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Spectrum of insulin sensitivity in the Korean population

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Abstract

The aims of the present study were to (1) examine the range of values for insulin sensitivity measures such as fasting serum insulin, homeostasis model assessment (HOMA), and quantitative insulin sensitivity check index (QUICKI) and (2) to identify cutoffs for indirect indexes of insulin sensitivity such as insulin, HOMA, and QUICKI that confer increased risk of metabolic syndrome in a large sample of Korean adults. The total number of study subjects involved was 83 186. All of them presented for a routine health status checkup at the Kangbuk Samsung Hospital between January 2003 and December 2004, and none of them was currently taking medication for hypertension, diabetes, or dyslipidemia. We used 3 measures of insulin sensitivity: the fasting serum insulin, the HOMA, and the QUICKI. The age- and sex-adjusted prevalence of metabolic syndrome was examined by tenths of the distribution of each index of insulin. The fasting serum insulin, HOMA, and QUICKI were compared by using receiver operating characteristic curves. The fasting serum insulin ranged from 1.71 to 70.40 μU/mL, with the 25th percentile = 5.97, the median = 7.69, and the 75th percentile = 9.82. The HOMA ranged from 0.34 to 17.72, with the 25th percentile = 1.33, the median = 1.74, and the 75th percentile = 2.27. The QUICKI ranged from 0.112 to 0.202, with the 25th percentile = 0.146, the median = 0.152, and the 75th percentile = 0.158. The insulin, HOMA, and QUICKI values at the point on the receiver operating characteristic curve closest to the ideal of 100% sensitivity and 100% specificity for detecting the presence of metabolic syndrome were 9.7 μU/mL, 2.43, and 0.145, respectively. In conclusion, these findings describe the spectrum of insulin sensitivity in Korean adults. This study is the first attempt to determine cutoff values for indirect indexes of insulin sensitivity such as insulin, HOMA, and QUICKI that confer an increased risk of metabolic syndrome. These findings may be useful for evaluating insulin resistance, particularly in epidemiological studies.

1. Introduction

Insulin resistance is an independent risk factor for cardiovascular and cerebrovascular disease [1-9]. The gold standard for measuring insulin resistance is the hyperinsulinemic-euglycemic clamp [10]. The minimal model analysis of a frequently sampled intravenous glucose tolerance test is an alternative to the clamp technique [11]. However, these are invasive, cost-intensive, and labor-intensive procedures that are not applicable to routine clinical practice or to large-scale epidemiological studies. Therefore, indirect indexes of insulin sensitivity have been proposed.

To date, it has been shown that the homeostasis model assessment (HOMA) [12-14] or the quantitative insulin sensitivity check index (QUICKI) [15], which are calculated from fasting plasma glucose (FPG) and insulin, are useful surrogate indexes of insulin resistance in healthy subjects and diabetic subjects because of their high correlation with the indexes assessed by the hyperinsulinemic-euglycemic clamp method.

Although researchers have used the fasting serum insulin, HOMA, and QUICKI methods in clinical studies, little research has been done to evaluate the cutoff values for the HOMA and QUICKI tests. Moreover, the range of values for these measures has not been assessed in a large Korean population sample.

The aims of the present study were (1) to examine the range of values for insulin sensitivity measures such as

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fasting serum insulin, HOMA, and QUICKI and (2) to identify the cutoff values for the indirect indexes of insulin sensitivity such as fasting serum insulin, HOMA, and QUICKI that confer increased risk of metabolic syndrome in a large sample of Korean adults.

2. Methods

2.1. Subjects

The total number of subjects involved in our study was 128 737, all of whom presented for a routine health status checkup at the Kangbuk Samsung Hospital, College of Medicine at Sungkyunkwan University, between January 2003 and December 2004, and the subjects were without any specific medical complaint. The subjects were asked questions concerning the risk factors for general cardiovascular disease (ie, medical history and lifestyle factors such as smoking, alcohol consumption, and regular exercise). We limited our analysis to the participants aged 20 years or older (128 705, 99.9% of all subjects). Of these potential participants, 45 519 (35.4%) were excluded: 5825 (4.5%) were currently taking medication for hypertension, diabetes, or dyslipidemia; 10 527 (8.2%) did not have information about their medical history; 10 539 (8.2%) did not have the fasting laboratory measurements needed to obtain the fasting serum insulin, HOMA, or QUICKI; 18 501 (14.4%) did not have the blood pressure (BP) measurement; and 127 (0.1%) were pregnant. Finally, 83 186 subjects (52 141 men, 31 045 women) were included in this study.

