Korean and Caucasian overweight premenopausal women have different relationship of body mass index to percent body fat with age

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BODY MASS INDEX (BMI) is the most commonly used surrogate measure of fatness, and single definitions are advocated by the World Health Organization (WHO) for both overweight (BMI ≥ 25.0 kg/m²) and obesity (BMI ≥ 30.0 kg/m²), irrespective of race/ethnicity (22, 24). However, some individuals whose BMI places them in the overweight category may have a normal percent body fat (PBF), whereas some individuals whose BMI is within the normal range may have a high PBF.

Over the past 5 years, an ever growing number of peer reviewed publications have proposed the need to redefine the BMI overweight and obesity cutoff points for Asian populations (22, 23). The rationale is primarily based on the findings that Asian populations have different associations between BMI, PBF, and health risks than do European populations. For a similar BMI, components of the metabolic syndrome/cardiovascular risk factors appear higher in Asians (22) and a higher prevalence of diabetes and hypertension appear with very modest increases in BMI (2, 22, 23). Because BMI is merely a proxy for fatness, it is important to determine the relationship between BMI and fatness and ascertain whether race/ethnic differences exist in this relationship (3–5, 22).

Of interest to us in the present study was whether race differences exist in the relationship between PBF and BMI in Korean-Asians compared with Caucasian premenopausal women, where PBF was determined by using dual-energy X-ray absorptiometry (DXA) and the Asian cohort was tested in Seoul, South Korea, and Caucasians (Ca) living in New York City. Healthy premenopausal women (50 Ko-As; 38 Ca), ages 22–50 yr, were studied. Weight, height, and PBF by dual-energy X-ray absorptiometry were measured. Total body dual-energy X-ray absorptiometry data were collected using GE-Lunar systems (Prodigy-Korea and DPXL-New York), and all scan analyses were performed by one technician in New York. Similar soft tissue phantoms were used for daily instrument calibrations at both sites. The relationship between PBF and BMI was assessed by multiple regression analysis with race, age, reciprocal of BMI (1/BMI), and a race-by-age interaction as the final independent variables. Race (P = 0.003) and 1/BMI (P < 0.001) were significantly related to PBF in this model. A significant race-by-age interaction (P = 0.039) indicated that the slope of the lines for PBF vs. age differed between Ko-As and Ca. This study demonstrates in a Ko-As sample that the BMI-fat relationship differs significantly from that in a comparable group of Caucasian women. Investigators who use BMI as an index of fatness should be aware of the well documented differences in the relationship of BMI and fatness across race/ethnic groups.

METHODS
Protocol

All medical and body composition evaluations were carried out on the same day for each participant, who was clothed in a hospital gown and without shoes. The studies were approved by the Institutional Review Boards of Konkuk University Hospital Center and College of Medicine, Konkuk University, Seoul; the St. Luke’s-Roosevelt Hospital and College of Physicians & Surgeons, Columbia University, New York; and the Tokyo Metropolitan Institute of Medical Science, Tokyo, Japan.

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Review Boards of St. Luke’s-Roosevelt Hospital in New York and Kyunghee Oriental Medical Center in Seoul, Korea, and each subject gave written consent before participation.

Subjects

**Korean-Asian.** Fifty subjects were required to be independent, community-dwelling overweight (BMI > 28 kg/m²) premenopausal Korean women, ages 22–47 yr, not taking oral contraceptives, and not currently pregnant or breast feeding. The data included in these analyses were collected as the baseline data in an intervention study looking at the effects of a traditional Korean diet on weight loss (15). Inclusion criteria required that subjects be ambulatory, nonexercising, nonsmoking, and have maintained current body weight ±3 kg over the previous 3 mo. Subjects with untreated diabetes mellitus, malignant/catabolic conditions, missing limb, joint replacement, on estrogen replacement therapy, or taking medications (including oral contraceptives, calcitonin, steroids, or diuretics) that could potentially influence body composition were excluded from the study. Recruitment occurred through advertisements in newspapers and website.

**New York-Caucasian.** Subjects from archived datasets were identified based on race and age. Thirty-eight Caucasians were participants in a weight-loss study (19), and only the baseline data were used in the present analyses. Race was determined by self-report, where subjects had to report both parents and four grandparents as Caucasian. Subjects were recruited from 1997 to 2002 through advertisements in local newspapers, radio stations, and flyers posted in the local community. Inclusion criteria were as follows: premenopausal as determined by self report of regular menstrual cycles; ages 26–50 yr; BMI > 28 kg/m² but not weighing >250 lbs. (due to size limitations with the DXA scan system); not on medication affecting bone homeostasis (including oral contraceptives, hormone replacement therapy, calcitonin, fluoride, steroids, or diuretics); ambulatory, nonexercising, and nonsmoking. All subjects were healthy according to medical history, physical examination, and routine blood chemistry analyses.

