Original Article

Occurrence of Diabetes Mellitus in Obese Nondiabetic Patients, with Correlative Analysis of Visceral Fat, Fasting Insulin, and Insulin Resistance: A 3-year Follow-up Study (Mysore Visceral Adiposity in Diabetes Follow-up Study)

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Abstract

Objective: To assess the occurrence of diabetes in obese nondiabetic patients over a 3-year follow-up period with a correlative analysis of visceral fat (VF), fasting insulin levels, (FILs) and insulin resistance (IR). **Material and Methods:** Thirty-seven obese and nineteen nonobese nondiabetics of our previous study, Mysore Visceral Adiposity in Diabetes were followed for the next 3 years. Their blood pressure, body mass index, waist circumference (WC), fasting blood sugar (FBS), FIL, lipid profile and subcutaneous fat (SCF), and VF measurement by US method were repeated every 6 months for the next 3 years. The findings were analyzed with appropriate statistical methods. **Results:** Twenty-three obese and 18 nonobese nondiabetics completed the study. There were 17 dropouts. The changes in the physical and biochemical characteristics of the two groups before and after the study were not significant. SCF had no correlation with IR whereas VF correlated with FIL and IR. There were three diabetics in the obese group and two from the control group at the end of the study. There were 12 impaired glucose tolerance (IGT) in the test group and 2 in the control group. Those who developed diabetes had higher VF, WC, FBS, FIL, and IR. Those who showed IGT also had these at higher levels compared to others. There was no change in the VF at the end of the study. **Conclusions:** This follow-up study on South Indians has shown that VF is a significant risk factor for the development of IR. IR can develop without any increase in the volume of the VF, is the essential finding of this study. SCF has not shown any significant relationship with IR. We recommend FBS and FIL in all the obese nondiabetics to calculate IR, which has given much insight in the development of IGT and diabetes. Large multicentric, longitudinal studies are required to establish the cause of IR.

Keywords: Diabetes, insulin resistance, visceral fat

Introduction

Obesity is at the background of severe metabolic abnormalities in India. Nearly 30%–65% of adult urban Indians are either overweight, obese, or have abdominal obesity.[1] Abdominal obesity plays a major role in the pathogenesis of Type 2 diabetes, cardiovascular diseases, and hypertension.[2,3] Central adiposity is more strongly associated with these problems than total adiposity.[2,4,5]

Indian data suggest that standard cutoff points to define abdominal obesity, are not appropriate for Asian Indians[1] who are at risk of developing obesity-related comorbidities at a lower level of body mass index (BMI). They have waist circumference (WC), which is abnormal at any value of BMI.[6] Despite the lack of clear explanation, there is a strong relationship between visceral fat (VF) and insulin resistance (IR), and this fact has been reported in a number of studies.[2] Whether it is the mechanism of large free fatty acid (FFA) flux into the portal

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circulation by VF or the increased production of tumor necrosis factor-alpha and interleukin-6 and less secretion of adiponectin by abdominal fat, IR is the end result, thereby causing glucose intolerance. Even obese adolescents with a high proportion of VF and relatively low subcutaneous fat (SCF) have a phenotype, reminiscent of partial lipodystrophy. These adolescents may not be severely obese, yet they suffer from severe metabolic complications.[7,8] It is also postulated that SCF behaves exactly opposite to VF. Most favorable metabolic profile was found with lowest VF and higher SCF. VF showed a strong association with Type-2 diabetes and SCF did not show such an association.[9]

Mysore Visceral Adiposity in Diabetes (MYVAD) Study[10]* showed that neither VF nor SCF had any correlation with IR. To ascertain whether changes in the VF and or SCF over a period of time would correlate with IR, this study in the obese, and nonobese nondiabetic patients of MYVAD study, was undertaken and were followed for the next 3 years.

Methodology

Objective

To assess the occurrence of diabetes in obese nondiabetic patients over a 3-year follow-up period with a correlative analysis of VF, fasting levels, and IR.

Inclusion criteria

Participants in the age group of 18–65 years, whose BMI is >25 kg/m^2 for obese nondiabetics and whose BMI was <23 kg/m^2 for nonobese nondiabetics. (These were the criteria used for them in the previous study).

