Original Article

Type 2 Diabetes and Precursors in Community Dwelling Asian Indian Adult Youth

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Abstract

Background: Recent studies have shown a high prevalence of Type-2-diabetes (T2DM) (24%) and prediabetes (18.1%) in Kerala. There is no community based study from South Asia regarding the prevalence of type 2 diabetes and its precursors in the young adult population. This community based study was done to find the prevalence of type 2 diabetes and its precursors in South Indian adult youth (18–30 years age) of Thiruvananthapuram district. **Research Design and Methods:** Cross sectional design was used for this study. Multistage cluster sampling was used to enrol community dwelling youth of 18 to 30 years, residing in Thiruvananthapuram district. Six panchayath wards from rural and urban regions and 4 from coastal area were randomly selected as the primary sampling units. Trained staff nurses conducted the survey with the help of accredited-social-health-activists (ASHA). Socio-demographic data, anthropometry, clinical features of insulin resistance, and random capillary glucose (CG) and blood pressure were assessed and recorded. Oral Glucose tolerance test or HbA1c was done for participants with a CG ≥130 mg/dl for diagnosis of diabetes and prediabetes. **Results:** A total of 1031 participants were included from the rural ($n = 394$), coastal ($n = 269$) and urban ($n = 368$) areas. Prevalence of hyperglycaemia i.e., T2DM and pre-diabetes was 0.48% ($n = 5$) and 2.4% ($n = 25$) respectively. Family-history of T2DM was present in 35.1% subjects. Prevalence of overweight, obesity and abdominal-obesity was 28.2%, 16.1% and 28.4% respectively. Clinical-features of insulin resistance (CFIR) were present in 27.1% subjects (acanthosis [17.7%], skin tags [1.7%] and PCOS phenotype [10.7%]). Among various anthropometric measurements and their derivatives, CFIR correlated best ($r = 0.24$, $P < 0.01$) with the product of BMI and the sum of abdominal circumference and hip circumference (Trivandrum Medical College [TMC] -adiposity-index), which is a newly proposed parameter. Hyperglycaemia was more common in males, did not correlate with waist hip ratio, and correlated best again with TMC-adiposity-index (($r = 0.13$, $P < 0.01$). **Conclusions:** The burden of insulin resistance in the young South Indian population, hitherto unknown in any community based study, has been studied for the first time. The prevalence of precursors of T2DM is high in this population. Early identification of 'at risk' individuals could provide a window of opportunity for preventing or delaying future diabetes and its long term complications. TMC adiposity index could become a valuable tool in the anthropometric assessment for predicting future T2DM.

Keywords: Insulin resistance, obesity, pre-diabetes, T2DM, young adult

Introduction

India accounts for second highest number of persons with diabetes mellitus among all countries. The overall prevalence of diabetes is 7·3%.[1] The average age of onset of type 2 diabetes is 44 years and is coming down over the years.[2] Diabetes related age standardised disability adjusted life years (DALYs) was 1059 per 1000000 in 2016.[3] Economic burden to individual with Diabetes in India is approximately Rs. 6000–10,000 per month.[4] The progression from the onset of diabetes risk factors to the onset of diabetes takes years to decades. In view of the rapid increase in the prevalence of diabetes in the middle aged and older population, proper preventive strategies need to be formulated at a much younger age. As an initial step it is important to know the prevalence of the risk factors of diabetes at a young age to prevent or

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delay the onset of diabetes, so as to decrease the morbidity and economic impact of the diabetes pandemic before it snowballs as an unmanageable global challenge.

Although a large number of studies regarding the epidemiology of diabetes, its manifestations, risk factors and complications have already been done, there are no previous community based studies on prevalence of type 2 diabetes or its precursors (prediabetes, obesity, overweight and clinical features of insulin resistance) in South Asian adult youth less than 30 years age. To estimate the size of diabetes prone population, this study aimed to determine the prevalence of diabetes, prediabetes, obesity, overweight and clinical features of insulin resistance in community dwelling youth of 18–30 years age using multistage cluster sampling.