**Body Composition**

**Korean-Asian.** While subjects wore a hospital gown, body weight was measured to the nearest 0.1 kg (Jenix; Dongsan, Korea) and height was measured to the nearest 0.5 cm using a stadiometer (CAS). Total body fat, fat-free body mass, and bone mineral content were measured with a whole body DXA (Prodigy, GE Lunar, Madison, WI) using software version 6.5. The raw DXA scan data were stored on CD-ROM and sent to the DXA laboratory of St. Luke’s-Roosevelt Hospital in New York for analysis.

**New York-Caucasian.** While subjects wore a hospital gown and were barefoot, body weight was measured to the nearest 0.1 kg (Weight Tronix, New York, NY) and height to the nearest 0.5 cm using a stadiometer (Holtain; Crosswell). Total body fat, fat-free body mass, and bone mineral content were measured with a whole body DXA (DPXL, GE Lunar) using software version 3.4. Analyses of all Korean and New York DXA scans were performed by the same DXA technician in New York.

**DXA Quality Control**

A standard soft-tissue calibration method for DXA developed in New York and used daily since 1987 was employed in both the Korean and New York laboratories. Bottles with an 8-liter volume capacity (Fischer Scientific, Pittsburgh, PA) containing methanol and water, simulating fat and fat-free soft tissues, respectively, were scanned on the day of study as soft-tissue quality control markers. The coefficient of variation over the study period was 4.39 and 12.98% for methanol and water, respectively, for Korea and 1.18 and 6.23% for methanol and water, respectively, for New York. The purpose of this calibration procedure is twofold: 1) to monitor the stability of a DXA machine over time and 2) to allow for the pooling of DXA soft-tissue data (i.e., PBF) collected on different machines. The latter is essential when data collected at different locations on similar machines from the same manufacturer are compared, because machines do not read the same exact soft-tissue values.

**PBF Conversion Equation**

To answer the question of whether, for a similar BMI, Korean-Asians have a greater PBF compared with Caucasians, the percent fat readings (derived from the ratio of the attenuation at 2 energy peaks) from the methanol and water bottles were used to generate a regression equation where PBF for the Korean (Asian) sample was converted to New York (Caucasians) values. The conversion equation was:

\[
PBF_{\text{New York-Caucasian}} = 1.132215 \cdot (PBF_{\text{Korean-Asian}} - 2.251266)
\]

**Statistical Analysis**

All analyses were carried out with the statistical software program SPSS, version 11.5 (SPSS, Chicago, IL), and P < 0.05 was considered to be statistically significant. Student’s t-test was used to test for race differences in the study sample. The relationship between PBF and BMI was assessed by multiple regression analysis with race, age, reciprocal of BMI (1/BMI), and a race-by-age interaction as the final independent variables. Potential interaction terms were explored in model development. The reciprocal of BMI (1/BMI) was used instead of BMI to improve the linearity in the regression model as justified previously (6, 7).

**RESULTS**

**Subject Characteristics**

The descriptive characteristics for Korean-Asian and New York-Caucasian premenopausal overweight women in this sample are summarized in Table 1. Korean-Asians were younger (P < 0.001) and weighed less (P < 0.001) compared with New York-Caucasians. The difference in height was marginal (P = 0.061). BMI and hip circumference (both P < 0.001) were smaller, and waist circumference (P = 0.046) and waist-to-hip ratio (P < 0.001) were larger in the Korean-Asian group. In terms of body composition, Korean-Asians had a higher PBF (P = 0.005) with less total lean tissue (P < 0.001),