Exclusion criteria

(1) Patients with type 2 diabetes mellitus (T2DM), (2) any acute illness, (3) pregnancy, (4) patients on antiobesity medications, (5) comorbid conditions such as chronic obstructive pulmonary disease, HIV, and tuberculosis, and (6) those who were overweight with a BMI values between 23-24.9 kg.m^2 (these were the exclusion criteria used for the participants in the previous study).

Study design

This was essentially the follow-up of the MYVAD study cohort that was carried out between March 2010 and April 2011. 37 obese and 19 nonobese nondiabetics from that study were followed for the next 3 years. Ethical approval was obtained from the Institutional Ethical Committee of JSS Medical College. Fresh informed consent was obtained from each individual who participated in this study. This study was started in September 2011 and completed in August 2014. The first follow-up was done exactly 6 months after the completion of MYVAD study. Each participant was clinically examined, for height (to the nearest cm) and weight (to the nearest 100 g). WC in centimeter was done in the standing position and was measured midway between lower border of the ribs and the iliac crest. Their sitting blood pressure (BP) was measured with a standard sphygmomanometer after 5 min of rest. Average of three readings was taken.

Their fasting blood sugar (FBS) (GOD-PAP method), HbA1C (high-performance liquid chromatography method), serum cholesterol (CHOD-PAP method), serum triglycerides (Enzymatic method), high-density lipoprotein (third-generation direct assay), low-density lipoprotein (third-generation direct assay), and serum insulin fasting assay (fasting insulin levels [FILs]) (CLIA method) values were obtained for each patient at a NABL accredited standard laboratory. IR was calculated by the homeostatic model assessment-IR assessment formula of FBS in millimoles multiplied by fasting insulin in mIU divided by 22.5.[11] Clinical examination, laboratory measurements, and the sonographic assessment of abdominal fat were repeated every 6 months for the next 3 years. Cutoff values for BMI and WC for Asian Indians according to the IDF criteria have been followed in this study.[1]

Sonographic measurements

All measurements were made with GE P5 Logic system, using multifrequency (2-5 Mega HZ) convex probe for measurements of intra-abdominal fat thickness and a multifrequency (8–12 Mg Hz) linear probe for the measurements of abdominal wall fat.

Intra-abdominal fat (VF) thickness is defined as the distance between the anterior border of lumbar vertebra and posterior surface of rectus abdominis muscle. In is measured midway between xiphisternum and umbilicus, i.e. approximately 5 cm from umbilicus at three positions along the horizontal line, each measure were repeated 3 times [Figure 1]. All measurements were done at the end of quiet expiration, applying minimal pressure, not displacing or deforming the abdominal contents.[12]

Abdominal wall fat index is the ratio of maximum preperitoneal to minimum SCF thickness. It is measured using a linear probe (8–12) placed at the epigastrium perpendicular to the skin. Longitudinal scans are obtained along the midline (linea alba) and fat skin barrier. The thickness of the SCF is defined as the distance between the anterior surface of the linea alba and the fat skin barrier [Figure 2]. The preperitoneal fat extends from

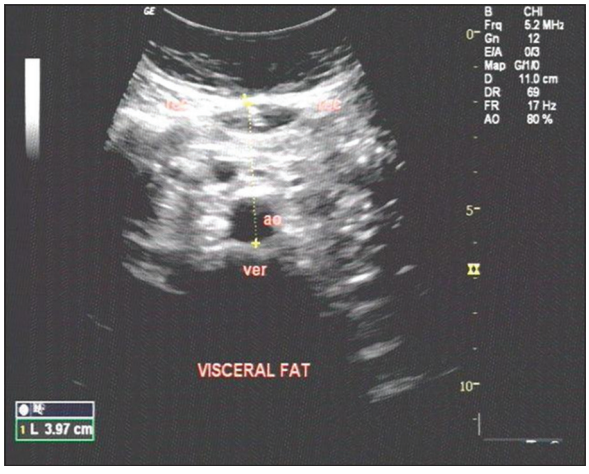

Figure 1: Measurement of visceral fat by ultrasound

the anterior surface of the left lobe of the liver to the posterior surface of the linea alba. The minimum SCF and maximum preperitoneal fat thickness are located at the epigastrium.