Materials and Methods

After obtaining the approval of the Human Ethics Committee of Government Medical College Thiruvananthapuram (HEC. No 04/19/2018 dated 23/2/2018), this cross sectional study was done over a period of two years starting May, 2018**.** Participants with age between 18 years and 30 years were included. One primary health centre in the Urban, rural and coastal areas each in Trivandrum District, Kerala, India were chosen for the study. The urban health unit (Urban Health Centre Pangappara) caters for approximately 140,000 population and the other centres (Primary Health centres Vakkom and Anchuthengu) for 30000 inhabitants each**.** The required sample size was calculated to be 1021 subjects assuming 80% power and alpha error fixed at 5% on a desired precision level of 5% and an expected prevalence of 20%.

Multi-stage cluster sampling was used to get a representative sample. A randomly selected panchayath ward (local body) was taken as the primary sampling unit. Six panchayath wards from urban and rural areas and four wards from the coastal area selected were included in the study. From each panchayath ward, 60 subjects aged 18–30 years were recruited through house-to-house survey starting at a house considered nearest to a health facility like a primary health centre or subcentre. Consecutive houses were visited going in a clockwise manner from the initial house and including the houses along pocket roads till all the houses in the street were completed or needed sample size of 60 was achieved in given ward. Subjects with any acute illness in last 2 weeks, history of smoking, alcoholism, or any other chronic illness were excluded from the study. Patients on any type of steroid medication (systemic, topical or inhaled) were excluded from the study. Only one subject was included from one house. In households having more than one subject fulfilling the inclusion and exclusion criteria, KISH tables were used to ensure the randomness of sampling.

The field survey was conducted by registered nurses who were specially trained by the investigators for conducting this survey. The services of a resident community level health worker (accredited social health activist-ASHA) was utilised for finding subjects eligible for the study. This survey team, on visiting the households of eligible participants, explained the procedure, and confirmed their willingness. A written informed consent was obtained from all participants for participation in the study and for use of the patient data for research and educational purposes. All the procedures in the study followed the guidelines laid down in Declaration of Helsinki 2013.

Each participant was subjected to a detailed interview using an interviewer administered questionnaire including socio-demographic characteristics of the individuals, their risk factors for diabetes and metabolic syndrome, and their personal habits pertaining to dietary practices, physical activity, tobacco use and alcohol consumption. The information was recorded in a predesigned proforma. The socioeconomic classification method used was based on an occupation based 3 class classification previously described[5] It divides the population into routine class, intermediate class and the higher class based on the occupation of the head of the family.[5] An anthropometric assessment, including measurement of height, weight, body mass index, abdominal circumference, hip circumference, waist circumference, neck circumference, mid arm circumference and calf circumference were measured. Abdominal circumference was measured as the circumference of the abdomen at the level of the umbilicus measured with the measuring tape parallel to the ground. Hip circumference was measured as the body circumference measured at the level of greater trochanters with the measuring tape kept parallel to the ground. Waist Circumference was measured as the circumference of the abdomen at the level of midpoint between the lowest rib and iliac crest in the mid axillary line. Neck Circumference was measured at the level of mid-point between the vertebra prominence (C7) and the occipital protuberance. Midarm circumference was measured at the level of midpoint between the acromion process and the lateral epicondyle. Calf circumference was taken at the level of maximum circumference of the calf which approximately at the junction of upper 1/3rd and lower 2/3rd of the line joining the tibial tuberosity and the medial malleolus. Features of insulin resistance like acanthosis nigricans and skin tags, features of hyperandrogenism like hirsutism and severe acne were also noted on examination. Hirsutism was assessed by examining the 5 accessible areas (upper lip, chin, arms, upper and lower abdomen) out of the 9 areas from the Ferriman Gallaway score[6] A score of 3 or more from these 5 areas (maximum score of 20) was considered to be significant. Severe acne was defined as more than 20 lesions on face, pustular acne or involvement of atypical sites like chest or back. In the absence of information on sonographic appearance of the ovaries (for polycystic morphology), women having one of the other 2 components i.e clincal hyperandrogenism (hirsuitism or severe acne) and menstrual irregularity (signifying anovulation) or both were considered to be having clinical features of PCOS for the purpose of this study. Hicks digital weighing scale (Aligarh, India), Non-stretchable tape (Hamburg, Germany), were the equipment used for anthropometric evaluation. A single seated

