44±0.05	0.51±0.06	0.61±0.05	174.399***
ABSI	0.13±0.01	0.14±0.01	0.14±0.01	0.154
Cindex	1.22±0.12	1.27±0.14	1.31±0.12	11.966***
BAI	25.48±2.88	29.48±3.62	35.95±4.21	166.941***
Hb	10.91±1.64	11.17±1.64	11.59±1.71	3.065*
Ferritin	24.40±11.21	25.59±11.68	32.80±35.00	4.96**
BG	89.74±28.48	95.20±36.00	103.52±41.56	2.975
HbA1C	4.76±1.00	4.95±1.25	5.30±1.49	3.603*
Significance level at *P<0.05; **P<0.01; ***P<0.001				

The study noted that age was significant positively associated with blood glucose (r=0.194; P<0.001) and HbA1C (r=0.191; P<0.001). Such positive association of these two biochemical parameters were also observed in BMI (P<0.01), PBF (P<0.001) and BAI (P<0.05) while negative association was noted with ABSI (P<0.05). Serum ferritin was significantly associated with BMI (r=0.132; P<0.01), MUAC (r=0.099; P<0.05), BC (r=0.137; P<0.01), WC (r=0.232; P<0.01), HC (r=0.123; P<0.01), WHR (r=0.173; P<0.01), PBF (r=0.126; P<0.01), WHtR (r=0.204; P<0.01), ABSI (r=0.144; P<0.01), Cindex (r=0.175; P<0.01), BAI (r=0.129; P<0.01) (Table 3).Cox and linear regression analyses suggest that the changes in serum albumin and serum albumin versus serum ferritin ratio were inversely associated with T2D risk. This ratio is also related to insulin sensitivity (33). Protein regulations and its relation to ferritin metabolism is indirectly associated with calorie consumption. Other than diabetes, ferritin may be a key risk factor for nonalcoholic fatty liver disease in children with obesity (34).

Table 3: Impact Of Age On The Anthropometric And Biochemical Parameters

Parameters	Haemoglobin	Ferritin	Blood Glucose	HbA1C
Age	0.001	0.030	0.194***	0.191***
Weight	0.193***	0.109*	0.107*	0.112*
Height	0.137**	0.007	-0.036	-0.037
BMI	0.146**	0.132**	0.136**	0.142**
HeC	0.013	0.073	0.031	0.033
MUAC	0.158***	0.099*	0.072	0.074
BC	0.177***	0.137**	0.081	0.086
WC	0.232***	0.187***	0.021	0.027
HC	0.138**	0.123**	0.073	0.075

WHR	0.229***	0.173***	-0.036	-0.029
PBF	0.131**	0.126**	0.177***	0.182***
WHtR	0.204***	0.204***	0.035	0.042
ABSI	0.131**	0.144**	-0.105*	-0.102*
Cindex	0.200***	0.175***	-0.067	-0.063
BAI	0.038	0.129**	0.094*	0.097*
Significance level at *P<0.05; **P<0.01; ***P<0.001				

The stepwise linear regression was conducted among the four biochemical/pathological markers such as haemoglobin, serum ferritin, blood glucose, and HbA1C as dependent parameters and all the anthropometric parameters including weight, height, BMI, HeC, MUAC, BC, WC, HC, WHR, PBF, WHtR, ABSI, Cindex, and BAI as independent parameters. The study showed that PBF was the significant predictor for blood glucose, and HbA1C while WC was for haemoglobin and WHtR was for serum ferritin (Table 4). Gender dimorphic role in calorie metabolism is noticed. A significant difference in the T2DM incidence was observed between men and women. Though, abdominal obesity and compound obesity are risk factors for T2DM, but categorically no significant differences were observed between men and women with these types of obesity (35).

Table 4 Stepwise Linear Regression

Dependant variables	Significant predictors	Beta	t value	Significance	R^2	Adjusted R^2	F
Haemoglobin	WC	0.232	4.952	P<0.001	0.054	0.051	24.520 ***
Ferritin	WHtR	0.204	4.326	P<0.001	0.041	0.039	18.718 ***
Blood Glucose	PBF	0.177	3.740	P<0.001	0.031	0.029	13.984 ***
HbA1C	PBF	0.182	3.847	P<0.001	0.033	0.031	14.802 ***
Significance level at ***P<0.001							

Table 4. The stepwise linear regression was conducted among the four biochemical/pathological markers such as haemoglobin, serum ferritin, blood glucose, and HbA1C as dependent parameters and anthropometric indices.

