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Comparison of Insulin Sensitivity Measures in South Asians

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Abstract

Objective—South Asians have increased visceral adiposity, insulin resistance and greater prevalence of type 2 diabetes and cardiovascular disease when compared to Caucasians of European origin. Surrogate markers of insulin resistance such as the composite insulin sensitivity (Matsuda) index correlate with glucose clamps in other populations, but ethnicity can affect these indices. We compared the Matsuda index, homeostasis model assessment (HOMA-IR), quantitative insulin sensitivity check index (QUICKI), and triglyceride/HDL ratio to insulin sensitivity derived from euglycemic clamps in healthy South Asians and Caucasians.

Materials/Methods—Twenty-three healthy South Asians and 18 Caucasians matched for age (mean±SE = 33.6±2.1 vs. 36.0±3.0 yrs) and BMI (25.2±1.1 vs. 24.6±0.9 kg/m²) underwent 75 gram oral glucose tolerance test (OGTT), 2-hr euglycemic hyperinsulinemic clamp (240 pmol·m⁻²·min⁻¹), fasting lipid profile, and anthropometric measures.

Results—South Asians had higher fasting insulin (41±5 vs. 21±2 pmol/l; p=0.002) and lower HDL-C (1.25±0.06 vs. 1.56±0.10 mmol/l; p=0.010), but similar fasting glucose (5.0±0.1 vs. 4.9±0.1 mmol/l) levels vs. Caucasians. South Asians had significantly decreased measures of insulin sensitivity derived from both the euglycemic clamp (24.9±1.3 vs. 41.4±1.9 μmol·kg⁻¹·min⁻¹; p<0.0001) and OGTT (Matsuda Index 7.60±0.99 vs. 13.60±1.79; p=0.004). The Matsuda index correlated highly with clamp insulin sensitivity in South Asians (r=0.50; p=0.014) and Caucasians (r=0.47; p=0.046). HOMA-IR, QUICKI, and triglyceride/HDL ratio correlated with clamp values in South Asians, but not in Caucasians.

Conclusions—In South Asians, Matsuda index, HOMA-IR, QUICKI, and triglyceride/HDL ratio offer simple and valid surrogate measures of insulin sensitivity that can be employed in larger clinical or epidemiological studies in this ethnic group.

Keywords

composite insulin sensitivity index; Matsuda index; euglycemic clamp; HOMA-IR; QUICKI

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Introduction

South Asians have increased visceral adiposity, insulin resistance, type 2 diabetes and cardiovascular disease when compared to Caucasians of European origin [1, 2]. Recent projections estimate that in 2010 about 51 million patients with diabetes live in India, and these estimates project an increase to 87 million by 2030 [3]. South Asians have emerged as one of the fastest growing ethnic minority group in the United States. They develop myocardial infarction 5–10 years earlier than Caucasians and have more severe coronary artery disease [4, 5]. It has been shown that South Asians have decreased insulin sensitivity in addition to decreased HDL and increased triglycerides, which add to the risk of premature coronary artery disease.

Quantification of insulin sensitivity in this ethnic group has growing importance for large clinical and epidemiological studies. Currently the hyperinsulinemic euglycemic clamp serves as the gold standard for estimating whole body insulin sensitivity. However, glucose clamps are time consuming, complex and need a large amount of technical expertise; hence, they are not practical for large studies. Surrogate indices of insulin sensitivity including homeostasis model assessment (HOMA-IR) and the composite insulin sensitivity (Matsuda) index have been shown to correlate with SI_{clamp} values derived from euglycemic hyperinsulinemic clamps in other populations. However ethnicity and body composition may affect these surrogate indices [6, 7]. A recent study in Asian-Indian men showed only modest correlations with the quantitative insulin sensitivity check index (QUICKI) and beta cell secretory indices like fasting insulin-to-glucose ratio (FIGR) and fasting insulin (FI). However, these surrogate indices were obtained from fasting blood glucose and insulin levels and do not use dynamic measures to assess insulin sensitivity. The ratio of triglycerides to HDL cholesterol also has been proposed as a practical method for assessing insulin resistance based on readily available clinical laboratory information, and it is known to correlate with fasting insulin levels [8]. However, the cut-off value for the relationship between this ratio, fasting insulin, and the presence of insulin resistance also varies across different racial and ethnic populations [9, 10]. In the present study we compared insulin sensitivity measured by the euglycemic clamp to the Matsuda index obtained from a 75 gram oral glucose tolerance test (OGTT), HOMA-IR, QUICKI, and the triglyceride/HDL ratio among non-diabetic South Asians and Caucasians of European ancestry.

