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Research: Epidemiology

Hypertriglyceridaemic waist phenotype as a simple predictive marker of incident diabetes in Asian-Indian men with prediabetes

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Abstract

Aim To determine prospectively the association of baseline hypertriglyceridaemic waist phenotype with incident diabetes in Asian-Indian men with impaired glucose tolerance.

Methods In a randomized 2-year diabetes prevention trial in 517 men with impaired glucose tolerance, 123 (23.8%) developed diabetes. Baseline anthropometric, metabolic and clinical variables were estimated. Associations of hypertriglyceridaemic waist phenotype (waist circumference ≥ 90cm and a serum triglyceride level of ≥ 1.7 mmol/l) with insulin resistance and incident diabetes were assessed using multiple linear regression and Cox's proportional hazard models, respectively.

Results Men with an isolated enlarged waistline and hypertriglyceridaemic waist phenotype had significantly higher BMI and percentage of total body fat compared with the group with normal waistline and triglyceride levels and the group with isolated hypertriglyceridaemia. The men with hypertriglyceridaemic waist phenotype had higher insulin resistance (mean ± SD homeostasis model assessment of insulin resistance value: 3.6 ± 1.5) compared with those in the isolated enlarged waistline, the isolated hypertriglyceridaemia or the normal waistline and triglyceride level groups (3.1 ± 1.4, 2.7 ± 1.0 and 2.5 ± 1.1, respectively, all $P < 0.05$ compared with hypertriglyceridaemic waist phenotype). Multiple linear regression analyses showed that hypertriglyceridaemic waist phenotype was significantly associated with insulin resistance after adjusting for age, BMI, family history, percentage of total body fat, smoking, alcohol intake, 2-h plasma glucose and HDL cholesterol level. Hypertriglyceridaemic waist phenotype was independently associated with incident diabetes after adjusting for the above confounders and gamma-glutamyl transferase (hazard ratio 1.49, 95% CI 1.01–2.21; $P = 0.047$). The association of hypertriglyceridaemic waist phenotype with incident diabetes was abolished when insulin resistance was introduced into the model (hazard ratio 1.39, 95% CI 0.092–2.10; P=0.12).

Conclusions Hypertriglyceridaemic waist phenotype is a simple clinical proxy measurement for insulin resistance and is strongly associated with incident diabetes in Asian-Indian men with impaired glucose tolerance.

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Introduction

The prevalence of cardiometabolic risk factors [1–4], particularly overweight/obesity [5], has increased in the last three decades, especially in developing countries, as a result of unhealthy dietary habits and sedentary behaviour. Multi-ethnic, prospective, long-term clinical trials have conclusively shown that diabetes can be prevented by lifestyle modification [6]. The identification of people at high risk of developing diabetes is therefore imperative for targeted prevention strategies. There is strong evidence that excess visceral fat, as measured by an enlarged waist circumference, is closely associated with insulin resistance and disturbance in lipid glucose metabolism [7]. Previous studies in Asian-Indian people [8], including one by the present authors [9], have reported an association of waist circumference with diabetes, suggesting that the increased accumulation of fat in the abdominal cavity may be one of the contributors to diabetes in this ethnic group. The increasing prevalence of central obesity, sedentary behaviour

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What's new?

- Hypertriglyceridaemic waist phenotype is shown to be associated with insulin resistance and can be used as a simple proxy for insulin resistance.
- In this study among Asian-Indian men with impaired glucose tolerance, the presence of hypertriglyceridaemic waist phenotype at baseline was found to be predictive of incident diabetes over the 2-year follow-up period.
- A combined measurement of waist circumference and fasting serum triglyceride levels may help in identifying people at risk of developing Type 2 diabetes and in the institution of preventive strategies.