The present study indicated that the women belonging to the overweight group were most affected with the diabetes and HbA1C while the underweight group showed the highest percentage in anaemia and low ferritin (fig 2).The HbA1c levels, serum ferritin, hemoglobin (Hb), insulin, Insulin Resistance, C - reactive protein (CRP), lipid profiles, and uric acid levels were compared between several groups. This report suggests a strong positive correlation between serum ferritin levels and HbA1c and fasting blood glucose (FBG) levels (p<0.01) (36).While considering the effect of nutritional status (viz. Underweight, normal weight and overweight) on the mean haemoglobin level of varied age group, it was noted that the significant difference in the mean haemoglobin in the different group of based on nutritional status of the women who were belonging to the age group of 40-49 years (F=4.484; P<0.05), but these association was not observed in other age groups (fig 3).While no case of overweight was noted in the age group of <20 years in the present study, in the other age group viz. 20-29, 30-39 and 40-49 years the prevalence of overweight were 8.22%, 12.93% and 11.11% respectively. The study showed a significant association between age and nutritional status with free fatty acid (FA) (χ^2=16.780; P<0.01) (fig 3). It should be also stressed that FA oversupply activates inflammatory signals, induces endoplasmic reticulum stress, increases mitochondrial oxidative stress and influences the regulation of genes that contributes to impaired glucose metabolism. These cellular insults are thought to engage stress-sensitive serine kinases disrupting insulin signaling. In conclusion, reduced dietary lipid intake in association with physical exercise could be a therapeutic option to improve [37].

In conclusion, in the current study hemoglobin, ferritin and HbA_1C were measured and the three parameters are found to be associated with glucose metabolism in the overweight group. The serum ferritin was found to be associated significantly with BMI, BC, HC, WHR, PBF, WHtR, ABSI, cindex and WHtR (weight to height ratio) was found to be significant predictor of serum ferritin. The overweight group was found having more prevalence of diabetes and underweight group found having more anemia and low ferritin. Hemoglobin and ferritin was indirectly associated with glucose metabolism and HBA_1C night play a connecting link between hemoglobin level and glycemic status. Thus ferritin level might affect the association between glucose and HBA1C which should be taken into account when using HBA1C as a diagnostic criterion for diabetes and pre-diabetes.

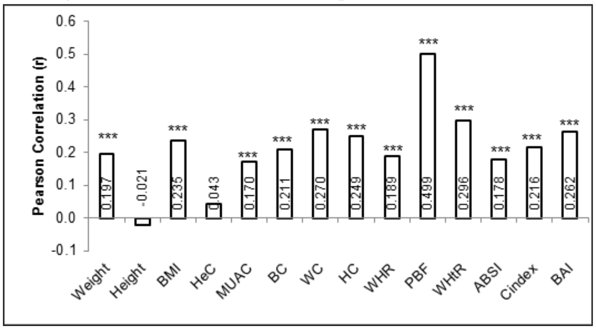

Fig 1: Relationship between different age and different anthropometric parameters. This study showed that almost all the studied anthropometric parameters were positively associated with age. The PBF shoed the best association with age as it showed the highest values of Pearson product moment correlation (r=0.499; P<0.001).

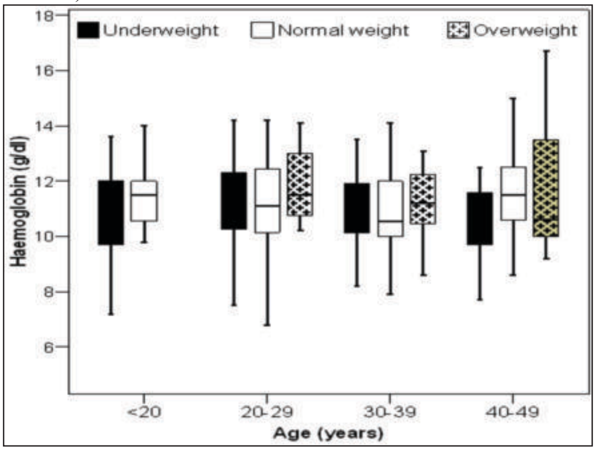

Figure 4. This study indicated that prevalence underweight among the women belong to the age group of <20, 20-29, 30-39 and 40-49 years were 30.36%, 45.89%, 33.62% and 32.48% respectively.