Methods

Study participants

Twenty three South Asians and 18 Caucasians of European origin participated in the study. South Asians were classified as participants who originated from India, Pakistan, Bangladesh, Nepal and Srilanka. Both first generation immigrants and second generation volunteers whose parents came from the above countries were included in the study. These participants were between the ages of 20 and 60 and lived in Boston and the eastern Massachusetts area. The groups were matched for age and BMI. Study participants with diabetes, hypertension, hyperlipidemia, coronary artery disease, hematological abnormalities, and liver or kidney disorders were excluded from the study. Women were studied during the follicular phase of the menstrual cycle to avoid the possible influence of gonadal steroids on insulin action. The results on some of these subjects have been reported previously [1, 2]. The study was conducted with the approval of the institutional review board of Brigham and Women's Hospital, and all study participants gave voluntary informed written consent at the screening visit.

Study procedures

Oral glucose tolerance test (OGTT)—All study participants underwent a standard 75 gram OGTT (Tru-Glu 75, Custom Laboratories, Inc., Baltimore, MD) after an 8 hr overnight fast. Blood was drawn from an IV catheter placed in a forearm vein before glucose administration (time 0) and at 30, 60, and 120 minutes after glucose ingestion for ascertaining glucose and insulin concentrations.

Euglycemic hyperinsulinemic clamp technique—The study was conducted in the Center for Clinical Investigation at Brigham and Women's Hospital. The euglycemic hyperinsulinemic clamp was performed on all participants as described by DeFronzo et al. [11]. All study participants received 200–300 gram carbohydrate diet for 3 days prior to the clamp. After an overnight fast, one intravenous line was inserted in the arm for administration of test substances, and a second line was inserted in a distal forearm or hand vein for drawing blood. Following the collection of basal samples, a priming dose of regular human insulin (Novolin U-100, Novo Nordisk, Princeton, NJ) was infused at a rate of $480 \text{ pmol} \cdot \text{m}^{-2} \cdot \text{min}^{-1}$ for 10 minutes followed by infusion at a constant rate of $240 \text{ pmol} \cdot \text{m}^{-2} \cdot \text{min}^{-1}$ for 110 minutes. Blood samples were obtained every 5 min from the hand vein that was kept in a hand warmer thermostatically controlled at 70°C to arterialize venous blood. A 20% dextrose solution was infused continuously to maintain the plasma glucose at fasting levels throughout the procedure.

Anthropometric measurements—Standard procedures were used to measure height and weight. With the participant standing, the waist circumference was measured at the narrowest point between the lower costal margin and iliac crest. The hip circumference was measured at the maximum circumference at the level of the femoral trochanters. Total fat and fat-free mass were measured using bioelectrical impedance (RJL systems, Clinton Township, MI). All anthropometric measurements and bioelectrical impedance measurements were done by the same investigator to minimize inter-investigator variability.

Biochemical analyses—Plasma glucose was measured by the glucose oxidase method (Glucose Analyzer, Hemocue, Inc., Mission Viejo, CA). Plasma insulin levels were assayed by radioimmunoassay (Linco Research, Inc., St. Louis, MO). Lipid profile was determined at the Brigham and Women's Hospital laboratory, which is accredited by the Lipid Standardization Program of the Centers for Disease Control and Prevention.

Calculations—HOMA-IR was calculated as $\text{fasting insulin (in } \mu\text{U/mL}) \times \text{fasting glucose (in mmol/L)} / 22.5$ [12]. QUICKI was calculated as inverse of the sums of logarithms of fasting insulin and fasting glucose [13]. Matsuda index was calculated from the OGTT using the formula described by Matsuda and DeFronzo [$10,000 / \text{square root of (fasting glucose} \times \text{fasting insulin)} \times (\text{mean glucose} \times \text{mean insulin during OGTT})$] [14]. The rate of glucose metabolism (M) during the euglycemic clamp was calculated as the steady state glucose infusion rate ($\mu\text{mol} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) during the last 40 min of the clamp after correcting for changes in the plasma glucose concentrations. Insulin sensitivity during the clamp (SI_{clamp}) was defined as the M value divided by the steady state plasma insulin concentration.