and unhealthy dietary habits lead to hypertriglyceridaemia which is a risk factor for insulin resistance, Type 2 diabetes and prediabetes [10]. Enlarged waist circumference cannot be distinguished from intra-abdominal adiposity and subcutaneous fat depots; therefore, Lemieux *et al.* [11] proposed that the presence of elevated triglyceride levels in the presence of central adiposity be used as a 'proxy' measure to identify individuals with an increased risk of the atherogenic lipid triad (elevated triglycerides, decreased high-density lipoprotein cholesterol, and raised small dense low-density lipoprotein cholesterol), hyperinsulinaemia and subclinical inflammation. In fact, the presence of the hypertriglyceridaemic waist phenotype was proposed as a simple screening method to identify participants at high cardiometabolic risk [12,13]. Although cross-sectional studies [14–17], including a study by the present authors [18], have shown an association of this phenotype with diabetes, the usefulness of this measure for the prediction of incident diabetes has been little studied. The present ancillary cohort analysis was performed using the prospective data from a primary prevention trial in Asian-Indian men with prediabetes [19] with the aim of analysing the possible association of hypertriglyceridaemic waist phenotype with incident diabetes, considering the simplicity of identifying the presence of hypertriglyceridaemic waist phenotype and its known association with other cardiometabolic risk factors.

Methods

Study participants

The present analyses are based on a cohort of men with impaired glucose tolerance who were followed up for 2 years in a randomized controlled primary prevention trial of diabetes in India [19]. A total of 537 men were randomized into two groups: a control arm, which received standard care advice only at baseline, and an intervention arm, which received automated, customized text messages about healthy lifestyle habits in addition to standard care advice. The study showed for the first time that text messaging is an effective and acceptable tool to deliver and support lifestyle modification to prevent Type 2 diabetes in Asian-Indian men with impaired glucose tolerance [19]. The present analysis was limited to 517 participants who had completed the 2-year follow-up. As both the control and intervention groups received one-to-one lifestyle advice at baseline and as the major objective of the present analysis was to explore the association of hypertriglyceridaemic waist phenotype with incident diabetes, we considered both the groups as a single cohort for our analysis. The men gave written informed consent to participate in the study, which was approved by the Institutional Ethics Committee of the India Diabetes Research Foundation, India.

Physical and biochemical analyses: body weight, height, waist circumference, percentage of total body fat and blood pressure were measured using standard procedures [19]. Body Mass Index (BMI; Kg/m^2) was calculated. The presence of impaired glucose tolerance was confirmed by a standard oral glucose tolerance test on two occasions in the course of 1 week. Plasma glucose (hexokinase method), fasting serum triglycerides, total cholesterol and HDL cholesterol levels, gamma-glutamyl transferase and alanine transaminase were measured using an automated analyser with appropriate quality control measures. Plasma insulin was measured using an electro chemiluminiscence assay in an Elesys Cobas e411 auto-analyzer (Roche Diagnostics, Mannheim, Germany). The lower detection limit was 0.2 μU/ml with a measuring range of 0.2–1000 μU/ml. Homeostasis model assessment was used to assess insulin resistance [20] using fasting plasma glucose and insulin values. The insulinogenic index was calculated by dividing the increment in serum insulin at 30 min by plasma glucose at 30 min during the oral glucose tolerance test [21].

Definition of variables

The diagnosis of diabetes was based on the World Health Organization (WHO) diagnostic criteria [22]: a fasting plasma glucose concentration of ≥ 7.0 mmol/l (≥ 126 mg/dl) and/or a 2-h plasma glucose concentration of ≥ 11.1 mmol/l (≥ 200 mg/dl) after a 75-g oral glucose load [22]. At 6- and 18-month reviews, 2-h plasma glucose concentration was measured and if the value was ≥ 11.1 mmol/l, the diagnosis was confirmed with an oral glucose tolerance test within 1 week. At annual follow-up, all participants without diabetes underwent an oral glucose tolerance test.

The thresholds for waist circumference and triglyceride level recommended for the Asian population by the International Diabetes Federation [23] were used to categorize the participants into four groups: (1) a group with normal waistline and triglycerides (waist circumference < 90 cm; serum triglyceride level < 1.7 mmol/l); (2) a group with an enlarged waistline and normal triglyceride level (isolated enlarged waistline: waist circumference ≥ 90 cm and serum triglycerides < 1.7 mmol/l);

(3) a group with normal waistline and raised triglycerides level (isolated hypertriglyceridaemia: waist circumference < 90 cm; serum triglycerides ≥ 1.7 mmol/l); and 4) a group with hypertriglyceridaemic waist phenotype (waist circumference ≥ 90 cm and serum triglycerides ≥ 1.7 mmol/l).