2.2. Measurements

The blood samples were collected after more than 12 hours of fasting, and the total cholesterol, triglyceride, high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) values were measured enzymatically using an automatic analyzer (Advia 1650 Autoanalyzer, Bayer Diagnostics, Leverkusen Germany). The BP was determined using a mercury manometer between 8:00 and 10:00 AM after the subject had been sitting upright for at least 10 minutes. When the systolic or diastolic BP exceeded 140 or 90 mm Hg, respectively, the BP was remeasured twice after the subjected rested, and the values were then averaged. The waist circumference was measured at the midlevel between the lowest rib and the iliac crest or the narrowest part without adding pressure according to the recommendation of the World Health Organization [16]. The body mass index was calculated as the weight in kilograms divided by the square of height in meters to the nearest 0.1 from the measured body weight and height with the subject in a light gown using an automatic scale.

We used 3 measures of insulin sensitivity: fasting serum insulin expressed in microunits per milliliter, the HOMA, and the QUICKI. The serum insulin was measured by an immunoradiometric assay (Biosource, Nivelles, Belgium). The maximum inter- and intra-assay coefficients of variation for the range of concentrations that were evaluated were 12.2% and 4.5%, respectively, for the fasting serum insulin. The HOMA was calculated from the equation HOMA = [fasting serum glucose (mmol/L) × fasting serum insulin (μU/mL)]/22.5 [12]. For both the fasting serum insulin and HOMA, increasing values corresponded to decreasing insulin sensitivity. The QUICKI was calculated from the equation QUICKI = 1/{log [fasting serum insulin (μU/mL)] + log [fasting serum glucose (mg/dL)]}.

Metabolic syndrome was defined according to ATP III criteria. A participant has metabolic syndrome if he or she has 3 or more of the following: increased waist circumference (>102 cm in men and >88 cm in women), high triglycerides (≥150 mg/dL), low HDL-C (<40 mg/dL in men and <50 mg/dL in women), and high BP (≥130/85 mm Hg) and fasting glucose (≥110 mg/dL).

We defined 3 mutually exclusive categories of glucose metabolism (normoglycemia, impaired fasting glucose, and diabetes) based on the American Diabetes Association criteria [17]. Normoglycemia was defined as a normal fasting glucose level (an FPG concentration ≤99 mg/dL). Impaired fasting glucose was defined by an FPG level of 100 to 125 mg/dL. Diabetes was defined by an FPG level of 126 mg/dL or higher.

2.3. Statistical analyses

The Kolmogorov-Smirnov test was used to determine if continuous variables were normally distributed. To describe the spectrum of insulin sensitivity in this study, we used measures for both the spread of the data (range, 10th, 25th, 75th, and 90th percentiles, and SD) and of the central tendency of the data (median and mean). We did not transform either the fasting serum insulin or the HOMA to describe the spectrum of the fasting serum insulin and HOMA.

2.3.1. Frequency distributions

The prevalence of metabolic syndrome was determined in 83 186 subjects (52 141 men and 31 045 women). The age- and sex-adjusted prevalence of metabolic syndrome was examined according to the tenths of the distribution for each index of insulin sensitivity such as insulin, HOMA, and QUICKI. This approach was used because it provided the highest precision for examining the possible threshold effects while maintaining adequate numbers within each percentile band. The age and sex standardization was estimated using the direct method to the age and sex structure of the subjects.

2.3.2. Receiver operating characteristic analysis

In this study, the fasting serum insulin, HOMA, and QUICKI were compared by using the characteristic receiver operating characteristic (ROC) curves [18]. This method compares the diagnostic properties of a test by expressing sensitivity as a function of 1 − specificity. The areas under the curve represent the probability that a subject chosen at

random who had metabolic syndrome had a higher test value than a subject who did not have this complication.

The statistical analysis for the data was done with SAS version 8.2 (SAS Institute, Cary, NC) and SPSS version 12.0 (SPSS, Chicago, IL).