Statistical Analyses

All statistical analyses were performed with STATA (College station, TX) statistical software. Data are expressed as mean $\pm$ standard error (SE), except where specified otherwise. Group comparisons were performed using the t-test for unpaired data after checking for normality, and linear correlation was performed using Pearson's method to determine the correlation of the insulin sensitivity indices to the clamp measurements. The

strength of the rank correlation of each of the surrogate measures with the glucose clamp was also assessed by Kendall's tau coefficient.

Results

Table 1 shows the baseline demographic and clinical characteristics of the South Asian and Caucasian participants. The groups were well matched for age, BMI and other anthropometric measures. HDL levels were significantly lower among the South Asians when compared to Caucasians. Although South Asians had higher triglyceride levels than Caucasians, this difference was not significant. The total cholesterol and LDL levels between the two groups were comparable. There was a non-significant trend towards higher systolic and diastolic blood pressure in the South Asians.

South Asians had significantly higher fasting insulin levels and mean OGTT insulin levels compared to the Caucasians, whereas fasting glucose and mean OGTT glucose levels were similar in the two groups (Table 2). The South Asian subjects had significantly lower Matsuda index (7.60 ± 0.99 vs. 13.60 ± 1.79 ; $p = 0.004$), higher HOMA (1.56 ± 0.19 vs. 0.77 ± 0.07 $\mu\text{U/ml} \cdot \text{mmol/L}$; $p = 0.001$), and lower QUICKI (0.37 ± 0.01 vs. 0.41 ± 0.01 ; $p = 0.003$) than the European Caucasians (Figure 1). Fig 1 also shows significantly lower M values (24.9 ± 1.3 vs. 41.4 ± 1.9 $\mu\text{mol} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$; $p < 0.0001$) and SI_{clamp} values (8.15 ± 0.85 vs. 14.01 ± 0.87 $\mu\text{mol} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ per $\text{pmol/l} \cdot 100$; $p < 0.0001$) in the South Asians as compared to the Caucasian group. The insulin levels during the euglycemic clamp were slightly higher in South Asians when compared to Caucasians (338 ± 16 vs. 303 ± 12 pmol/l), but this difference was not statistically significant. The triglyceride/HDL ratio also was higher in South Asians vs. Caucasians (1.00 ± 0.16 vs. 0.57 ± 0.08 ; $p = 0.032$).

We performed linear correlations between Matsuda index, HOMA-IR, QUICKI, triglyceride/HDL ratio and the M value derived from the euglycemic clamp. Matsuda index strongly correlated with M value among South Asians ($r = 0.50$; $p = 0.014$), Caucasians ($r = 0.47$; $p = 0.046$), and in both groups combined ($r = 0.62$; $p < 0.0001$) (Figure 2). HOMA-IR correlated with M value among South Asians ($r = -0.56$; $p = 0.005$) but not in Caucasians ($r = -0.34$; $p = 0.173$). However HOMA-IR strongly correlated with M value when both the groups were combined ($r = -0.61$; $p < 0.0001$). Similarly, QUICKI correlated with clamp M value in the combined group ($r = 0.59$; $p < 0.0001$) and in South Asians ($r = 0.48$; $p = 0.020$), but not in Caucasians ($r = 0.37$; $p = 0.127$). The triglyceride/HDL ratio also was highly correlated with the M value in South Asians ($r = -0.55$, $p = 0.008$), but not in Caucasians ($r = -0.07$; $p = 0.791$).

The rank correlations (Kendall's tau) showed that all four surrogate measures were significantly associated with the clamp M value, although this relationship was strongest for the Matsuda index ($\tau = 0.55$; $p < 0.0001$), and somewhat weaker for HOMA ($\tau = -0.44$; $p < 0.0001$), QUICKI ($\tau = 0.44$; $p < 0.0001$), and the triglyceride/HDL ratio ($\tau = -0.32$; $p = 0.004$).