blood pressure measurement after 5 minutes of rest using Heine G5 non-mercuric sphygmomanometer (Deutschland, Germany) and random capillary blood glucose measurement using On Call® Plus glucometer (AconBiotech, Hangzhou, China**)** was done.

Adults with body mass index (BMI) 23–24.9 kg/m^2 were considered as overweight and those with BMI of 25 kg/m^2 or more were considered as obese based on South Asian cut offs[7] Prevalence of obesity based on the global cut offs (overweight as BMI 25–29.9 kg/m^2 and obesity as BMI ≥ 30 kg/m^2) was also calculated.[8] Participants who had a random capillary blood glucose level more than 130 mg% were called to the nearby health facility (primary health centre) where an oral glucose tolerance test (OGTT) was done to confirm or rule out diabetes mellitus.[9] OGTT started with a fasting (8 hour fasting) blood sample collection, which was followed by a 75-gram anhydrous (or equivalent) glucose given orally as a solution in 250 ml of water, and plasma collection at120 minutes from glucose ingestion was done for plasma glucose estimation. The patients who refused to come to the hospital for OGTT were given the option of sampling from home for venous blood HbA1c estimation. Diagnosis of diabetes was made if the fasting plasma glucose (FPG) value was ≥126 mg/dl, or 2-hour post glucose load plasma glucose (PPG) value was ≥200 mg/dl, or HbA1c was ≥6.5%. Prediabetes was diagnosed if FPG value was ≥100 mg/dl and <126 mg/dl (impaired fasting glucose -IFG), or PPG value was 140 mg/dl to 199 mg/dl (impaired glucose tolerance -IGT), or HbA1c was between 5.7 and 6.4% based on ADA guidelines.[10] All subjects with a random capillary glucose more than 140 mg% were also considered to be prediabetic. Subjects with acanthosis nigricans, two or more skin tags and in women, any of the components of polycystic ovary syndrome (PCOS) phenotype (menstrual cycle length >35 days or <21 or hirsutism), or significant acne were considered to have 'clinical features of insulin resistance' (CFIR). In accordance with the ACC-AHA guidelines for hypertension 2017, a participant was considered to have a normal blood pressure (BP) if Systolic BP was <120 mm of Hg and Diastolic BP was <80 mm of Hg. Systolic BP of 120–129 mm of Hg with a diastolic BP <80 mm of Hg was defined as 'elevated'. Stage 1 hypertension was said to be present if systolic BP was 130–139 mm of Hg with or a diastolic BP was 80–89 mm of Hg. Stage 2 hypertension was said to be present if systolic BP was ≥140 mm of Hg with or a diastolic BP was ≥90 mm of Hg.[11]

Each biochemical parameter was estimated using same analyser for all subjects under a National Accreditation Board for Laboratories (NABL) certified quality control program. Plasma glucose estimation was done with the glucose oxidase- peroxidase method (GOD-POD). HbA1c was estimated using a National Glucose Standardization Program (NGSP) certified high performance liquid chromatography (HPLC) system (BIORAD-D10, USA).

The demographic, anthropometric, clinical and biochemical data were tabulated in MS Excel 2017. Quantitative variables were summarized as mean ± SD or median and interquartile range (IQR) based on the normality of distribution. Statistical analysis was done using SPSS version 25. Prevalence of diabetes, prediabetes, obesity overweight and CFIR is expressed in percentages. To find the associations of prediabetes, diabetes, obesity and CFIR, categorical variables are compared using Chi-square test. To compare two independent groups of continuous variables, Student t-test or Mann-Whitney U test was used, based on the distribution. Pearson R was used to express the correlation between variables. A P value of < 0.05 was considered significant for all comparisons. Missing data points were not imputed. To find independence of association of interrelated variables with hyperglycemia and CFIR, binary logistic regression was used after dichotomizing the variables at the mean or median.