Statistical analysis

General characteristics of individuals among the study phenotypes were compared using one-way ANOVA for normally distributed variables after Bonferroni *post hoc* correction, the Kruskal–Wallis test for skewed variables with Dunn's multiple comparison test, and the chi-squared test for categorical measures after Bonferroni *P*-value correction. Linear regression analyses were used to assess associations of isolated enlarged waistline, isolated hypertriglyceridaemia and hypertriglyceridaemic waist phenotype with insulin resistance as measured by homeostasis model assessment (dependent variable). Adjustment for age, BMI, family history of diabetes, hypertension, percentage of total body fat, smoking and alcohol consumption was also performed in Models 1 and 2 for 2-h plasma glucose concentration and HDL cholesterol level. Cox regression analysis was used to calculate hazard ratios and the corresponding 95% CIs for the risk of Type 2 diabetes for different categories of enlarged waistline and/or hypertriglyceridaemia as shown above, after adjusting for potential confounding factors known to affect the outcome variable. All associations of an enlarged waistline ≥ 90cm (irrespective of triglyceride level) and hypertriglyceridaemia (triglycerides ≥ 1.7 mmol/l, irrespective of waist circumference) with incident diabetes were also assessed. Cox's proportional hazard models were computed to assess the relative risk of hypertriglyceridaemic waist phenotype with incident diabetes after adjusting for the potential confounding variables. The covariates that were shown to have significant univariate associations with hypertriglyceridaemic waist phenotype were chosen for the multivariate analyses. Age, family history of diabetes and 2-h plasma glucose concentration values were included in the model because of their strong associations with diabetes. Analyses were adjusted for the dichotomous variables (study group, family history, known hypertension, smoking and drinking habits) and for the continuous variables (baseline age, BMI, percentage of total body fat, 2-h plasma glucose concentration, gamma-glutamyl transferase and homeostasis model assessment of insulin resistance). Survival curves were computed based on the phenotype categories. A P value < 0.05 was taken to indicate statistical significance. SPSS software (IBM SPSS Statistics for Windows, v. 19.0. IBM Corp., Armonk, NY, USA) was used for the analyses.

Results

The baseline characteristics of the four subgroups are shown in Table 1. The mean ± SD age of the study participants was 46.1 ± 4.7 years and the mean ± SD BMI was 25.8 ± 3.2 kg/m^2. At baseline, no participant was receiving lipid-modifying treatment and 138 were receiving hypotensive medication. At the 2-year follow-up, 123 (23.8%) of the men had developed diabetes.

Baseline characteristics of the study cohort stratified by waist circumference and triglyceride level are shown in Table 1. Isolated hypertriglyceridaemia was present in 64 men (12.4%), 167 men (32.3%) had the hypertriglyceridaemic waist phenotype and 231 men (44.7%) had fasting hypertriglyceridaemia. Central adiposity was present in 358 (69.2%) men, of whom 191 (36.9%) had isolated enlarged waist phenotype. The men with isolated enlarged waistline and hypertriglyceridaemic waist phenotypes had significantly higher BMI and percentage of total body fat compared with the group with normal waist circumference and triglyceride levels and the group with isolated hypertriglyceridaemia ($P < 0.001$). Men with the hypertriglyceridaemic waist phenotype had higher diastolic blood pressure compared with the group with normal waistline and triglyceride levels ($P < 0.05$). No significant differences in fasting and 2-h plasma glucose concentration levels were observed between the groups. As expected, the groups with hypertriglyceridaemic waist phenotype and isolated hypertriglyceridaemia phenotypes had significantly higher total cholesterol and triglyceride levels and lower HDL cholesterol levels compared with the group with normal waistline and triglyceride levels and the group with isolated enlarged waistline ($P < 0.0001$). The group with hypertriglyceridaemic waist phenotype had higher insulin resistance compared with the group with normal waistline and triglyceride levels and the group with isolated hypertriglyceridaemia ($P < 0.0001$ for both), and also had higher values than the group with isolated enlarged waistline ($P < 0.05$). The men with the hypertriglyceridaemic waist phenotype also had a higher insulinogenic index compared with the group with normal waistline and triglyceride levels ($P < 0.05$).