Abdominal fat measurement, which included the SCF, properitoneal fat (PPF), and VF were measured as per the protocol that was used in our previous study, by the same radiologist at each visit.

Those individuals either in the test sample or in the control sample who reached a HbA1C value of more than 6.5 were considered as diabetic, and their follow-up was stopped as they had reached the end point. Those individuals whose HbA1C was between >5.6 and but <6.4 were considered as having impaired glucose tolerance (IGT), and they were followed up until the end of the study. HbA1c was not repeated in those who had reached the end point as there was no provision.

The results of the six monthly follow-ups were entered it to the Excel sheets after each follow-up, both group-wise as well as individually.

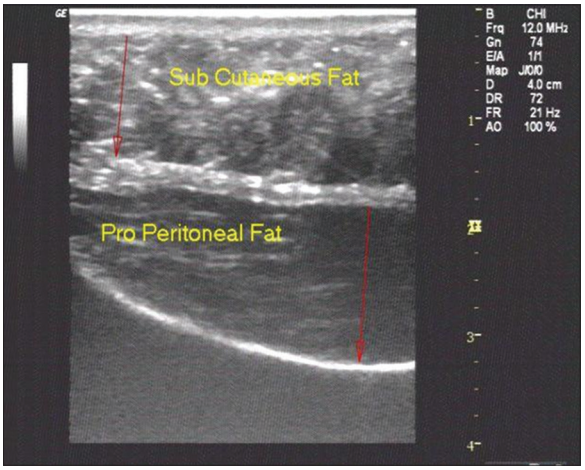

Figure 2: Measurement of subcutaneous fat by ultrasound

Statistical methods

The following statistical methods were used in this study: (1) descriptive statistics, (2) one-way ANOVA, (3) GLM repeated measures to define factors, and (4) Pearson's product moment correlation. All the statistical calculations were done through SPSS for windows (SPSS for Windows, Version 16, Chicago, SPSS Inc).

Results

The two groups that were taken from our previous study (MYVAD) for follow-up in this study were the obese and nonobese nondiabetics. The two groups had 37 participants at the end of MYVAD study. All the 37 participants of the obese group and 19 from the nonobese control group formed the subject material for the follow-up. There were a total of 14 dropouts in the obese group and one in the control group in the 3 years of follow-up. Eleven dropouts occurred in the first two follow-ups in the obese group and two in the fourth follow-up, whereas one each dropout occurred in the fifth follow-up. The data of the lost to follow-up cases were not considered for analysis. In the end, 23 from the obese group and 18 from the control group finished the study, and their data were taken for analysis [Figure 3].

Maximum participants in the obese group were in the age group of 30–50+ and <30–40 years in the control group [Table 1].

There were 11 males and 12 females in the obese group and 16 males and only 2 females in the control group [Table 2].

The various parameters that were taken for analysis both at the start of the follow-up and at the end of 3 years were weight, BMI, WC, BP (both systolic and diastolic), FBS, FILs, HbA1C, components of lipid profile, SCF, PPF, and VF. They have been depicted in Table 3. The significance between the groups, between the sexes, and between group and sex is also shown

FOLLOW UP	OBESE NON DIABETIC	DROPOUTS	NON OBESE	NON DIABETIC
INITIAL	37		19	
FIRST	32	05+0	19	
SECOND	26	06+0	19	
THIRD	26		19	DM
FOURTH	24	02+0	19	1
FIFTH	23	01+1	18	2
SIXTH	23		18	3

Figure 3: Follow up tree of the participants

Table 1: Age group analysis of the participants (crosstab)

	Group		Total
	Test	Control	
Ages			
<30			
Count	3	6	9
Percentage within group	13.0	33.3	22.0
31-40			
Count	5	8	13
Percentage within group	21.7	44.4	31.7
41-50			
Count	9	3	12
Percentage within group	39.1	16.7	29.3
50+			
Count	6	1	7
Percentage within group	26.1	5.6	17.1
Total			
Count	23	18	41
Percentage within group	100.0	100.0	100.0

Table 2: Gender analysis

	Group		Total
	Test	Control	
Sex			
Male			
Count	11	16	27
Percentage within group	47.8	88.9	65.9
Female			
Count	12	2	14
Percentage within group	52.2	11.1	34.1
Total			
Count	23	18	41
Percentage within group	100.0	100.0	100.0

in the same table. As seen none of the parameters have shown any statistical significance at the end of the study.