Results

Of the 1128 persons meeting the age criteria 97 were excluded due to various exclusion criteria. A total of 1031 participants were eligible for the inclusion in the study. Rural, urban and coastal areas constituted 394, 368 and 269 of the participants respectively. Females constituted 806 participants. On the basis of the occupation of the earning member of the family, 10.96% (n = 113) subjects were from higher class, 17.3% (n = 174) were from the intermediate class and the remaining 71.6 (n = 739) were from the routine class. Other demographic characteristics of the participants are shown in Table 1.

Prevalence of diabetes and prediabetes, obesity and overweight: Prevalence of diabetes and pre-diabetes was found to be 0.48%. (n = 5) and 2.4% (n = 25) respectively. Using the cut-offs for Asian Indians for obesity and overweight, 291 (28.2%) and 166 (16.1%) subjects respectively were obese and overweight [Figure 1]. When using the WHO BMI cut-offs for overweight and obesity 55 (5.3%) subjects were obese (BMI ≥30 kg/m^2) and 237 (23.0%) were overweight (BMI ≥25 kg/m^2 & < 30 kg/m^2). Prevalence of over-weight/obesity was found to be statistically similar in participants from rural and coastal areas when compared to the urban population. The mean abdominal circumference of subjects was 75.2 ± 12.8 cm in women and 73.8 ± 13.5 among men. Significantly higher proportion of females (258, 31.9%) than males (35, 15.6%) P < 0.001) had abdominal circumference more than the recommended cut-offs of abdominal obesity for South Asians (ie 80 cm for females and 90 cm for males).[12] **Family history of diabetes:** Family history of diabetes in a first degree relative was present in 362 (35.1%) participants, 253 (24.5%) subjects had a family history of hypertension, 66 (6.4%) gave a family history of dyslipidaemia, and 25 (2.42%) subjects reported a family history of cardiovascular/cerebrovascular disease in a first degree relative. **Acanthosis:** 182 (17.7%) participants showed features of acanthosis nigricans, 18 (1.74%) participants had 2 or more skin tags in the neck or upper chest. **PCOS Phenotype:** 86 (10.66% women had menstrual cycle length