The association between insulin resistance and the categories of abnormality assessed by multiple linear regression analyses are shown in Table 2. Hypertriglyceridaemic waist phenotype was positively associated with insulin resistance after adjusting for an array of potential confounders. Isolated enlarged waistline was observed to have a significant association with insulin resistance in an unadjusted model, but the association was attenuated when anthropometric and other confounding variables were entered into the model. Isolated hypertriglyceridaemia was not shown to be significantly associated with homeostasis model assessment of insulin resistance.

Table 3 shows the hazard ratios attributed to the different variables, with and without adjusting for the study groups (intervention vs standard care), baseline age, BMI, percentage of total body fat, family history, smoking and alcohol habits (Model 1), 2-h plasma glucose concentration, total cholesterol and HDL cholesterol (Model 2) and gamma-glutamyl

Table 1 Anthropometric and clinical characteristics of subjects based on the categories of waistline and triglyceride levels

Characteristic	Study group				
	All participants: $N = 517$	Normal waistline and triglyceride levels: $n = 95$, 18.4%	Isolated enlarged waistline: $n = 191$, 36.9%	Isolated hypertriglyceridaemia: $n = 64$, 12.4%	Hypertriglyceridaemic waist phenotype: $n = 167$, 32.3%
Mean ± SD age, years	46.1 ± 4.7	46.2 ± 4.8	46.0 ± 4.8	45.3 ± 4.4	46.4 ± 4.5
Mean ± SD BMI, kg/m^2	25.8 ± 3.2	23.5 ± 2.3	26.8 ± 2.7†,¶	23.8 ± 2.7	26.8 ± 3.2†,¶,**
Mean ± SD waist circumference, cm	92.6 ± 7.3	85.2 ± 3.6	95.8 ± 5.4†,¶	84.9 ± 3.2	96.4 ± 6.4†,¶,**
Mean ± SD total percentage of body fat,%	27.5 ± 4.7	24.6 ± 4.5	28.6 ± 4.4†,¶	26.1 ± 4.3	28.3 ± 4.3†,¶,**
Mean ± SD blood pressure, mmHg					
Systolic	123.1 ± 13.7	120.6 ± 13.3	124.3 ± 13.0	120.2 ± 12.9	124.2 ± 14.9
Diastolic	80.2 ± 8.4	77.8 ± 8.4	80.6 ± 7.9*	80.0 ± 6.8	81.1 ± 9.3 *
Hypertension, *n* (%)	133 (25.7)	21 (22.1)	59 (30.9)	10 (15.6)	43 (25.7)
Family history, *n* (%)	273 (53.3)	43 (45.2)	107 (56.9)	35 (54.8)	88 (53.4)
Smoking, *n* (%)	117 (22.7)	17 (17.6)	40 (21.3)	19 (26.8)	41 (26.2)
Drinking, *n* (%)	191 (38.0)	30 (30.2)	64 (35.5)	24 (40.2)	73 (41.8)
Mean ± SD plasma glucose concentration, mmol/l					
Fasting	5.62 ± 0.54	5.57 ± 0.54	5.63 ± 0.53	5.54 ± 0.52	5.67 ± 0.56
2-h glucose	8.78 ± 0.82	8.72 ± 0.82	8.82 ± 0.82	8.82 ± 0.81	8.73 ± 0.82
Lipid profile, mmol/l					
Median (IQR) triglycerides	1.60 (1.19–2.11)	1.20 (0.99–1.39)	1.23 (1.04–1.47)	2.35 (1.93–2.82)†,¶	2.19 (1.91–2.70)†,¶
Mean ± SD total cholesterol	4.87 ± 0.91	4.67 ± 0.66	4.63 ± 0.88	5.09 ± 1.02*	5.16 ± 0.92†
Mean ± SD HDL cholesterol	0.89 ± 0.20	0.95 ± 0.18	0.93 ± 0.23	0.84 ± 0.17*	0.85± 0.17*
Mean ± SD gamma-glutamyl transferase	32.6 ± 25.5	25.8 ± 15.6	29.8 ± 21.6	37.2 ± 37.2*	37.7 ± 27.3*,‡
Mean ± SD alanine transaminase	15.0 ± 8.8	14.3 ± 8.6	14.1 ± 7.1	16.5 ± 10.3	15.8 ± 8.8
Mean ± SD HOMA-IR (dimensionless)	3.1 ± 1.4	2.5 ± 1.1	3.1 ± 1.4*,§	2.7 ± 1.0	3.6 ± 1.5†,‡,**
Median (IQR) insulinogenic index, pmol/mmol	48.1 (28.8–79.7)	41.8 (24.0–62.2)	50.3 (30.6–81.5)	45.2 (26.9–73.6)	53.8 (32.1–83.0)*