Pearson correlation coefficient method was used to correlate, SCF, VF, FIL, IR, and HbA1C with one another in both obese and control groups SCF had no correlation with any of the other parameters, whereas VF had a significant correlation with FIL (0.019) and IR (0.033). IR significantly correlated with FIL (0.000), HbA1C (0.000), and VF (0.033) in the obese group as shown in Table 4.

In the control group, both SCF and VF had no correlation with FIL, HbA1C, and IR. Here, also IR correlated significantly with both FIL (0.000) and HbA1C (0.003) shown in Table 5.

To have more information on those who developed IGT and diabetes, the total participants were divided into three groups; the five diabetics formed the first group, the 14 participants who showed HbA1C in the range of 5.6–6.4 (IGT) formed the second group, and the rest 22 formed the third group. In this analysis, it was clearly shown that those who showed diabetes had statistically significant higher values of FIL (0.000), HbA1C (0.000), IR (0.000), total cholesterol (0.007), and BMI (0.042). They also had higher values of VF but not statistically significant. Even those who had IGT showed higher values of FIL, HbA1C, and IR compared to the others group [Table 6].

Table 7 shows the values of VF in the obese and control groups before the study and their values after a follow-up of 3 years. As can be seen, the VF has decreased in the obese group by 0.05 cm, and by 0.59 cm in the control group, both were not significant.

Table 8 shows the risk of diabetes with IR, in the cohort of 41 cases to be 1.278 with 95% confidence interval (CI) from 1.030 to 1.585.

Discussion

Obesity is perhaps the longest studied and best-described risk factor for type 2 diabetes. Studies have shown that WC predicted T2DM.[13] Two long-term big studies found that both overall and abdominal obesity strongly and independently predicted T2DM.[14,15] Body surface measurements such as WC, do not distinguish between various adipose tissue depots. Hence, CT and MRI were used to differentiate SCF and VF and many studies documented that VF was more associated with IR and T2DM than SCF.[16-20]

Debate is going on regarding which of these fat depots are more important in determining IR. One study found that both VF and SCF being independently and strongly related to IR.[8] VF also increased the risk of development of IGT.[21] A South Indian study showed that only VF and not SCF was associated with IR.[22]

Most of the evidence on VF and SCF has emerged from analyses that have used cross-sectional designs, in which exposure variability of interest is measured at the same time as the outcome variability. Results from studies using such design have to be interpreted with caution since temporality of association cannot be determined. In contrast, longitudinal study designs, in which measurement of the exposure precedes the occurrence of the outcome is more desirable.[23]

We found in our earlier MYVAD study,[10] which had a cross-sectional design that BMI, WC, VF, and SCF had no correlation with IR. Even there, obese diabetics as well as nondiabetics had higher VF. Since it was a study limited for only 6 months, we thought a long-term follow-up of obese nondiabetics would throw some light on the changes in their abdominal fat as well as IR. Our primary goal was to find out whether any change in the abdominal fat, be it SCF or VF would have any influence in the causation of IR and diabetes after following them for 3 years. Obese males showed increase in their BMI, FBS, SCF, and HbA1C, whereas as decrease in their WC, VF, FIL, and IR but none were statistically significant. Obese females showed increase in their BMI, WC, FBS, IR, HbA1C, SCF, and VF and decrease in FIL, but again none were of any statistical significance [Table 3]. Since no conclusions could be drawn

Table 3: Values of physical and biochemical parameters at the beginning and completion of the follow-up