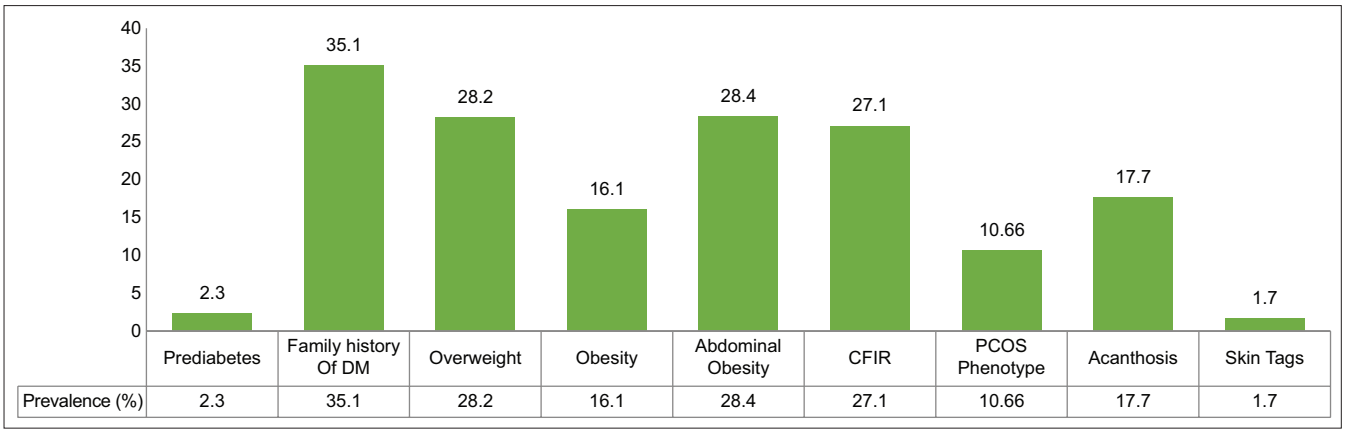

Figure 1: Prevalence of various precursors of T2DM in young adults

greater than 35 or lesser than 21 days, 12 had hirsutism and 38 women had significant acne. 115 women participants had at least one clinical manifestation of PCOS. **Clinical features of insulin resistance (CFIR):** Considering acanthosis, skin tags and presence of any of the components of PCOS phenotype, 279 (27.1%) subjects were found to have clinical features of insulin resistance (CFIR). **Hypertension:** Using the 2017-ACC- AHA criteria - 131 (12.7%) participants had 'elevated BP, 314 (30.5%) had stage 1 hypertension and 63 (6.1%) had stage 2 hypertension, whereas 508 (49.3%) participants had a normal blood pressure [Figure 2].

Associations of diabetes and prediabetes: Young men were more likely to have diabetes or prediabetes (4.9%) than young women (2.3%). Participants with diabetes and prediabetes had significantly higher waist circumference, neck circumference, Mid Arm circumference, hip circumference and calf circumference than the normoglycemic individuals. Notably, waist hip ratio (WHR) and abdominal circumference were not statistically different among the 2 groups [Table 2]. Significant association of diabetes or prediabetes status was also found with the anthropometry derived parameters of the product of BMI and Abdominal circumference (BMI X AC), the product of BMI with the sum of abdominal and hip circumference (BMI X [AC + HC]) and ratio of abdominal circumference by height (AC/Height). Of all the above parameters, the product of BMI with the sum of abdominal and hip circumference (BMI X [AC + HC]) correlated best with the status of hyperglycaemia (Pearson's r = 0.13, P value < 0.001) [Table 3].

Associations of CFIR: Dietary consumption of fat or sugar per day was not statistically different among those with features of IR and those without. Anthropometric parameters of weight, abdominal circumference, waist circumference, neck circumference, mid Arm circumference, hip circumference and calf circumference all were significantly higher in those with CFIR than those without. Among the derived parameters Abdominal circumference by height, product of abdominal circumference and BMI, and the product of BMI with the sum of abdominal and hip circumference were significantly higher in subjects with CFIR than those without. Among all the statistically significant parameters, the product of BMI with the sum of abdominal and hip circumference (BMI X [AC + HC]) correlated the best with CFIR (Pearson's r = 0.24, P value < 0.001) [Table 3].

Table 1: Socio demographic and anthropometric characteristics of studied population

Parameter	Mean±Std. Deviation or Mean (IQR) or *n* (%)
Socio geographic area - Rural	394
Urban	368
Coastal	269
Gender - Female	806
Mean Age (years)	24.0±4.0
Mean sleep duration per day (Hrs)	7.8±1.2
Sugar consumption (g/day)	17.8±8.8
Cooking oil consumption (g/day)	16.1±9.5
First degree relative with diabetes	362
First degree relative with hypertension	253
First degree relative with hyperlipidaemia	66
Clinical features of insulin resistance	279
Physical Activity Category -Sedentary	981
Moderately active	41
Highly active	2
BMI (kg/m2)	23.0±4.4
Mean systolic BP (mm of Hg)	114.1±13.9
Mean diastolic BP (mm of Hg)	76.2±10.6
Abd Circ (cm)-Females	75.2±12.8
Males	74.3±13.1
Waist Circumference (cm)- Females	84.9±13.6
Males	84.9±13.9
Hip Circumference (cm) Females	93.8±12.8
Males	93.5±13.3
Waist: hip ratio Females	0.90±0.07
Males	0.90±0.14
Random capillary glucose (mg/dl)	101.1±17.3
Total caloric intake/day (Kcal) : Females	1936±564
Total caloric intake/day (Kcal) : Males	1906±506