3. Results

The baseline characteristics of the subjects (N = 83 186) are provided in Tables 1 and 2.

The sex ratio of the study subjects was 1.68:1 (male to female), and their mean age was 41.1 ± 8.4 years, 41.2 ± 8.0 for males and 40.9 ± 9.0 for females. Eighty-three percent of the subjects were between 30 and 40 years; 65 978 subjects (79.3%) had normoglycemia, 15 698 subjects (18.9%) had impaired fasting glucose, and 1158 subjects (2.6%) had untreated diabetes. The overall prevalence of metabolic syndrome was 2.8% in men and 2.2% in women.

Table 1
Baseline characteristics of the participants

	Total (N = 83 186)	Male (n = 52 141)	Female (n = 31 045)
Age (y)			
20-29	2199 (2.6)	750 (1.4)	1449 (4.7)
30-39	36 627 (44.0)	22 659 (43.5)	13 968 (45.0)
40-49	32 736 (39.4)	21 911 (42.0)	10 825 (34.9)
50-59	8369 (10.1)	5043 (9.7)	3326 (10.7)
60-69	2824 (3.4)	1526 (2.9)	1298 (4.2)
≥ 70	431 (0.5)	252 (0.5)	179 (0.6)
Smoking			
Nonsmoker	41 929 (54.1)	15 205 (30.9)	26 724 (94.5)
Ex-smoker	12 796 (16.5)	12 171 (24.8)	625 (2.2)
Smoker	22 723 (29.3)	21 789 (44.3)	934 (3.3)
Alcohol drinking			
Very rare	27 287 (44.6)	13 954 (30.6)	13 333 (85.6)
2-3 times/mo	21 669 (35.4)	19 765 (43.3)	1904 (12.2)
1-2 times/wk	9272 (15.2)	8995 (19.7)	277 (1.8)
≥ 3 times/wk	2973 (4.9)	2906 (6.4)	67 (0.4)
Exercise			
No exercise	38 293 (49.8)	21 388 (43.9)	16 905 (59.9)
1-2 times/wk	25 364 (33.0)	19 191 (39.4)	6173 (21.9)
3-4 times/wk	9768 (12.7)	6220 (12.8)	3548 (12.6)
5-6 times/wk	2007 (2.6)	1045 (2.1)	962 (3.4)
Everyday	1459 (1.9)	828 (1.7)	631 (2.2)
BMI (kg/m^2)			
< 18.5	2549 (3.1)	673 (1.3)	1876 (6.0)
18-24.9	54 341 (65.3)	30 377 (58.3)	23 964 (77.2)
25.0-29.9	24 357 (29.3)	19 655 (37.7)	4702 (15.1)
≥ 30.0	1939 (2.3)	1436 (2.8)	503 (1.6)
Glucose metabolism			
Normoglycemia	65 978 (79.3)	39 001 (74.8)	26 977 (86.9)
IFG	15 698 (18.9)	11 908 (22.8)	3790 (12.2)
Untreated DM	1510 (1.8)	1232 (2.4)	278 (0.9)
MS component			
0	42 062 (50.6)	21 382 (41.0)	20 593 (66.3)
1	27 932 (33.6)	20 348 (39.0)	7634 (24.6)
2	11 060 (13.3)	8947 (17.2)	2148 (6.9)
≥ 3	2132 (2.6)	1464 (2.8)	670 (2.2)

Values are given as n (%). BMI indicates body mass index; IFG, impaired fasting glucose; DM, type 2 diabetes mellitus; MS, metabolic syndrome.

