Upper-Body Fat Distribution: A Hyperinsulinemia-Independent Predictor of Coronary Heart Disease Mortality

The Paris Prospective Study

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The fact that hyperinsulinemia is an independent predictor for coronary heart disease (CHD) mortality has been ascertained by three large prospective studies in the last 10 years. This result remained unchanged in the Paris Prospective Study over a longer follow-up period. This epidemiological finding is consistent with the hypothesis of cardiovascular risk attached to "syndrome X" as defined by Reaven, i.e., that hyperinsulinemia is linked to insulin resistance and potentially atherogenic abnormalities (high very low density lipoprotein triglyceride level, low high density lipoprotein cholesterol level, elevated blood pressure, and glucose intolerance). Stout also proposed some physiological hypotheses that could give credibility to a causal role of hyperinsulinemia per se.

In parallel during the last decade, upper-body fat distribution has emerged as another "new" independent risk factor for CHD and as a correlate of angiographically documented coronary atherosclerosis. This prospectively confirmed Jean Vague’s observations, published in 1956, that women with cardiovascular complications or non-insulin-dependent diabetes tended to have android (upper-body) rather than gynoid obesity. Some epidemiological results suggest that android fat distribution is closely linked to hyperinsulinemia, and there are physiological hypotheses to explain this relation, mostly those involving free fatty acid metabolism.

Thus, it seemed interesting to compare the respective roles of hyperinsulinemia and upper-body fat distribution as predictors of CHD mortality. The Paris Prospective Study provided the means of performing this comparison, since baseline variables included measurements of both anthropometric indices and plasma insulin concentrations.
Methods

The present analysis was performed on data from the Paris Prospective Study, of which the general aims, detailed methodology, and population characteristics have been previously described. Only relevant data are detailed here. The inclusion session took place between 1967 and 1972.

The first of four consecutive annual follow-up examinations, performed during the period 1968–1973, involved 7,152 male employees of the Paris police, aged 43–54 years, who were included after having given consent to participate and who were assessed with respect to the following conditions: place of birth in metropolitan France (i.e., excluding Caribbean natives) and freedom from any cardiovascular history. Among this population, the iliac and the thigh circumferences had been measured 1 year before, i.e., at the initial entry examination, in 7,141 subjects. Anthropometric indices were measured by three specially trained technicians, with the subjects in a standing position (the arms at rest along the body) and in apnea fixed at the midrespiratory phase. Iliac (at the iliac crest level) and left thigh (middle distance between the trochanter and external condylus) circumferences to the nearest millimeter were obtained with a flexible measuring tape. The ratio of these two circumferences, or the iliac-to-thigh ratio (ITR), was used as an estimate of fat distribution. The first annual examination included a 0–2-hour 75-g oral glucose tolerance test, with measurement of glucose levels in 7,003 men; of fasting plasma insulin level in (FPI) in 6,937 men; and of postload insulin (PI) levels in 6,889. The major CHD mortality risk factors were recorded: blood pressure, smoking habits, body mass index (BMI, weight/height2, in kilograms per square meter), and plasma cholesterol and triglyceride levels. Diabetes prevalence was estimated by grouping subjects with newly diagnosed diabetes (2-hour plasma glucose equal to or above 11.1 mmol/l) and subjects with known diabetes. Also, because alcohol is supposed to increase intra-abdominal fat deposits, erythrocyte mean corpuscular volume (MCV), a marker of alcohol consumption, was calculated (MCV=hematocrit/red blood cell count, fl).

All deaths up to January 1, 1983 were counted (mean follow-up, 11 years), and the present analysis was performed at this point, where the predictive power of insulin concentrations was shown to be the strongest. Nevertheless, the major results were checked at the next reckoning point, January 1, 1987 (mean follow-up, 15 years). Deaths were systematically reported by the different administrative departments of the Paris Police Service. Complementary inquiries to families, health practitioners, and hospitals were organized to obtain information regarding the circumstances and causes of death. The underlying cause of death was ascertained and coded by a panel of physicians. Coding was performed according to the International Classification of Diseases (8th revision); in the present analysis, only deaths caused by CHD to a large extent (codes 410.0–414.9, myocardial infarction; 795.0, sudden death; 782.0–782.9, 427.0, 427.1, and 519.1, heart failure) were considered.