### Table 1. Subject characteristics

<table>
<thead>
<tr>
<th>Measure</th>
<th>Korean-Asians (n = 50)</th>
<th>New York-Caucasians (n = 38)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>32.0 ± 7.0</td>
<td>40.6 ± 6.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Anthropometric measurements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body weight, kg</td>
<td>82.4 ± 9.4</td>
<td>91.8 ± 8.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Height, m</td>
<td>1.60 ± 0.05</td>
<td>1.62 ± 0.06</td>
<td>0.061</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>32.1 ± 3.1</td>
<td>34.9 ± 3.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>97.5 ± 6.8</td>
<td>96.3 ± 7.1</td>
<td>0.046</td>
</tr>
<tr>
<td>Hip circumference, cm</td>
<td>113.9 ± 6.6</td>
<td>119.4 ± 7.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.86 ± 0.04</td>
<td>0.81 ± 0.05</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total lean tissue, kg</td>
<td>44.6 ± 4.3</td>
<td>44.1 ± 4.2</td>
<td>0.005</td>
</tr>
<tr>
<td>Total fat, kg</td>
<td>44.6 ± 5.5</td>
<td>50.7 ± 4.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total BMC, kg</td>
<td>36.3 ± 6.1</td>
<td>40.3 ± 6.5</td>
<td>0.004</td>
</tr>
<tr>
<td>Total BMD, g/cm²</td>
<td>2.7 ± 0.3</td>
<td>2.6 ± 0.2</td>
<td>0.021</td>
</tr>
<tr>
<td>Total BMD, g/cm²</td>
<td>1.20 ± 0.07</td>
<td>1.21 ± 0.06</td>
<td>0.264</td>
</tr>
</tbody>
</table>

Values are means ± SD. DXA, dual-energy X-ray absorptiometry; BMC, bone mineral content; BMD, bone mineral density; PBF, percent body fat.
less total fat \((P = 0.004)\), and greater total bone mineral content \((P = 0.021)\) compared with the New York-Caucasians. There was no significant between-group difference in total bone mineral density \((P = 0.264)\).

**Regression Models for PBF**

The results from the regression model described in Eq. 2 are shown in Table 2 where PBF equals \(b_0 + b_1(\text{race}) + b_2(\text{age}) + b_3(\text{1/BMI}) + b_4(\text{age} \times \text{race}) + \epsilon\) (Eq. 2) with \(b_0–b_4\) representing the intercept and regression coefficients of the terms in the model.

Race \((P = 0.003)\) and 1/BMI \((P < 0.001)\) were significantly related to PBF in this model. After adjusting for age and age \(\times\) race, there was a significant difference in PBF \((P = 0.015)\) such that Korean-Asians had a greater PBF compared with New York-Caucasians (Fig. 1). A significant race-by-age interaction \((P = 0.039)\) was found, indicating that the slope of the lines for PBF vs. age differed between Korean-Asians and New York-Caucasians (Fig. 2).

**DISCUSSION**

Obesity is a global epidemic. Pacific populations, although small, have the highest rates of obesity in the world (22). A few published reports indicate that, in the Asian populations studied, there was a higher PBF and a high prevalence of obesity-related diseases at a lower BMI (2, 5, 23) compared with other race groups. The results of the present study support the hypothesis that overweight premenopausal Korean-Asian women have a higher PBF than Caucasian women. To our knowledge, the present study is the first to investigate whether the relationship between PBF and BMI in overweight premenopausal Korean women differs from that in Caucasian women.

These findings add to and are in agreement with previous reports involving Asian populations (7, 9, 21). Wang et al. (21), using DXA, showed that Asians living in the New York area had a lower BMI but a higher PBF compared with age-matched Caucasians \((51 \pm 17\, \text{yr})\). Gallagher et al. (7) reported higher PBF levels at lower BMIs in Japanese-Asians \((39.3 \pm 15.9\, \text{yr})\) compared with Caucasians (from the United States and the UK) and African-Americans. The predicted PBF values at different age ranges and BMI ranges, in the subgroup of women ages 60–79 yr with BMI over 25, were higher in Asians compared with Caucasians (7) and are consistent with the findings of He et al. (9). He et al. also found that, among postmenopausal women, with increasing BMI, Asians living in Beijing had significantly less PBF compared with African-Americans and Caucasians living in New York City.

The relationship between BMI and PBF is influenced by age and should be considered when PBF is compared among different ethnic groups (8) but has frequently been overlooked in previous reports (7, 9, 21). In the present study, although overweight premenopausal Korean-Asian women had a higher PBF than Caucasian women, with increasing age PBF was found to decrease in Korean-Asian women. This trend was not evident in the Caucasian sample. That is, at similar ages \((e.g., <40\, \text{yr})\) and BMIs (within range studied), PBF in Asian women was greater than in Caucasian women. With increasing age, PBF decreased or at least increased to a lesser degree in Asians compared with Caucasians. At older ages \((e.g., >50–60\, \text{yr})\) and higher BMIs \((>\approx 30.0\, \text{kg/m}^2)\), PBF in Asian women may be less compared with that in Caucasian women.