Table 2
Clinical characteristics of the participants

	Total (N = 83 186)	Male (n = 52 141)	Female (n = 31 045)
Age (y)	41.1 ± 8.4	41.2 ± 8.0	40.9 ± 9.0
WBC (10^3/mm^3)	5.9 ± 1.5	6.1 ± 1.5	5.4 ± 1.4
Uric acid (mg/dL)	5.4 ± 1.4	6.1 ± 1.2	4.2 ± 0.9
Total cholesterol (mg/dL)	199.7 ± 35.5	204.0 ± 35.1	192.4 ± 35.0
Triglyceride (mg/dL)	132.8 ± 86.7	153.4 ± 94.5	98.2 ± 56.9
HDL-C (mg/dL)	56.7 ± 11.6	54.5 ± 10.5	60.5 ± 12.4
LDL-C (mg/dL)	116.8 ± 29.5	121.0 ± 29.2	109.8 ± 28.7
Apolipoprotein A-I (mg/dL)	127.3 ± 23.7	125.0 ± 23.2	130.3 ± 24.0
Apolipoprotein B (mg/dL)	96.3 ± 25.0	101.6 ± 24.1	89.2 ± 24.5
BMI (kg/m^2)	23.7 ± 3.0	24.4 ± 2.8	22.4 ± 2.9
Waist circumference (cm)	79.9 ± 9.3	84.3 ± 7.3	72.7 ± 7.5
SBP (mm Hg)	115.1 ± 13.9	117.7 ± 12.9	110.6 ± 14.2
DBP (mm Hg)	74.8 ± 10.1	77.7 ± 9.4	70.0 ± 9.3
HSCRP (mg/dL)	0.106 ± 0.176	0.119 ± 0.190	0.087 ± 0.154
FBS (mg/dL)	93.7 ± 14.1	95.3 ± 15.2	91.0 ± 11.6

Values are given as mean ± SD. WBC indicates white blood cell count; SBP, systolic BP; DBP, diastolic BP; HSCRP, high-sensitivity C-reactive protein; FBS, fasting blood sugar.

A Kolmogorov-Smirnov test showed that neither the fasting serum insulin nor the HOMA were normally distributed. However, the QUICKI appeared to be normally distributed by the logarithmic transformation of fasting insulin and glucose levels.

The fasting serum insulin ranged from 1.71 to 70.40 μU/mL; the 25th percentile was 5.97 μU/mL, the median was 7.69 μU/mL, and the 75th percentile was 9.82 μU/mL. When compared across the range of the subjects' glucose metabolism, the fasting serum insulin increased from a median of 7.49 μU/mL in participants with normoglycemia to 8.52 μU/mL in participants with impaired fasting glucose, and to 9.08 μU/mL in participants with untreated diabetes (Table 3).

The HOMA values ranged from 0.34 to 17.72; the 25th percentile was 1.33, the median was 1.74, and the 75th percentile was 2.27. Compared across the range of the subjects' glucose metabolism, the HOMA increased from a median of 1.63 in participants with normoglycemia to 2.19 in participants with impaired fasting glucose, and to 3.49 in participants with untreated diabetes (Table 4).

The QUICKI values ranged from 0.112 to 0.202; the 25th percentile was 0.146, the median was 0.152, and the 75th percentile was 0.158. Compared across the range of the subjects' glucose metabolism, the QUICKI decreased from a mean of 0.153 in participants with normoglycemia to 0.147 in participants with impaired fasting glucose, and to 0.137 in participants with untreated diabetes (Table 5).

The age- and sex-adjusted prevalence of metabolic syndrome was examined according to the tenths of the distribution of the fasting serum insulin, HOMA, and QUICKI (Fig. 1). The figure provides clear evidence of a

Table 3
Distribution of fasting serum insulin (μU/mL)