Parameter	Group								Significance change (*P*)		
	Test				Control				Group	Sex	Group and sex
	Male		Female		Male		Female				
	Before	After	Before	After	Before	After	Before	After			
BMI	29.77±2.97	30.76±3.36	32.3±4.23	33.10±4.41	21.55±1.53	22.05±1.46	19.5±6.36	19.87±6.89	0.431	0.708	0.882
WC	100.54±11.13	102.54±11.71	97.0±8.93	98.2±7.98	83.37±4.52	83.87±4.77	72.00±9.89	73.2±11.6	0.521	0.985	0.497
BP (systolic)	130.54±16.34	131.81±14.62	131.66±9.37	134.33±11.65	126.62±8.69	123.62±10.33	115.00±7.07	120.00±0.00	0.724	0.093	0.234
BP (diastolic)	80.00±8.94	83.09±6.94	81.83±5.74	81.50±8.00	81.37±2.70	78.37±6.45	75.00±7.07	75.00±7.07	0.295	0.938	0.243
HbA1C	5.62±0.56	6.11±0.88	5.76±0.76	5.95±0.62	5.46±0.34	5.58±0.41	5.42±0.10	5.20±0.28	0.211	0.293	0.964
TC	178.27±26.91	158.48±36.30	174.83±22.73	170.42±30.23	177.21±19.47	162.34±38.30	154.00±12.72	140.91±66.59	0.879	0.504	0.597
TG	157.50±61.69	152.4541.16	137.74±54.24	139.33±36.17	141.58±53.74	130.56±46.06	126.80±39.88	150.59±30.40	0.698	0.323	0.501
HDL	43.26±3.95	41.18±4.87	43.36±4.47	42.08±5.93	42.40±3.99	43.25±5.65	40.95±8.41	46.00±7.07	0.060	0.301	0.479
LDL	129.00±39.92	122.81±52.45	122.27±33.28	115.75±25.17	122.62±33.28	127.12±40.06	100.10±12.30	100.00±49.49	0.682	0.906	0.919
FBS	84.97±8.84	95.81±6.36	87.61±10.36	94.50±13.86	86.11±5.14	93.93±15.24	88.00±5.79	95.00±4.24	0.823	0.713	0.809
FIL	17.33±14.48	13.50±8.66	13.13±8.65	12.61±8.27	8.05±7.71	10.35±7.56	10.71±4.97	4.90±2.68	0.942	0.676	0.322
IR	3.63±2.89	3.26±2.25	2.86±2.05	3.16±2.75	1.71±1.67	2.42±1.82	2.29±0.92	1.16±0.68	0.900	0.669	0.365
SCF	1.21±0.51	1.48±0.61	2.00±0.58	2.21±0.54	0.84±0.36	1.00±0.25	0.78±0.32	1.39±0.65	0.391	0.254	0.132
VF	9.98±2.16	9.61±2.30	6.24±3.19	6.78±3.30	5.75±3.03	5.32±2.74	4.54±2.26	4.88±2.71	0.849	0.246	0.915

VF: Visceral fat, SCF: Subcutaneous fat, LDL: Low-density lipoprotein, TC: Total cholesterol, IR: Insulin resistance, FIL: Fasting insulin level, FBS: Fasting blood sugar, WC: Waist circumference, BMI: Body mass index, HDL: High-density lipoprotein, TG: Triglyceride, BP: Blood pressure

Table 4: Pearson correlation of various parameters (test group)

Parameter	SCF	FIL	HbA1C	VF	IR
SCF					
r	1	−0.286	−0.128	−0.333	−0.267
P		0.185	0.560	0.121	0.219
FIL					
r	−0.286	1	0.717	0.486	0.987
P	0.185		0.000	0.019	0.000
HbA1C					
r	−0.128	0.717	1	0.364	0.736
P	0.560	0.000		0.087	0.000
VF					
r	−0.333	0.486	0.364	1	0.446
P	0.121	0.019	0.087		0.033
IR					
r	−0.267	0.987	0.736	0.446	1
P	0.219	0.000	0.000	0.033	

VF: Visceral fat, SCF: Subcutaneous fat, IR: Insulin resistance, FIL: Fasting insulin level

Table 5: Pearson correlation of various parameters (control group)