Discussion

Our study demonstrates that South Asians have significantly higher fasting insulin, mean OGTT insulin levels, HOMA levels and triglyceride/HDL ratio, and lower Matsuda index, QUICKI and rates of glucose metabolism during the clamp when compared to Caucasians of European origin. We found a strong correlation of Matsuda index, HOMA-IR, QUICKI and triglyceride/HDL with the M value from the glucose clamp among South Asians. This relationship was also noted in Caucasians for the Matsuda index but not for HOMA-IR, QUICKI, or triglyceride/HDL. It is likely that these latter measures did not correlate with M

value in Caucasians because there was not sufficient variability in the fasting glucose and insulin levels in this population. While euglycemic clamps remain the most definitive method to measure whole body insulin sensitivity, they are expensive and labor intensive, which limits their use in large scale clinical research studies in South Asians. In the present study we show that Matsuda index, HOMA-IR, QUICKI, and triglyceride/HDL ratio can reliably be used to predict insulin sensitivity in this population.

There are few studies comparing surrogate indices of insulin sensitivity to the euglycemic hyperinsulinemic clamp among South Asians. One recent study by Muniyappa et al. [15] used surrogate indices of insulin sensitivity including HOMA-IR, QUICKI, fasting insulin to glucose ratio (FIGR) and fasting insulin (FI) to predict SI_{clamp} derived from glucose clamps among 70 Asian Indian men with diabetes ($n=9$), impaired fasting glucose ($n=8$), and normal fasting glucose ($n=53$). In this study QUICKI ($r = 0.36$; $p = 0.002$), FIGR ($r = -0.36$; $p = 0.002$), FI ($r = -0.27$; $p = 0.02$) showed low, but significant, correlations with SI_{clamp} , although HOMA-IR did not [15]. The authors in this study concluded that these surrogate indices have a “limited ability” to predict insulin sensitivity in Asian Indians. However, this study used only fasting surrogate indices, which primarily reflect hepatic insulin sensitivity, and included subjects with impaired fasting glucose as well as diabetes. In addition they included only Asian Indian men and used two different insulin assays as the glucose clamps were done in two different centers. In our study all the glucose clamps were conducted at a single site, analyzed with single insulin assay, and included both male and female study participants.

Our study also differed as we used indices derived from the OGTT (Matsuda index), which includes a composite of both hepatic and peripheral tissue sensitivity to insulin [14]. This may be an important factor in explaining the differences in the results of our respective studies, as Asian Indian men have increased intrahepatic triglyceride [16], increased prevalence of nonalcoholic fatty liver disease [16], increased intramyocellular lipid content, and reduced muscle mass [17].

In the context of similar studies done in other East Asian population, our results also were consistent with results reported in 77 Japanese subjects with varying degrees of glucose tolerance [18]. These subjects also had a normal BMI ($23 - 26.6 \text{ kg/m}^2$), similar to our study population. Matsuda index showed good correlation with the M value measured on euglycemic clamp ($r = 0.450$; $p = 0.046$). The authors also report that other insulin sensitivity indices derived from the OGTT such as Stumvoll's formula ($r = 0.641$; $p = 0.0001$) and Gutt's formula ($r = 0.526$; $p = 0.0001$) correlated strongly with the M value. However, a weak correlation was noted between HOMA-IR and M values in that study ($r = -0.227$; $p = 0.046$).

In a study with 22 healthy Korean volunteers (predominantly men) with normal glucose tolerance and 68 subjects with IGT and type 2 diabetes, log transformed HOMA-IR showed a strong inverse correlation ($r = -0.56$; $p < 0.001$) with total glucose disposal rate measured from a 3 hour euglycemic hyperinsulinemic clamp [19]. When subjects were analyzed according to BMI, those with higher BMI ($> 25 \text{ kg/m}^2$) had better correlation coefficients ($r = -0.61$) compared to subjects with lower BMI ($< 25 \text{ kg/m}^2$), in whom the correlation coefficient was $r = -0.44$. Another study of 33 healthy volunteers with mean BMI of $22.0 \pm 3.9 \text{ kg/m}^2$ from Thailand [20] showed a more robust correlation of Matsuda index with glucose clamp ($r = 0.73$; $p < 0.0001$) as compared to HOMA-IR ($r = 0.40$; $p = 0.02$). Overall these results show that surrogate indices of insulin sensitivity derived from OGTT are generally better than measures derived from fasting states in a variety of Asian populations, although both types of measures are statistically significant if the sample size is sufficiently large.

Our study comprised subjects with normal glucose tolerance as compared to prior studies in Asians, which have pooled subjects with varying degrees of normal and impaired glucose tolerance. We show that simpler measures of insulin sensitivity derived from fasting samples or OGTT correlate well with M values from the glucose clamp. As South Asians even with normal body weight have higher insulin resistance, dyslipidemia and cardiovascular risks than Caucasians, it is vital to develop simple, precise ways to quantify their insulin sensitivity. These surrogate indices can be used in large scale epidemiological and clinical research studies on South Asians to evaluate the risks of cardiovascular disease or diabetes.