Characteristic	Range	Mean ± SD	Percentile				
			10th	25th	Median	75th	90th
Overall	1.71-70.40	8.27 ± 3.28	4.89	5.97	7.69	9.82	12.20
Age (y)							
≤39	1.79-64.10	8.35 ± 3.37	4.95	6.02	7.73	9.89	12.36
40-49	1.78-54.73	8.20 ± 3.19	4.84	5.93	7.66	9.77	12.08
50-59	1.71-70.40	8.22 ± 3.21	4.89	6.00	7.69	9.75	12.02
≥60	2.04-41.53	8.19 ± 3.30	4.83	5.90	7.58	9.70	12.03
Sex							
Male	1.71-70.40	8.33 ± 3.41	4.85	5.95	7.71	9.89	12.40
Female	1.78-54.74	8.18 ± 3.06	4.96	6.01	7.66	9.70	11.88
Smoking							
Nonsmoker	1.78-64.10	8.18 ± 3.17	4.91	5.96	7.61	9.71	11.96
Ex-smoker	1.71-70.40	8.38 ± 3.36	4.92	6.05	7.78	9.96	12.49
Smoker	1.90-61.86	8.23 ± 3.44	4.77	5.82	7.57	9.82	12.33
BMI (kg/m^2)							
<18.5	1.78-34.70	6.88 ± 2.41	4.32	5.14	6.46	8.25	10.05
18.5-24.9	1.71-70.40	7.64 ± 2.73	4.72	5.69	7.18	9.14	11.06
25.0-29.9	2.02-64.10	9.46 ± 3.59	5.60	6.93	8.89	11.14	13.95
≥30.0	3.82-61.86	12.91 ± 5.50	7.44	9.41	11.63	15.24	20.10
Glucose metabolism							
Normoglycemia	1.78-64.10	8.03 ± 3.08	4.82	5.85	7.49	9.57	11.79
IFG	1.71-70.40	9.12 ± 3.73	5.28	6.52	8.52	10.79	13.64
DM	2.25-48.21	10.00 ± 4.64	5.48	7.00	9.08	11.68	15.64
MS component							
0	2.09-70.40	8.56 ± 2.83	5.46	6.61	8.19	9.98	12.07
1	1.90-61.86	9.55 ± 3.45	5.90	7.21	9.01	11.20	13.77
2	1.71-64.10	10.67 ± 3.99	6.44	8.00	9.98	12.55	15.63
≥3	3.93-54.36	12.11 ± 4.98	7.03	8.64	11.18	14.48	18.56

Table 4
Distribution of HOMA

Characteristic	Range	Mean ± SD	Percentile				
			10th	25th	Median	75th	90th
Overall	0.34-17.72	1.91 ± 0.88	1.07	1.33	1.74	2.27	2.91
Age (y)							
≤39	0.35-16.74	1.89 ± 0.87	1.07	1.31	1.71	2.24	2.86
40-49	0.34-14.44	1.91 ± 0.86	1.07	1.33	1.74	2.28	2.92
50-59	0.42-17.72	1.98 ± 0.94	1.08	1.36	1.80	2.35	3.02
≥60	0.48-11.06	2.00 ± 0.97	1.06	1.36	1.78	2.39	3.13
Sex							
Male	0.35-17.72	1.96 ± 0.93	1.07	1.34	1.77	2.33	3.01
Female	0.34-14.44	1.83 ± 0.78	1.06	1.30	1.69	2.18	2.75
Smoking							
Nonsmoker	0.35-15.43	1.86 ± 0.83	1.06	1.31	1.70	2.22	2.81
Ex-smoker	0.45-17.72	1.96 ± 0.92	1.10	1.37	1.80	2.36	3.08
Smoker	0.39-16.74	1.92 ± 0.93	1.04	1.30	1.70	2.29	2.97
BMI (kg/m^2)							
<18.5	0.36- 7.38	1.49 ± 0.56	0.91	1.10	1.39	1.77	2.21
18.5-24.9	0.34-17.72	1.73 ± 0.69	1.02	1.25	1.60	2.07	2.57
25.0-29.9	0.42-15.43	1.25 ± 0.99	1.26	1.59	2.07	2.66	3.42
≥30.0	0.87-16.74	3.18 ± 0.59	1.70	2.18	2.80	3.76	5.02
Glucose metabolism							
Normoglycemia	0.34-14.41	1.76 ± 0.70	1.03	1.26	1.63	2.11	2.62
IFG	0.44-17.72	2.36 ± 0.99	1.35	1.67	2.19	2.79	3.55
DM	0.72-16.74	3.90 ± 1.88	2.04	2.66	3.49	4.61	6.30
MS component							
0	0.39-17.72	1.89 ± 0.68	1.15	1.42	1.79	2.29	2.75
1	0.39-14.44	2.19 ± 0.88	1.30	1.60	2.04	2.58	3.25
2	0.46-14.41	2.62 ± 1.15	1.47	1.86	2.39	3.11	4.04
≥3	0.94-13.14	3.56 ± 1.67	1.83	2.37	3.20	4.30	5.79