Table 2: Anthropometric indices and their association with hyperglycaemia and CFIR

	Hyperglycaemia			Clinical features of insulin resistance		
	Normal	Pre-diabetes/Diabetes	*P*	Normal	CFIR	*P*
BMI	22.9±4.3	25.2±5.7	0.010	22.48±3.9	25.03±5.26	<.001
Abdominal Circumference (AC)	74.6±12.8	79.2±12.4	0.079	73.5±12.4	79.4±13.9	<.001
Waist to Hip ratio	0.90±0.09	0.89±0.07	0.725	0.89±0.09	0.92±0.11	0.003
TMC Adiposity index	39.05±12.65	46.82±18.94	0.003	37.72±11.59	45.17±16.32	<.001

Table 3: Correlation of various anthropometric measures with CFIR and hyperglycemia

Parameter	Clinical features of IR		Hyperglycaemia	
	Pearson correlation (*r*)	*P*	Pearson Correlation (*r*)	*P*
Body Weight	0.21	<0.001	0.09	0.001
Abd Circumference	0.187	<0.001	0.09	0.004
Body Mass Index (BMI)	0.23	<0.001	0.10	0.001
Hip Circumference	0.13	<0.001	0.02	<0.001
Waist Circumference	0.15	<0.001	0.09	0.006
Neck Circumference	0.17	<0.001	0.02	0.002
Mid Arm Circumference	0.15	<0.001	0.10	0.002
Calf Circumference	0.21	<0.001	0.10	0.002
BMI X AC	0.24	<0.001	0.11	<0.001
AC/height	0.19	<0.001	0.08	0.006
TMC Adiposity Index	0.24	<0.001	0.13	<0.001

Upper limit of BMI X [AC + HC]: Among participants without any features of insulin resistance or hyperglycaemia the 97.5th centile of BMI X [AC + HC] for females and males respectively was 51.6 kg/m and 56.5 kg/m which may be considered as the upper cut off for this parameter index in South Asians. The upper limits of the other anthropometric parameters derived from the participants without CFIR or hyperglycaemia are presented in Table 4. These may be considered the normal values for Indian youth.

Discussion

This community-based cross sectional study done using multistage cluster sampling actively screened more than 1000 subjects from rural, urban and coastal areas of Thiruvananthapuram district in Kerala, India. This is the first study from India to do a community-based screening for diabetes and pre diabetes exclusively in a young adult population. The study showed a prevalence of diabetes in young Indians (18–30 years) to be 0.48% in this age group. One in forty (2.5%) subjects had pre-diabetes. Almost one half of the young adult population (47.7% subjects) is found to be overweight or obese. Similarly nearly half of the population has hypertension or 'elevated BP'.

There are no previous studies in South Asians reporting the community based prevalence of type 2 diabetes precursors in young adults. The mean age of onset of diabetes in a recently published study from a diabetes care centre in India was 44 years.[2] Studies from the USA report high prevalence of prediabetes in young adults (up to 15%).[13] Indirect estimates

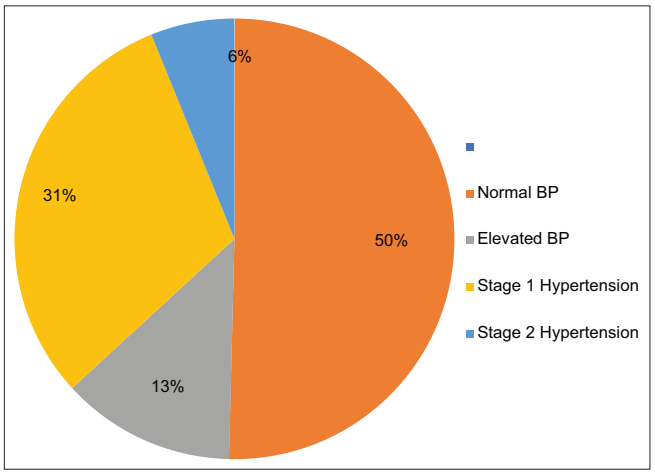

Figure 2: Frequency distribution of participants according to blood pressure categories (ACC-AHA 2017)