P values were calculated using one-way ANOVA after *post hoc* Bonferroni correction, the Kruskall–Wallis test (for skewed variables) after *post hoc* Dunns correction and the chi-squared test (categorical measures) after Bonferroni correction.
*$P < 0.05$ vs normal waistline and triglycerides level.
$^{\dagger}P < 0.001$ vs normal waistline and triglycerides level.
$^{\ddagger}P < 0.05$ vs enlarged waistline and normal triglycerides level (isolated enlarged waist).
$^{\P}P < 0.001$ vs enlarged waistline and normal triglycerides level (isolated enlarged waist).
$^{\S}P < 0.05$ vs normal waistline and high triglycerides level (isolated hypertriglyceridemia).
**$P < 0.001$ vs normal waistline and high triglycerides level (isolated hypertriglyceridemia).

Table 2 Linear regression analyses showing the association of different abnormalities with insulin resistance

	Unadjusted analysis		Model 1		Model 2	
Baseline variable	Regression coefficient (95% CI)	*P*	Regression coefficient (95% CI)	*P*	Regression coefficient (95% CI)	*P*
Normal waistline and triglyceride level	Ref	–	Ref	–	Ref	–
Isolated enlarged waist	0.25 (0.13–0.36)	< 0.0001	0.13 (−0.01–0.26)	0.052	0.13 (−0.01–0.26)	0.067
Isolated hypertriglyceridaemia	0.14 (−0.02–0.28)	0.090	0.08 (−0.08–0.22)	0.345	0.04 (−0.12–0.20)	0.620
Hypertriglyceridaemic waist phenotype	0.38 (0.27–0.50)	< 0.0001	0.27 (0.14–0.41)	< 0.0001	0.23 (0.09–0.37)	0.001

Dependent variable: insulin resistance (homeostasis model assessment: log-transformed).
Model 1: adjusted for age, BMI, family history of diabetes, hypertension, body fat percentage, smoking and drinking habits.
Model 2: Model 1 further adjusted for 2-h plasma glucose during oral glucose tolerance test and HDL cholesterol.

transferase levels (Model 3). The hazard ratio of the unadjusted model was 1.53 (95% CI 1.07–2.20; $P = 0.019$). The relationship remained significant after adjusting for the above confounding factors [Model 3: hazard ratio 1.49, 95% CI 1.01–2.21; $P = 0.047$ (Fig. 1)]. Addition of insulin resistance to Model 3 nullified the significance (Model 4; hazard ratio 1.39, 95% CI 0.92–2.10; $P = 0.119$); however, addition of β-cell function (as estimated by the insulinogenic index, omitting insulin resistance) did not affect the association of hypertriglyceridaemic waist phenotype with incident diabetes (Model 5: hazard ratio 1.59, 95% CI 1.05–2.23; $P = 0.040$). Hypertriglyceridaemia (≥ 1.7 mmol/l, ignoring waist circumference) was observed to have a significant association with diabetes in an unadjusted model (hazard ratio 1.48, 95% CI 1.04–2.11; $P = 0.029$) which was attenuated when anthropometric and demographic variables were added (Model 1: hazard ratio 1.41, 95% CI 0.99–2.03; $P = 0.059$). Waist circumference did not show a significant association, even in the unadjusted model [hazard ratio 1.34, 95% CI 0.90–2.01; $P = 0.152$ (Table 3)].

Alternative combinations of thresholds for waist circumference and triglyceride levels were explored in relation to incident diabetes and baseline insulin resistance (homeostasis model assessment of insulin resistance value ≥ 4.1), but offered no improvement regarding sensitivity and specificity over the chosen threshold of waist circumference ≥ 90 cm and triglyceride level ≥ 1.7 mmol/l (results not shown).