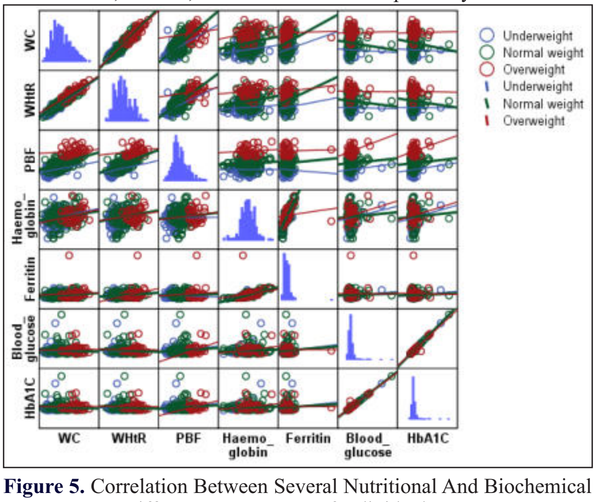

Figure 5. Correlation Between Several Nutritional And Biochemical Parameters In Different BMI Groups Of Individuals.

REFERENCES

1. Teufel et. al., Body-mass index and diabetes risk in 57 low-income and middle-income countries: a cross-sectional study of nationally representative, individual-level data in 685 616 adults. Lancet. 2021 Jul 17;398(10296):238-248. doi: 10.1016/S0140-6736(21)00844-8. PMID: 34274065.
2. Rivers K, Hanna-Mahase C, Frankson M, Smith F, Peter S. Association between Obesity and Impaired Glucose Tolerance in New Providence Adolescents as Demonstrated by the HbA1c Test. West Indian Med J. 2013 Nov;62(8):705-10. doi: 10.7727/wimj.2013.212. PMID: 25014855.
3. Liu J, Li Q, Yang Y, Ma L. Iron metabolism and type 2 diabetes mellitus: A meta-analysis and systematic review. J Diabetes Investig. 2020 Jul;11(4):946-955. doi:

10.1111/jdi.13216. Epub 2020 Feb 23. PMID: 31975563; PMCID: PMC7378429.
4. Feng Y, Feng Q, Lv Y, Song X, Qu H, Chen Y. The relationship between iron metabolism, stress hormones, and insulin resistance in gestational diabetes mellitus. Nutr Diabetes. 2020 Jun 8;10(1):17. doi: 10.1038/s41387-020-0122-9. PMID: 32513913; PMCID: PMC7280284.
5. Handiso YH, Belachew T, Abuye C, Workicho A, Baye K. A community-based randomized controlled trial providing weekly iron-folic acid supplementation increased serum- ferritin, -folate and hemoglobin concentration of adolescent girls in southern Ethiopia. Sci Rep. 2021 May 6;11(1):9646. doi: 10.1038/s41598-021-89115-5. PMID: 33958657; PMCID: PMC8102612.
6. Katz ML, Kollman CR, Dougher CE, Mubasher M, Laffel LM. Influence of HbA1c and BMI on Lipid Trajectories in Youths and Young Adults With Type 1 Diabetes. Diabetes Care. 2017 Jan;40(1):30-37. doi: 10.2337/dc16-0430. Epub 2016 Oct 20. PMID: 27797924; PMCID: PMC5180464.
7. Kumar P, Srivastava S, Mishra PS, Mooss ETK. Prevalence of pre-diabetes/type 2 diabetes among adolescents (10-19 years) and its association with different measures of overweight/obesity in India: a gendered perspective. BMC Endocr Disord. 2021 Jul 7;21(1):146. doi: 10.1186/s12902-021-00802-w. PMID: 34233661; PMCID: PMC8261995.
8. Dandona P, Ghanim H. Diabetes, Obesity, COVID-19, Insulin, and Other Antidiabetes Drugs. Diabetes Care. 2021 Jul 8:dci210003. doi: 10.2337/dci21-0003. Epub ahead of print. PMID: 34244331.
9. Son NE. Influence of ferritin levels and inflammatory markers on HbA1c in the Type 2 Diabetes mellitus patients. Pak J Med Sci. 2019 Jul-Aug;35(4):1030-1035. doi: 10.12669/pjms.35.4.1003. PMID: 31372137; PMCID: PMC6659066.
10. Issaka A, Cameron AJ, Paradies Y, Kiwallo JB, Bosu WK, Houehanou YCN, Wesseh CS, Houinato DS, Nazoum DJP, Stevenson C. Associations between obesity indices and both type 2 diabetes and impaired fasting glucose among West African adults: Results from WHO STEPS surveys. Nutr Metab Cardiovasc Dis. 2021 Jun 6:S0939-4753(21)00251-9. doi: 10.1016/j.numecd.2021.05.028. Epub ahead of print. PMID:
11. Wung CH, Lee MY, Wu PY, Huang JC, Chen SC. Obesity-Related Indices Are Associated with Peripheral Artery Occlusive Disease in Patients with Type 2 Diabetes Mellitus. J Pers Med. 2021 Jun 9;11(6):533. doi: 10.3390/jpm11060533. PMID: 34207835; PMCID: PMC8229333.
12. Ke P, Wu X, Xu M, Feng J, Xu H, Gan Y, Wang C, Deng Z, Liu X, Fu W, Tian Q, He Y, Zhong L, Jiang H, Lu Z. Comparison of obesity indices and triglyceride glucose-related parameters to predict type 2 diabetes mellitus among normal-weight elderly in China. Eat Weight Disord. 2021 Jun 30. doi: 10.1007/s40519-021-01238-w. Epub ahead of print. PMID: 34195936.
13. Yu L, Yan J, Zhang Q, Lin H, Zhu L, Liu Q, Zhao C. Association between Serum Ferritin and Blood Lipids: Influence of Diabetes and hs-CRP Levels. J Diabetes Res. 2020 Mar 24;2020:4138696. doi: 10.1155/2020/4138696. PMID: 32280714; PMCID: PMC7128071.
14. Sun C, Wu QJ, Gao SY, Ma ZM, Liu YS, Zhang JY, Zhao YH. Association between the ferritin level and risk of gestational diabetes mellitus: A meta-analysis of observational studies. J Diabetes Investig. 2020 May;11(3):707-718. doi: 10.1111/jdi.13170. Epub 2019 Dec 2. PMID: 31667982; PMCID: PMC7232272.
15. Jiang L, Wang K, Lo K, Zhong Y, Yang A, Fang X, Akezhuoli H, Song Z, Chen L, An P, Xu M, Min J, Wang F. Sex-Specific Association of Circulating Ferritin Level and Risk of Type 2 Diabetes: A Dose-Response Meta-Analysis of Prospective Studies. J Clin Endocrinol Metab. 2019 Oct 1;104(10):4539-4551. doi: 10.1210/jc.2019-00495. PMID: 31074789.
16. Ryan BJ, Foug KL, Gioscia-Ryan RA, Ludzki AC, Ahn C, Schleh MW, Gillen JB, Chenevert TL, Horowitz JF. Skeletal muscle ferritin abundance is tightly related to plasma ferritin concentration in adults with obesity. Exp Physiol. 2020 Sep 5:10.1113/EP089010. doi: 10.1113/EP089010. Epub ahead of print. PMID: 32888323; PMCID: PMC7933310.
17. International Institute for Population Sciences (IIPS) and ICF. National Family Health Survey (NFHS-5), India, 2018-20: West Bengal. Mumbai: IIPS. 2021.