A limitation of our study is the modest sample size; however, most prior studies on healthy subjects with normal glucose tolerance had similar numbers, and we did observe statistically significant associations. Also, we did not use labeled glucose tracers to calculate hepatic glucose production during the glucose clamp, so we can not determine whether the primary site of the defect in insulin sensitivity is in the liver or muscle. However, the large magnitude of the difference in glucose infusion rates between the two groups during the clamp (approximately $17 \mu\text{mol}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) suggests that muscle is quantitatively the predominant site of insulin resistance. Nevertheless further studies in larger groups of South Asians are needed to validate our results.

Our study has demonstrated that South Asians have higher fasting insulin, lower HDL cholesterol and impaired surrogate indices of insulin sensitivity when compared to Caucasians of European origin. The Matsuda index, HOMA-IR, QUICKI, and triglyceride/HDL ratio can be reliably used in South Asians to predict insulin sensitivity, and may be useful in large scale clinical research and epidemiological studies in this population.

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S.T. performed the statistical analyses, wrote the manuscript and was involved in the design and implementation of the overall study. A.R. researched the data and was involved in the design and implementation of the overall study. B.C. and E.W.S. contributed to the discussion and reviewed/edited the manuscript. D.C.S. was involved in the design and implementation of the study, reviewed the statistical analyses, and edited the manuscript.

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Figure 1. Comparison of glucose metabolic rate during the euglycemic hyperinsulinemic clamp (Panel A), insulin sensitivity during the clamp (SI_{clamp} , Panel B), Matsuda Index (Panel C), HOMA (Panel D), QUICKI (Panel E), and triglyceride/HDL ratio (Panel F) between South Asians and Caucasians.

Figure 2A

Figure 2B

Figure 2.

Correlation of glucose metabolic rate during the euglycemic hyperinsulinemic clamp with the Matsuda Index, HOMA, QUICKI, and triglyceride/HDL ratio in South Asians (Figure 2A) and Caucasians (Figure 2B).

Table 1

Baseline demographic, anthropometric and clinical characteristics of study participants. Data presented as mean $\pm$ standard error of mean (SEM).

	South Asians (n=23)	Caucasians (n=18)
Age (yrs)	33.6 $\pm$ 2.1	36.0 $\pm$ 3.0
Sex (M/F)	16/7	8/10
BMI (kg/m ²)	25.2 $\pm$ 1.1	24.6 $\pm$ 0.9
Waist circumference (cm)	82 $\pm$ 3	80 $\pm$ 2
Waist/Hip ratio	0.81 $\pm$ 0.02	0.77 $\pm$ 0.02
Fat-Free Mass (%)	74.3 $\pm$ 2.2	72.8 $\pm$ 2.7
Fat Mass (%)	25.7 $\pm$ 2.2	27.2 $\pm$ 2.7
Total Cholesterol (mmol/l)	4.59 $\pm$ 0.20	4.60 $\pm$ 0.21
LDL-C (mmol/l)	2.76 $\pm$ 0.16	2.68 $\pm$ 0.19
HDL-C (mmol/l)	1.25 $\pm$ 0.06	1.56 $\pm$ 0.10*
Triglycerides (mmol/l)	1.26 $\pm$ 0.18	0.91 $\pm$ 0.11
Systolic BP (mm Hg)	131 $\pm$ 4	123 $\pm$ 4
Diastolic BP (mm Hg)	69 $\pm$ 3	65 $\pm$ 3

*
p = 0.010

Table 2

Metabolic parameters during the OGTT. Data presented as mean $\pm$ SEM.

	South Asians (n=23)	Caucasians (n=18)	P value
Fasting Glucose (mmol/l)	5.0 $\pm$ 0.1	4.9 $\pm$ 0.1	NS
Fasting Insulin (pmol/l)	41 $\pm$ 5	21 $\pm$ 2	0.002
Mean OGTT Glucose (mmol/l)	6.4 $\pm$ 0.3	6.0 $\pm$ 0.3	NS
Mean OGTT Insulin (pmol/l)	295 $\pm$ 37	159 $\pm$ 25	0.006