Parameter	SCF	FIL	HbA1C	VF	IR
SCF					
r	1	−0.132	−0.171	0.150	−0.267
P		0.603	0.497	0.552	0.219
FIL					
r	−0.132	1	0.645	−0.106	0.983
P	0.603		0.004	0.675	0.000
HbA1C					
r	−0.171	0.645	1	−0.330	0.655
P	0.497	0.004		0.181	0.003
VF					
r	0.150	−0.106	−0.330	1	−0.082
P	0.552	0.675	0.182		0.745
IR					
r	−0.087	0.983	0.655	−0.082	1
P	0.732	0.000	0.003	0.745	

VF: Visceral fat, SCF: Subcutaneous fat, IR: Insulin resistance, FIL: Fasting insulin level

with these findings, correlation of VF and SCF was done with FIL, HbA1C, and IR in both the groups.

There is no consensus regarding the cutoff points of VF. Vlachos *et al*. opined that 7–9 cm for men and 7–8 cm for women nondiabetics would be the cutoff points.[24] So also different studies mention different cutoff points for IR. The pioneering study Matthews *et al*. said that 1.35–1.96 would be the lower and upper limits of IR in nondiabetics.[11] This study showed higher value of VF only in those who developed diabetes whereas higher IR values were seen not only in obese but also in nonobese nondiabetics.

FIL and HbA1C correlated significantly with IR (0.000), while SCF did not correlate with any of the parameters, VF correlated with IR (0.033) and FIL (0.019) in the obese group [Table 4]. In the control group, neither SCF nor VF correlated with FIL, IR, and HbA1C. These findings showed that VF has a probable role in the causation of IR in obese nondiabetics. This was a significant finding of this study.

Table 6: Comparison among the three groups by one-way ANOVA

Parameter	DM (5)	IGT (14)	Others (22)	*P*
BMI	29.97±5.81	30.09±5.85	25.32±5.70	0.042
WC	94.00±18.34	97.89±11.62	88.84±10.15	0.090
FBS	104.6±14.02	95.5±6.69	91.86±13.80	0.105
FIL	26.62±11.04	10.82±6.11	8.66±3.35	0.000
IR	7.01±3.35	2.59±1.57	1.98±0.85	0.000
HbA1C	7.08±0.98	5.98±0.26	5.42±0.22	0.000
TC	201.6±33.45	145.45±23.87	164.74±36.39	0.007
LDL	131.2±37.47	113.14±45.00	124.47±37.33	0.610
SCF	1.49±0.59	1.60±0.78	1.44±0.65	0.810
VF	9.23±3.30	7.26±3.60	6.09±2.81	0.128

VF: Visceral fat, SCF: Subcutaneous fat, LDL: Low-density lipoprotein, TC: Total cholesterol, IR: Insulin resistance, FIL: Fasting insulin level, FBS: Fasting blood sugar, WC: Waist circumference, BMI: Body mass index

Table 7: Comparison of visceral fat, after 3 years of follow-up

Group	VF		Significant
	2010-2011 (MYVAD)	2014-2015 (MYVAD FS)	
Obese nondiabetic	8.08±2.08	8.03±3.29	NS
Control (nondiabetic)	5.86±1.65	5.27±2.66	NS

MYVAD: Mysore Visceral Adiposity in Diabetes, VF: Visceral fat, NS: Not significant, FS: Follow up study

Table 8: Risk estimate for diabetes

	Value	95% CI	
		Lower	Upper
For cohort DM	1.278	1.030	1.585
Number of valid cases	5	0	5

DM: Diabetes mellitus, CI: Confidence interval

When we divided the whole participants into DM group, IGT group, and others, the findings were really significant as DM group showed significantly higher values of FIL, IR, HbA1C, BMI, and TC. These values were also higher in the IGT group, but VF and SCF in spite of being highest in DM and higher in IGT group were not statistically significant. These significant changes were seen despite the fact that the VF of the obese group had little change over a period of 3 years (8.08 ± 2.08 vs. 8.03 ± 3.29), so also in the control group (5.86 ± 1.65 vs. 5.27 ± 2.66) [Table 7].