Discussion

The present analyses showed that hypertriglyceridaemic waist phenotype was associated with insulin resistance and higher risk of diabetes in Asian-Indian men with impaired glucose tolerance. Men with the hypertriglyceridaemic waist phenotype were also observed to have elevated compensatory early phase insulin secretion. Although baseline glycaemia levels were similar in the four subgroups, the presence of hypertriglyceridaemic waist phenotype alone conferred a higher risk of diabetes. The findings are in accordance with other studies: a Canadian study of healthy men in which

Table 3 Cox-proportional hazard model for incident diabetes during the 2-year follow-up

	Hypertriglyceridaemic waist phenotype			Triglycerides only			Waist circumference only		
Variable	Regression coefficient (SE)	HR [95% CI]	*P*	Regression coefficient (SE)	HR [95% CI]	*P*	Regression coefficient (SE)	HR [95% CI]	*P*
Unadjusted	0.43 (0.18)	1.53 [1.07–2.20]	0.019	0.39 (0.18)	1.48 [1.04–2.11]	0.029	0.29 (0.21)	1.34 [0.90–2.01]	0.152
Model 1	0.38 (0.19)	1.47 [1.02–2.13]	0.041	0.35 (0.18)	1.41 [0.99–2.03]	0.059	–	–	–
Model 2	0.41 (0.20)	1.50 [1.01–2.22]	0.043	–	–	–	–	–	–
Model 3	0.40 (0.20)	1.49 [1.01–2.21]	0.047	–	–	–	–	–	–
Model 4	0.35 (0.21)	1.39 [0.92–2.10]	0.119	–	–	–	–	–	–
Model 5	0.41 (0.19)	1.59 [1.05–2.23]	0.040	–	–	–	–	–	–

HR, hazard ratio. Dependent variable: diabetes vs no diabetes.
Hypertriglyceridaemic waist phenotype category was dichotomized (hypertriglyceridaemic waist phenotype vs others); triglycerides only ≥ 1.7 mmol/l; waist circumference only ≥ 90 cm.
Model 1: Adjusted for age, group, BMI, total body fat percentage, family history of diabetes, hypertension, smoking and drinking; Model 2: Model 1 + 2 hr plasma glucose, cholesterol and HDL cholesterol; Model 3: Model 2 + gamma-glutamyl transferase; Model 4: Model 3 + insulin resistance
Model-5: Model-3 + insulinogenic index.

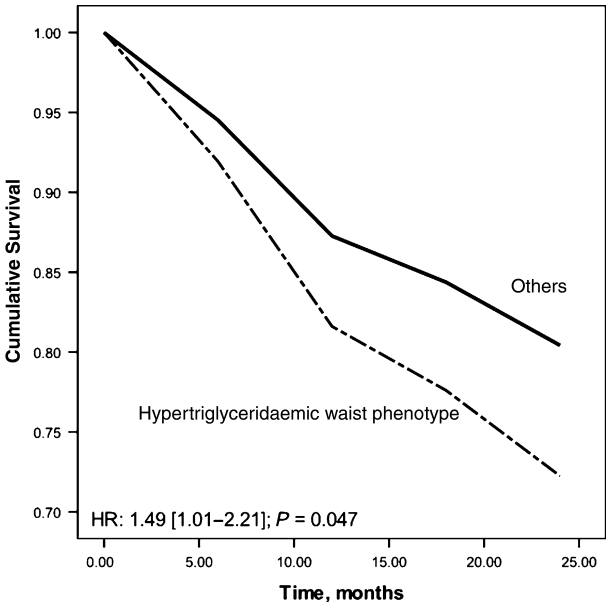

FIGURE 1 Survival curve for the men who remained free of diabetes, stratified by hypertriglyceridaemic waist phenotype category. Curve plotted after adjusting for study group, age, BMI, percentage of total body fat, family history of diabetes, hypertension, alcohol consumption, smoking habits, and 2-h plasma glucose, total cholesterol, HDL cholesterol and gamma-glutamyl transferase levels. HR, hazard ratio.

hypertriglyceridaemic waist phenotype was associated with hyperinsulinaemia as well as elevated apolipoprotein B, and small dense LDL [11], a Chinese community-based prospective study in urban adults which showed an association of hypertriglyceridaemic waist phenotype with diabetes [24] and a study in elderly men which showed an increased association of hypertriglyceridaemic waist phenotype with 'glucometabolic risk' and decreased insulin sensitivity [17]. Previously, our group showed an association of hypertriglyceridaemic waist phenotype with atherogenic dyslipidaemia and glucose intolerance in a cross-sectional analysis in an Asian-Indian population [18]. The present prospective data suggest a possible aetiological association of hypertriglyceridaemic waist phenotype with Type 2 diabetes. This was rendered nonsignificant by inclusion of insulin resistance in the model, suggesting that the association between hypertriglyceridaemic waist phenotype and risk of incident Type 2 diabetes was mediated through insulin resistance.