in young Indians have projected prevalence of overweight to be 14–25% in urban areas and 7–15% in rural areas, and that of obesity to be 4–7% in urban and 1–5% among rural subjects.[14] Hence the prevalence of overweight and obesity seen in the present study is much higher than what has been estimated previously. Also, in the present study the prevalence is similar in rural and urban areas which is against the trend seen in earlier studies. This could be due to the lack of difference in lifestyle and an overlap between the urban and rural regions. When overweight and obesity prevalence based on the Indian BMI cut off is compared to that of the WHO cut-offs the prevalence of overweight is seen to be lower (16.1% vs 23%) with the former.

Table 4: Normal values (2.5th, 85th, 95th and 97.5th percentiles) of the various anthropometric measures. (subjects without CFIR or hyperglycaemia)

Centile	Height (cm)	BMI (kg/m²)	Abd Circumference (cm)	Waist Circumference (cm)	Neck Circumference (cm)	Mid-arm Circumference (cm)	Calf Circumference (cm)	Hip Circumference (cm)	Waist to hip ratio
Females									
97.5th	176.0	29.0	97.0	106.0	37.0	36.0	37.0	112.1	1.08
95th	171.0	27.6	94.0	103.0	36.0	34.0	36.0	110.0	1.02
85th	165.0	25.3	85.0	96.0	34.0	32.0	34.0	104.0	0.95
2.5th	146.6	15.2	52.9	61.0	26.0	21.0	24.0	69.9	0.76
Males									
97.5th	174.3	29.7	97.3	111.4	36.0	38.3	38.0	116.0	1.19
95th	169.5	28.3	92.0	109.8	36.0	35.4	36.0	110.8	1.15
85th	164.0	26.1	83.1	96.0	34.0	31.0	34.0	102.0	0.97
2.5th	148.0	15.3	51.3	59.6	26.0	21.6	24.0	68.6	0.68

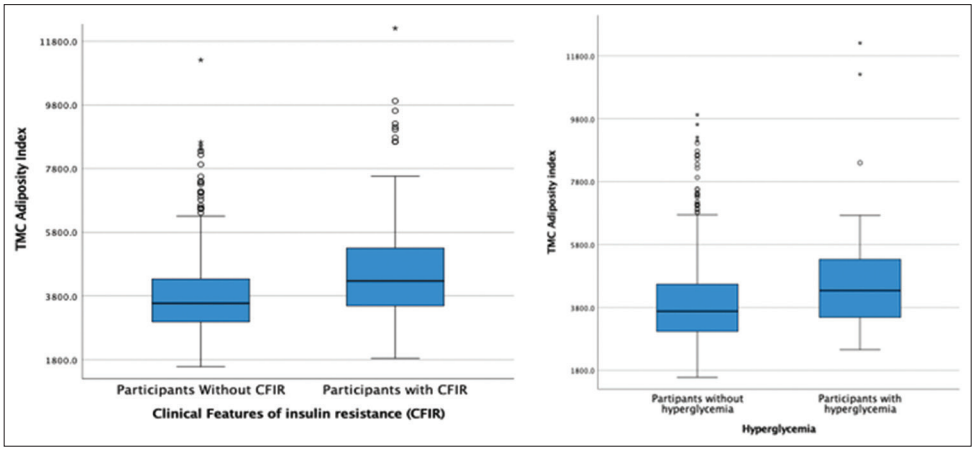

Figure 3: TMC-AI comparison between subjects with and without a) CFIR b) hyperglycemia

This could be because the class interval in the same is smaller compared to the latter ((23–24.9 kg/m² vs 25–29.9 kg/m²). Regarding clinical features of insulin resistance in Indian youth, previous community level data is absent. In the present study more than one fourth of young adults had CFIR. Studies done previously in the western population report a prevalence of hypertension to be around 12%, but the results may not be comparable to the present study as the criteria for diagnosis of hypertension may be heterogenous.[12]