Table 5
Distribution of QUICKI

Characteristic	Range	Mean ± SD	Percentile				
			10th	25th	Median	75th	90th
Overall	0.112-0.202	0.152 ± 0.009	0.141	0.146	0.152	0.158	0.164
Age (y)							
≤39	0.113-0.201	0.153 ± 0.009	0.141	0.146	0.152	0.159	0.164
40-49	0.115-0.202	0.152 ± 0.009	0.141	0.146	0.152	0.158	0.164
50-59	0.112-0.194	0.152 ± 0.009	0.140	0.145	0.151	0.158	0.164
≥60	0.119-0.189	0.152 ± 0.009	0.140	0.145	0.151	0.158	0.164
Sex							
Male	0.112-0.201	0.152 ± 0.009	0.140	0.146	0.152	0.158	0.164
Female	0.115-0.202	0.153 ± 0.009	0.142	0.147	0.153	0.159	0.164
Smoking							
Nonsmoker	0.114-0.201	0.153 ± 0.009	0.142	0.147	0.153	0.159	0.164
Ex-smoker	0.112-0.191	0.151 ± 0.009	0.140	0.145	0.151	0.158	0.163
Smoker	0.113-0.198	0.152 ± 0.010	0.141	0.146	0.152	0.159	0.165
BMI (kg/m^2)							
<18.5	0.124-0.200	0.158 ± 0.009	0.149	0.152	0.157	0.163	0.169
18.5-24.9	0.112-0.202	0.154 ± 0.008	0.144	0.148	0.154	0.160	0.165
25.0-29.9	0.114-0.195	0.148 ± 0.009	0.138	0.143	0.148	0.154	0.160
≥30.0	0.113-0.170	0.142 ± 0.009	0.131	0.136	0.142	0.147	0.153
Glucose metabolism							
Normoglycemia	0.115-0.202	0.154 ± 0.009	0.143	0.148	0.153	0.160	0.165
IFG	0.112-0.192	0.147 ± 0.008	0.137	0.142	0.147	0.153	0.158
DM	0.113-0.175	0.138 ± 0.008	0.127	0.132	0.137	0.143	0.148
MS component							
0	0.112-0.197	0.152 ± 0.008	0.142	0.147	0.152	0.157	0.162
1	0.115-0.198	0.149 ± 0.008	0.139	0.144	0.149	0.154	0.159
2	0.115-0.191	0.145 ± 0.008	0.135	0.140	0.145	0.151	0.156
≥3	0.116-0.167	0.140 ± 0.009	0.129	0.134	0.139	0.145	0.151

threshold at the 90th percentile of HOMA; below this, metabolic syndrome is absent or rare, and above this, the prevalence is considerably higher. At the 90th percentile of HOMA, the age- and sex-adjusted prevalence of metabolic syndrome was 2.8%, and the median HOMA value was 2.63 (range, 2.44-2.91). At the 100th percentile of HOMA, the age- and sex-adjusted prevalence of type 2 diabetes mellitus was 9.6%, and the median HOMA value was 3.45 (range, 2.91-17.72). Fig. 1 also provides clear evidence of a threshold at the 10th percentile of QUICKI, above which metabolic syndrome is absent or rare and below which the prevalence is considerably higher. At the 10th percentile of QUICKI, the age- and sex-adjusted prevalence of metabolic syndrome was 9.7%, and the median QUICKI value was 0.138 (range, 0.112-0.202). At the 20th percentile of QUICKI, the age- and sex-adjusted prevalence of metabolic