18. Bisai S, Mallick C. Prevalence of undernutrition among Kora-Mudi children aged 2-13 years in Paschim Medinipur District, West Bengal, India. World Journal of Pediatrics 2011; 7(1); 31-6.
19. Wani RT. Socioeconomic status scales-modified Kuppuswamy and UdaiPareekh's scale updated for 2019. J Family Med Prim Care.2019;8:1846-1849.
20. Lohman TG, Roche AF, Martorell R. Anthropometric Standardization Reference Manual. Champaign, Illinois: Human Kinetics Books. 1988.
21. Ulijaszek SJ, Kerr DA. Anthropometric measurement error and the assessment of nutritional status. Br J Nutr. 1999; 82: 165-177.
22. World Health Organization. Physical Status: The Use and Interpretation of Anthropometry. Report of a WHO Expert Committee. Technical Report Series, No. 854. Geneva: World Health Organization. 1995.
23. World Health Organization. Waist Circumference and Waist–Hip Ratio: Report of a WHO Expert Consultation. Geneva: World Health Organization.2008.
24. Deurenberg P, Weststrate JA, Seidell JC. Body mass index as a measure of body fatness: age- and sex-specific prediction formulas. Br J Nutr. 1991;65(2):105-14.
25. Koster A, Leitzmann MF, Schatzkin A, Mouw T, Adams KF, van Eijk JT, Hollenbeck AR, Harris TB. Waist circumference and mortality. Am J Epidemiol. 2008 Jun 15;167(12):1465-75. doi: 10.1093/aje/kwn079. Epub 2008 Apr 15. PMID: 18417494.
26. Krakauer NY, Krakauer JC. A new body shape index predicts mortality hazard independently of body mass index. PloS One (2012) p:7 (7). doi: 10.1371/journal. pone. 0039504
27. Flora MS, Mascie-Taylor CGN, Rahman M. Conicity index of adult Bangladeshi population and their socio-demographic characteristics. Ibrahim Med Coll J. 2009; 3(1): 1-8.
28. Bergman RN, Stefanovski D, Buchanan TA, Sumner AE, Reynolds JC, Sebring NG, Xiang AH, Watanabe RM. A Better Index of Body Adiposity. Obesity (Silver Spring). 2011 May;19(5):1083-9. doi: 10.1038/oby.2011.38.
29. Dallman PR. Diagnosis of anemia and iron deficiency: Analytic and biological variations of laboratory tests. Am J Clin Nutr. 1984;39: 937–941.
30. Bitkin EC, Kara C, Yılmaz GC, Mammadova J, Aydın HM. Evaluation of children with type 1 diabetes mellitus in terms of overweight/obesity in tertiary care hospital. J Pediatr Endocrinol Metab. 2021 Jun 23. doi: 10.1515/jpem-2021-0268. Epub ahead of print. PMID: 34162026.
31. Metwalley KA, Raafat DM, Tamer DM, Farghaly HS, Said GM. Ferritin levels in children and adolescents with type 1 diabetes mellitus: relationship with microvascular complications and glycemic control. Arch Endocrinol Metab. 2021 May 18;64(6):720-725. doi: 10.20945/2359-3997000000279. PMID: 34033281.
32. Li Y, Zhang F, Zhang X, Fu Z, Wang L, Zhao C, Guo G, Zhou X, Ji L. The impact of ferritin on the disassociation of HbA1c and mean plasma glucose. J Diabetes. 2021 Jun;13(6):512-520. doi: 10.1111/1753-0407.13138. Epub 2020 Dec 14. PMID: 33249774.
33. Aregbesola A, de Mello VDF, Lindström J, Voutilainen S, Virtanen JK, Keinänen-Kiukaanniemi S, Tuomainen TP, Tuomilehto J, Uusitupa M. Serum adiponectin/Ferritin ratio in relation to the risk of type 2 diabetes and insulin sensitivity. Diabetes Res Clin Pract. 2018 Jul;141:264-274. doi: 10.1016/j.diabres.2018.05.012. Epub 2018 May 17. PMID: 29777745.
34. Zhang J, Cao J, Xu H, Dong G, Huang K, Wu W, Ye J, Fu J. Ferritin as a key risk factor for nonalcoholic fatty liver disease in children with obesity. J Clin Lab Anal. 2021 Feb;35(2):e23602. doi: 10.1002/jcla.23602. Epub 2020 Nov 28. PMID: 33249617; PMCID: PMC7891541.
35. Lu Y, Yang H, Xu Z, Tang X. Association Between Different Obesity Patterns and the Risk of Developing Type 2 Diabetes Mellitus Among Adults in Eastern China: A Cross-Sectional Study. Diabetes Metab Syndr Obes. 2021 Jun 10;14:2631-2639. doi: 10.2147/DMSO.S309400. PMID: 34140792; PMCID: PMC8203197.
36. Son NE. Influence of ferritin levels and inflammatory markers on HbA1c in the Type 2 Diabetes mellitus patients. Pak J Med Sci. 2019 Jul-Aug;35(4):1030-1035. doi: 10.12669/pjms.35.4.1003. PMID: 31372137; PMCID: PMC6659066.
37. Gilbert M. Role of skeletal muscle lipids in the pathogenesis of insulin resistance of obesity and type 2 diabetes. J Diabetes Investig. 2021 Jun 15. doi: 10.1111/jdi.13614. Epub ahead of print. PMID: 34132491.