Irrespective of race/ethnicity, a single definition is advocated by the WHO for overweight \((\text{BMI} \approx 25.0\, \text{kg/m}^2)\) and obesity \((\text{BMI} \approx 30.0\, \text{kg/m}^2)\). With regard to Asian populations, a

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**Table 2. Percent body fat multiple regression analysis model**

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Regression coefficients (SE)</th>
<th>(P) values</th>
<th>(R^2)</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>59.331 (6.109)</td>
<td>&lt;0.001</td>
<td>0.378</td>
<td>3.59</td>
</tr>
<tr>
<td>Age</td>
<td>0.172 (0.094)</td>
<td>0.070</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race†</td>
<td>14.156 (4.544)</td>
<td>0.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age × race‡</td>
<td>-0.254 (0.121)</td>
<td>0.039</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/BMI</td>
<td>-767.494 (145.785)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Dummy codes are 0 = New York-Caucasian and 1 = Korean-Asians.
†Interaction variable between age and race.
WHO expert consultation committee recently suggested an additional definition or trigger point for public health action at a BMI of 23 kg/m² (22, 24). The inference here is that the risk from obesity for Asians with a BMI of 23 kg/m² may be similar to that for Caucasians with a BMI of 25 kg/m². The relative risk of having at least one risk factor for cardiovascular disease was reported high at a low BMI in Chinese, Filipinos, and Koreans (23), and the progression in the prevalence of diabetes with increasing BMI and waist circumference was observed in all populations (23). Although Asians had the smallest BMI, 63% had a PBF above the median values for whites within each gender (20). High rates of diabetes, hypertension, and dyslipidemia have been noted in middle-aged and elderly Koreans even at relatively low BMIs (10, 11). The relative risk of disorders in elderly Koreans doubled at a BMI of 23.0–24.0 kg/m² and tripled at a BMI of 26.0 kg/m² compared with a baseline BMI of 18.5–22.0 kg/m² (10).

There is disagreement, however, on the use of WHO/International Association for the Study of Obesity/International Obesity Task Force proposed lower cutoff points for overweight (BMI 23.0 kg/m²) and obesity (BMI 25.0 kg/m²) in Asian and Pacific Island populations (16, 17). Central to this debate is the accuracy of BMI to define obesity since body composition profiles differ across race groups, including among Asian populations (5, 7, 21). The amounts of lean tissue, adipose tissue, and adipose tissue distribution are important contributors to obesity-related diseases. Adipose tissue can be divided into subcutaneous adipose tissue and visceral adipose tissue. In obese men (13), obese postmenopausal woman (1), and obese premenopausal women (14), visceral adipose tissue has been reported to be a marker of insulin resistance. In Asians, higher PBF and higher quantities of visceral adipose tissue have been reported compared with African-Americans and Caucasians (12, 18). Asian-American women had a higher log-transformed visceral adipose tissue compared with European-American women, after adjusting for age and total body fat (12). Tanaka et al. (18) reported that Japanese adults had a significantly greater amount of abdominal visceral fat compared with Caucasians after adjusting for age, sex, and abdominal subcutaneous fat. In the present study, however, adipose tissue/fat distribution was not measured.

The present study findings show that, in the BMI range studied, PBF increased with age in Caucasians and decreased with age in Korean-Asians. Two possible factors could explain this difference: one is racial background (i.e., genetics) and the other is nutrition/environment. The South Korean population continues to advance through a nutrition transition, and significant socioeconomic changes are ongoing. Older Koreans (>50 yr) were exposed to a relative nutritional deficit, whereas younger Koreans (<40 yr) have not had such an experience and have, in fact, likely experienced a relative nutritional excess and less physical activity. Therefore, a cohort effect may be influencing BMI.

Study Limitations

Sample representativeness. The participants in this study were nonrandomly selected volunteers in BMI and age ranges not representative of all women. Had subjects with lower BMIs been included, a more representative cohort would have improved the external validity of the results. All subjects were in good health, which may not be representative of the general premenopausal populations in their respective locations.

In conclusion, the relationship between PBF and BMI was assessed in two distinct populations that differed by race. This study demonstrates in a Korean-Asian sample that the BMI-fat relationship differs significantly from that in a comparable group of Caucasian women. Investigators who use BMI as an index of fatness should be aware of the well documented differences in the relationship of BMI and fatness across race/ethnic groups.

ACKNOWLEDGMENTS

S. Chung was a visiting fellow at New York Obesity Research Center and participated in data analysis and manuscript writing. M. Song, H. Shin, and D. Kim collected Korean data. Q. He and S. Heshka participated in data analyses. J. Wang and J. Thornton participated in DXA phantom quality control. F. X. Pi-Sunyer and B. Laferre re provided Caucasian data. D. Gallagher was involved in study design, data quality control, and manuscript writing.

GRANTS

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REFERENCES


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