In the present cohort, hypertriglyceridaemia was found to have a marginal association with incident diabetes, whereas an enlarged waist circumference did not show an association. We reported a strong association of central adiposity with Type 2 diabetes in a previous cross-sectional study in an Indian population [9]. Similar observations have also been reported in a migrant South-Asian population by McKeigue *et al.* [8]. The discordant observation noted in the present study could be attributable to the fact that the majority of the at-risk participants in our study had an enlarged waist circumference at baseline (69.2%), such that an enlarged waist circumference *per se* might have offered less potential for Type 2 diabetes risk discrimination than in the general population.

In an earlier study of people with normoglycaemia, we noted a strong association between triglyceride levels and insulin resistance in the Asian-Indian population. Using the receiver-operating characteristic procedure, a triglyceride concentration of ≥ 1.7 mmol/l was found to have a sensitivity of 66.2% and specificity of 62.2% to distinguish insulin resistance [10]. The positive association of triglyceride levels with incident diabetes noted in the present study suggested that it might have a pathogenic role mediated through insulin resistance; however, the effect was enhanced when hypertriglyceridaemia co-existed with an enlarged waist circumference.

The association of hypertriglyceridaemic waist phenotype with incident diabetes was significant even after the adjusting for 2-h plasma glucose concentration and gamma-glutamyl transferase, but the relationship was attenuated after adjusting for homeostasis model assessment of insulin resistance. Additionally, hypertriglyceridaemic waist phenotype has been shown to be associated with increased visceral adiposity in patients with glucose intolerance [13]. For a given BMI, Asian-Indian people have a higher waist–hip ratio and a greater accumulation of abdominal fat than many other populations [10,25–27]. The presence of upper body adiposity coupled with hypertriglyceridaemia appears to induce a high degree of insulin resistance [18], even among non-obese Asian-Indian people.

There is no universally accepted, clinically approved numeric expression that defines insulin resistance and β-cell dysfunction. The threshold for insulin resistance varies among different ethnic groups, so the use of these measures requires careful interpretation and expertise, which may not be feasible in routine clinical practice. Although homeostasis model assessment provides a robust, clinical and epidemiological tool with which to assess insulin action, its application may be limited in non-obese participants [28]. Plasma insulin level is not routinely measured in most clinical laboratories, especially in developing countries; therefore, as an alternative simple approach, clinical measures such as BMI, waist circumference [29] and lipids (HDL cholesterol/triglycerides ratio) [18] have been proposed as proxy measures to identify participants with high risk of insulin resistance and compromised β-cell function; however, these measures explain only a modest amount of the variation in directly measured insulin resistance compared with insulin-based indices. Hypertriglyceridaemic waist phenotype offers a simple, alternative tool to screen for individuals with a higher risk of incident diabetes among those with prediabetes.

The strengths of the present study are its prospective design, its inclusion of Asian-Indian people who have a high

susceptibility to develop diabetes and the that fact that it shows, even among a group of individuals at high risk, with impaired glucose tolerance, that hypertriglyceridaemic waist phenotype could be used to predict incident diabetes.

The study also has some limitations. The study group comprised only men and, therefore, the association of hypertriglyceridaemic waist phenotype with incident diabetes in women remains to be studied. Although imaging data would be ideal for the determination of visceral adiposity, it is generally not feasible for a large epidemiological analysis, because of the high cost of imaging and the need for specialized technical expertise. The use of hypertriglyceridaemic waist phenotype as a predictor of incident diabetes has significant public health importance with regard to implementing preventive studies. Hypertriglyceridaemic waist phenotype can be assessed by routine laboratory measures and can serve as a simple screening tool to identify people with insulin resistance, who have a high risk of developing diabetes.

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Competing interests

None declared.

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