The various anthropometric indices used in the study like the abdominal circumference, waist circumference, neck circumference, mid arm circumference, hip circumference and calf circumference and the derived indices like ratio of abdominal circumference by height, product of abdominal circumference and BMI, and the product of BMI with the sum of abdominal and hip circumference were significantly associated with hyperglycaemia and insulin resistance. The product of BMI with the sum of abdominal circumference and hip circumference (in meters) was the derived anthropometric parameter showing best correlation among all the parameters studied [Figure 3]. We propose that the above newly described index be named as 'Trivandrum Medical College (TMC) Adiposity Index' for the ease of communication. This index should be validated by future community based studies. It may help in planning community interventions to screen persons with insulin resistance in tandem with other known risk factors. Previously, Mamtani *et al*. had studied the predictive performance of different anthropometric indices and had described that waist circumference had the highest overall predictive accuracy and that waist circumference showed higher positive correlation with insulin resistance than BMI even in non-obese individuals.[15] The advantage of the TMC adiposity index is that it takes into consideration the total body weight and the fat mass around the abdomen, and adjusts it for the square of height. Upper limit (97.5th centile) of TMC Adiposity Index for females and males respectively may be proposed as 51.6 kg/m and 56.5 kg/m for South Asian youth. Importantly we could note a significant association between all the circumferences studied with CFIR, hyperglycaemia and BP elevation. An increase in correlation with these outcomes was seen when hip circumference was added to abdominal circumference as a marker of central adiposity. This could be the reason why TMC adiposity index was showing a slightly better correlation than other parameters with the outcomes related to insulin resistance. Neck circumference

also, correlated independently with fasting insulin levels in a previous comparative study on obese and non-obese individuals.[16] A study on Chinese population described the association of BMI and risk of incident diabetes to be stronger in younger age groups in clear contrast to the present study.[17]

In summary, the present study has shown a high prevalence of the risk factors of diabetes in the form of prediabetes, overweight and obesity, clinical features of insulin resistance. Waist to hip ratio and abdominal circumference may not be a good marker of hyperglycaemia in young adults. TMC adiposity index is a better anthropometric marker of insulin resistance, dysglycemia and elevated Blood pressure when compared to other anthropometric indices for Indian youth.

The strengths of the study were the population based survey using a robust sampling strategy and data generation on precursors of diabetes in the young adult population for the first time in South Asians. Major limitation of the study was the absence of serum insulin levels in all subjects for biochemical estimation of insulin resistance. Serum insulin estimation was not done as sample transportation to central laboratory every day from the field survey areas would be costly, cumbersome and make the test liable to fallacies. Another limitation was the disproportionately lower number of males who could participate in the study. This may be because, the survey was mostly done during working hours when men would be out for work.

This study highlights the importance of early screening for the pre-runners of diabetes and insulin resistance starting in early adulthood which have been found in a high proportion of participants in the present study. It needs to be evaluated whether a community level intervention for reduction of these risk factors can delay or prevent the progression to diabetes and to its micro and macrovascular complications

Conclusions

This study has estimated the prevalence of type 2 diabetes, prediabetes, overweight, obesity, elevated BP or hypertension based on community level study for the first time in South Asians. The newly proposed "TMC Adiposity index" i.e., the product of BMI with the sum of abdominal circumference and hip circumference showed promising correlation with hyperglycaemia, clinical features of insulin resistance, and elevated BP. Early recognition of hyperglycaemia, markers of IR and elevated BP in young age could provide an important window of opportunity for delaying or preventing future diabetes and other consequences of insulin resistance in high diabetes prevalence countries like India.

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Author contributions

AN and CJ conceived the project, analyzed data and prepared the manuscript. PKJ, RVJ and JR, planned the survey and reviewed the manuscript. GVG and SV conducted and oversaw the field survey. RG, SS researched the literature and reviewed the manuscript.

Role of funding source

The funding agency had no role in data collection, analysis, or interpretation; study design; participant recruitment; or any aspect pertinent to the study.

Ethics Committee approval

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Conflicts of interest

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