Have we been successful in our endeavor? Our primary objective was to find changes in VF and we found very little change over the years. We wanted to know whether it would

influence the development of IR and diabetes. We have found three (13%) participants having HbA1C in the diabetic range and 12 (52%) in the IGT range out of the 23 followed in the obese group, despite no appreciable changes in the VF, which appears to us, highly significant. Increased VF was seen in the obese, who developed diabetes and was not seen in obese, who had IGT, but still a significant risk factor for the development of IR which culminates in IGT and DM. This has been the inference of many studies cited earlier. The importance of this study is that we have shown that an increase in VF over a period of time, is not necessary for the development of IR, as increased IR was seen not only in obese but also in the controls. As far as the reason for the causation of IR, it could be anything from FFA excess[10] to chronic inflammation in the VF,[25] both of which could not be proved in our earlier studies.

We also found HbA1C in the range of diabetes in 2 (11%) and IGT in 2 (11%) in the controls despite having lower VF which defies explanation and needs further research. The risk for development of diabetes in this whole cohort with IR has been 1.278 with 95% CI 1.030–1.585 [Table 8].

We would like to propose the estimation of FBS and FIL in all obese nondiabetics in the beginning itself to know their IR which would give an idea of the probability of them going into diabetes and measures for prevention could be taken at that time itself. Routine measurement of VF may not throw much light in the beginning, even though it is an important risk factor for the development of DM.

Limitations of the study

The only limitation of this study was the small sample size to begin with, which dwindled further with dropouts. This may be the reason for the lack of statistical significance of many parameters despite them showing changes. A multicentric large, longitudinal study would probably answer many unanswered questions.

Conclusions

This follow-up study on South Indians has shown that VF is a significant risk factor for the development of IR. IR can develop without any increase in the volume of the VF, is the essential finding of this study. SCF has not shown any significant relationship with IR. We recommend FBS and FIL in all the obese nondiabetics to calculate IR, which has given much insight in the development of IGT and diabetes. Large multicentric, longitudinal studies are required to establish the cause of IR.

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Conflicts of interest

There are no conflicts of interest.

References

1. Misra A, Chowbey P, Makkar BM, Vikram NK, Wasir JS, Chadha D, *et al*. Consensus statement for diagnosis of obesity, abdominal obesity and the metabolic syndrome for Asian Indians and recommendations for physical activity, medical and surgical management. J Assoc Physicians India 2009;57:163-70.
2. Hamdy O, Porramatikul S, Al-Ozairi E. Metabolic obesity: The paradox between visceral and subcutaneous fat. Curr Diabetes Rev 2006;2:367-73.
3. Kim SK, Kim HJ, Hur KY, Choi SH, Ahn CW, Lim SK, *et al*. Visceral fat thickness measured by ultrasonography can estimate not only visceral obesity but also risks of cardiovascular and metabolic diseases. Am J Clin Nutr 2004;79:593-9.
4. Warren M, Schreiner PJ, Terry JG. The relation between visceral fat measurement and torso level – Is one level better than another? The Atherosclerosis Risk in Communities Study, 1990-1992. Am J Epidemiol 2006;163:352-8.
5. Sturm W, Sandhofer A, Engl J, Laimer M, Molnar C, Kaser S, *et al*. Influence of visceral obesity and liver fat on vascular structure and function in obese subjects. Obesity (Silver Spring) 2009;17:1783-8.
6. Lele RD, Marta AR. Insulin resistance. In: Tripathy BB, Chandalia HB, Das AK, Rao PV, Madhu SV, Mohan V, editors. RSSDI Textbook of Diabetes. 2nd ed., Vol. 1. Hyderabad: RSSDI; 2008. p. 291-313.
7. Taksali SE, Caprio S, Dziura J, Dufour S, Cali AM, Goodman T, *et al*. High visceral and low abdominal subcutaneous fat stores in the obese adolescent. A determinant of adverse metabolic phenotype. Diabetes Care 2008;57:367-71.
8. Goodpaster BH, Krishnaswami S, Resnick H, Kelley DE, Haggerty C, Harris TB, *et al*. Association between regional adipose tissue distribution and both type 2 diabetes and impaired glucose tolerance in elderly men and women. Diabetes Care 2003;26:372-9.
9. Anjana M, Sandeep S, Deepa R, Vimaleswaran KS, Farooq S, Mohan V. Visceral and central abdominal fat and anthropometry in relation to diabetes in Asian Indians. Diabetes Care 2004;27:2948-53.
10. Premanath M, Basavanagowdappa H, Mahesh M, Suresh M. Correlation of abdominal adiposity with components of metabolic syndrome, anthropometric parameters and Insulin resistance, in obese and non obese, diabetics and non diabetics: A cross sectional observational study. (Mysore Visceral Adiposity in Diabetes Study). Indian J Endocrinol Metab 2014;18:676-82.
11. 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.
12. Stolk RP, Wink O, Zelissen PM, Meijer R, van Gils AP, Grobbee DE. Validity and reproducibility of ultrasonography for the measurement of intra-abdominal adipose tissue. Int J Obes 2001;25:1346-51.
13. Janiszewski PM, Janssen I, Ross R. Does waist circumference predict diabetes and cardiovascular disease beyond commonly evaluated cardiometabolic risk factors? Diabetes Care 2007;30:3105-9.
14. InterAct Consortium, Langenberg C, Sharp SJ, Schulze MB, Rolandsson O, Overvad K, *et al*. Long-term risk of incident type 2 diabetes and measures of overall and regional obesity: The EPIC-InterAct case-cohort study. PLoS Med 2012;9:e1001230.
15. Wang Y, Rimm EB, Stampfer MJ, Willett WC, Hu FB. Comparison of abdominal adiposity and overall obesity in predicting risk of type 2 diabetes among men. Am J Clin Nutr 2005;81:555-63.
16. Lee JJ, Beretvas SN, Freeland-Graves JH. Abdominal adiposity distribution in diabetic/prediabetic and nondiabetic populations: A meta-analysis. J Obes 2014;2014:697264.