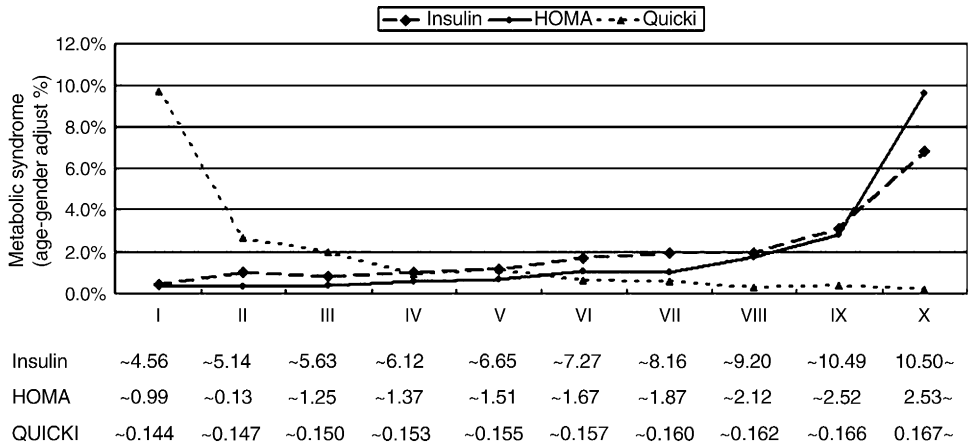

Fig. 1. Age- and sex-adjusted prevalence of metabolic syndrome by deciles of fasting serum insulin, HOMA, and QUICKI. The x-axis labels indicate the upper limit of each decile group except the 10th decile.

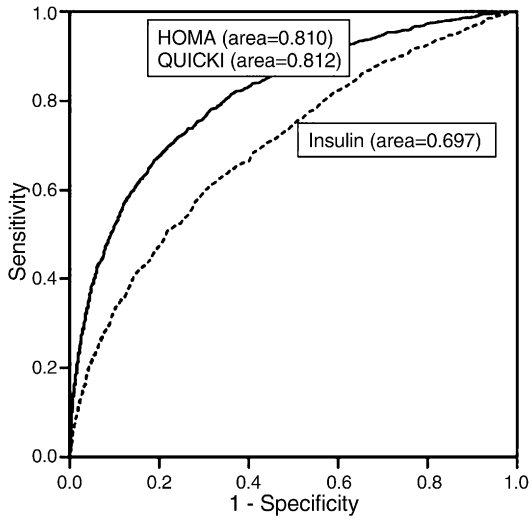

Fig. 2. Receiver operating characteristic curves for insulin, HOMA, and QUICKI for detecting the presence of metabolic syndrome. Receiver operating characteristic curve of HOMA was similar to that of QUICKI.

syndrome was 2.7%, and the median QUICKI value was 0.143 (range, 0.141-0.145).

Fig. 2 shows the analyses for the characteristics of the ROC curve for the prevalence of metabolic syndrome. The area under the curve for HOMA and QUICKI were greater than that of the fasting serum insulin for metabolic syndrome, and so this indicates a greater accuracy for detecting metabolic syndrome.

The cutoff point that maximizes the sum of sensitivity and specificity can be used to discriminate between groups of subjects who have a high risk for metabolic syndrome (Table 6). The insulin, HOMA, and QUICKI values at the point on the characteristic ROC curve that was closest to the ideal of 100% sensitivity and 100% specificity were 9.7 μU/mL, 2.43, and 0.145, respectively.

4. Discussion

Impaired insulin sensitivity is one of the main components in the pathogenesis of type 2 diabetes mellitus [19,20]. Therefore, simple methods of assessing insulin sensitivity are important for the evaluation and follow-up of people with obesity and who have risk factors for type 2 diabetes mellitus.

The hyperinsulinemic clamp is considered the gold standard for measuring insulin sensitivity. Given that we had no hyperinsulinemic clamp data for making comparisons with the fasting serum insulin, HOMA, and QUICKI measurements, we cannot determine which of the 3 measures of insulin sensitivity was more accurate. Yet previous studies have found high correlations for these 3 measurements with clamp measurements [12,15].

The HOMA ROC curve was very similar to that for QUICKI, and this is not surprising, given that both approaches involve mathematical manipulations of fasting glucose and insulin concentrations.

The current investigation shows that cutoff points for the indirect indexes of insulin sensitivity such as HOMA and QUICKI in some Koreans were 2.43 and 0.145, respectively. However, in the present study, the overall population was young and not obese. So, the age- and sex-adjusted prevalence of metabolic syndrome was examined according to the tenths of the distribution of the fasting serum insulin, HOMA, and QUICKI. In the case of HOMA, a threshold was evident for the age- and sex-adjusted prevalence of untreated diabetes at the 90th percentile, at 2.63. In the case of QUICKI, a threshold was evident for the age- and sex-adjusted prevalence of untreated diabetes at the 20th percentile, at 0.143.

To our knowledge, little research has been done to evaluate cutoff values for HOMA and QUICKI, so we cannot compare our result with that of other studies.