17. Bozorgmanesh M, Hadaegh F, Azizi F. Predictive performance of the visceral adiposity index for a visceral adiposity-related risk: Type 2 diabetes. Lipids Health Dis 2011;10:88.
18. Macor C, Ruggeri A, Mazzonetto P, Federspil G, Cobelli C, Vettor R. Visceral adipose tissue impairs insulin secretion and insulin sensitivity but not energy expenditure in obesity. Metabolism 1997;46:123-9.
19. Fox CS, Massaro JM, Hoffmann U, Pou KM, Maurovich-Horvat P, Liu CY, *et al*. Abdominal visceral and subcutaneous adipose tissue compartments: Association with metabolic risk factors in the Framingham Heart Study. Circulation 2007;116:39-48.
20. Wagenknecht LE, Langefeld CD, Scherzinger AL, Norris JM, Haffner SM, Saad MF, *et al*. Insulin sensitivity, insulin secretion, and abdominal fat: The Insulin Resistance Atherosclerosis Study (IRAS) family study. Diabetes 2003;52:2490-6.
21. Hayashi T, Boyko EJ, Leonetti DL, McNeely MJ, Newell-Morris L, Kahn SE, *et al*. Visceral adiposity and the risk of impaired glucose tolerance: A prospective study among Japanese Americans. Diabetes Care 2003;26:650-5.
22. Sandeep S, Gokulakrishnan K, Velmurugan K, Deepa M, Mohan V. Visceral and subcutaneous abdominal fat in relation to insulin resistance and metabolic syndrome in non-diabetic South Indians. Indian J Med Res 2010;131:629-35.
23. Hanley AJ, Wagenknecht LE. Abdominal adiposity and diabetes risk: The importance of precise measures and longitudinal studies. Diabetes 2008;57:1153-5.
24. Vlachos IS, Hatziioannou A, Perelas A, Perrea DN. Sonographic assessment of regional adiposity. AJR Am J Roentgenol 2007;189:1545-53.
25. Premanath M, Basavanagowdappa H, Mahesh M, Babu MS, Devananda D. Chronic sub-clinical inflammation in the abdominal adipose tissue – Evaluation of inflammatory cytokines and their link with insulin resistance in metabolically obese South Indians: A cross-sectional observational study. Indian J Endocrinol Metab 2016;20:84-91.