The present study provides data on the range of insulin sensitivity in a large sample of Korean adults. As expected, a progressive decrease in insulin sensitivity was seen according to insulin, HOMA, and QUICKI when the participants were compared across the glucose metabolism categories of normoglycemia, impaired fasting glucose, and untreated diabetes.

Our results are markedly lower than those reported by other investigators. Bravata and colleagues [21] used data from the Third National Health and Nutrition Survey, and they reported the fasting serum insulin measurements as follows: 25th percentile, 6.7 μU/mL; median, 9.3 μU/mL; 75th percentile, 13.3 μU/mL. Wedick and colleagues [22], in the Rancho Bernardo Study, reported their fasting serum insulin measurements as follows: 25th percentile, 6.9 μU/mL; median, 9.5 μU/mL; 75th percentile, 13.0 μU/mL (compared with our findings of 25th percentile, 6.0 μU/mL; median, 7.7 μU/mL; 75th percentile, 9.8 μU/mL). Bravata and colleagues [21] also reported HOMA values as follows: 25th percentile, 1.5; median, 2.2; 75th percentile, 3.3

Table 6
Performance of various cutpoints for detecting the presence and absence of metabolic syndrome

Indirect index of insulin sensitivity	Cutpoint	Sensitivity (%)	Specificity (%)
Insulin (μU/mL)	9.60	66.0	61.7
	9.60	65.4	62.8
	9.70	64.3	64.0
	9.80	63.6	65.2
	9.90	62.7	66.4
HOMA	2.37	75.4	71.5
	2.40	73.8	72.6
	2.43	73.7	73.7
	2.46	72.5	74.8
	2.49	71.8	75.9
QUICKI	0.143	80.9	66.8
	0.144	77.3	70.5
	0.145	73.6	73.7
	0.146	69.8	79.5
	0.147	64.0	81.4

(compared with our findings of 25th percentile, 1.3; median, 1.7; 75th percentile, 2.3). Wedick and colleagues [22] reported a mean HOMA of 2.9 compared with our mean HOMA of 1.9.

This large gap might originate from (1) the age factor: our study subjects were relatively younger than the other study subjects; 83.4% of our subjects were in their thirties and forties. (2) The volunteer health effect: these study subjects were those who undertook the periodic health examination on a voluntary basis, so it is highly probable that they were healthier that other populations.

In this study, the prevalence of the metabolic syndrome using the Asia-Pacific guideline for central obesity was 7.4% (95% confidence interval, 7.2-7.6) and the prevalence of metabolic syndrome by the ATP III criteria was 2.6% (95% confidence interval, 2.5-2.7), which is much lower than the prevalence of metabolic syndrome in Americans. The prevalence of the metabolic syndrome diagnosed using the ATP III criteria in Americans more than 20 years ago was estimated to be 22% [23]. This difference may be caused by (1) the exclusion of participants who were currently taking medication for hypertension, diabetes, or dyslipidemia because of the potential effect of medications on metabolic values; (2) the low prevalence of central obesity, which, according to the ATP III criteria, is much lower in Koreans than in Americans; and (3) as previously stated, the age factor; our study subjects were relatively young than the other studies subjects.

This study has some limitations. First, the diagnosis of diabetes and insulin resistance was made based only on the FPG level. In other words, oral glucose tolerance test and hyperinsulinemic-euglycemic clamp were not performed to confirm the diagnosis. Yet, the American Diabetes Association recommends that for epidemiological studies, estimates for the prevalence and incidence of diabetes should be based on an FPG of 126 mg/dL or higher for standardization [24]. Second, there was probably a selection bias. Our subjects were self-selected, so our data were definitely not a representative sample of the Korean population. So, these results need to be tested in a representative Korean population. Third, our study just included Korean subjects, so we cannot apply our data to western populations; but almost all the previous data only included western populations, so we can compare race differences by using these data. Fourth, we excluded any participants who were currently taking medication for hypertension, diabetes, or dyslipidemia. Accordingly, our findings cannot be applied to patients treated with these medications.

With all these limitations, this study is the first to attempt to determine cutoff values for the indirect indexes of insulin sensitivity such as fasting serum insulin, HOMA, and QUICKI, and to examine the range of these values for insulin sensitivity measures in Koreans.

In conclusion, these findings may be quite useful for evaluating insulin resistance, particularly in epidemiological studies.

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