For statistical analyses, subjects of the baseline cohort with missing values for one or more variables used in the test were excluded. All testing methods were the usual parametric ones. Multivariate analyses of the predictive power of baseline variables toward CHD death used the stepwise logistic-regression model. In the case of a nonlinear relation between a variable and CHD mortality, the variable was either logarithmically transformed or categorized to ensure a better fit to statistical modeling. Four interaction variables were created by calculating the product of ITR with FPI and 2-hour postload insulinemia (2hPI), either continuously or in two classes, and were expressed in standard deviation units. Because of the narrow age range of the population, no adjustment for age was made for univariate analyses. However, age was systematically included in multivariate analyses. All statistical analyses were done using the SAS statistical package.

Results

At 11-year follow-up, 129 men of the initial cohort had died of CHD. They differed significantly on all

<table>
<thead>
<tr>
<th>Variable</th>
<th>CHD death (n=129)</th>
<th>Other (n=7,023)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>48.9±2.1</td>
<td>48.4±2.0</td>
<td>0.006</td>
</tr>
<tr>
<td>Cigarettes (No/day)</td>
<td>13±10</td>
<td>9±10</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>157±30</td>
<td>144±21</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>26.8±3.3</td>
<td>26.0±3.3</td>
<td>0.008</td>
</tr>
<tr>
<td>Iliac-to-thigh ratio</td>
<td>1.83±0.15</td>
<td>1.77±0.15</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Cholesterol level (mmol/l)</td>
<td>6.0±1.0</td>
<td>5.6±1.0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Triglyceride level (mmol/l)*</td>
<td>1.79±0.02</td>
<td>1.24±0.02</td>
<td>&lt;0.004</td>
</tr>
<tr>
<td>Fasting glucose level (mmol/l)</td>
<td>5.9±1.0</td>
<td>5.7±0.8</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>2-Hour glucose level (mmol/l)</td>
<td>6.4±3.0</td>
<td>5.8±2.2</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td>Diabetes prevalence (%)</td>
<td>7.87</td>
<td>3.96</td>
<td>0.004</td>
</tr>
<tr>
<td>Fasting insulin level (pmol/l)*</td>
<td>85±14</td>
<td>71±14</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td>2-Hour insulin level (pmol/l)*</td>
<td>277±17</td>
<td>233±16</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>Mean corpuscular volume (fl)</td>
<td>98.6±6.0</td>
<td>96.7±5.3</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

*These values were computed in log values and then transformed into the original units.

CHD, coronary heart disease.
baseline variables listed in Table 1 from those who were alive or who had died of another cause. CHD mortality was significantly associated with older age; higher cigarette use; and higher levels of blood pressure, BMI, plasma cholesterol, triglyceride, fasting and postload blood glucose, and PI. Moreover, subjects who died of CHD had a significantly higher \( \text{ITR} \) (\( p<0.0001 \)) and a more elevated MCV (\( p<0.0001 \)). All of these variables were interrelated to some extent. Specifically, ITR was correlated with FPI (\( r=0.22, p<0.0001 \)) and 2hPI (\( r=0.18, p<0.0001 \)).

To study the interrelation of fat distribution and insulin concentration to CHD risk, two classes were created for each variable: for ITR, classes were above and below 1.77, which was the median of the distribution, and for FPI and 2hPI levels, the classes were the last quintile versus first four quintiles, in accordance with previous reports.\(^4.19\) The "high-ITR" group had approximately twice the annual CHD mortality rate of the "low-ITR" group: 2.22% versus 1.15% (\( p<0.0002 \)). Figures 1 and 2 illustrate CHD mortality in relation to ITR classes and FPI and 2hPI levels. Each factor, when isolated, either had little influence on CHD death rates or was inoperative (e.g., FPI). However, when a high ITR was observed concurrently with a high PI level, CHD mortality was 4.1 times higher (for FPI) and 2.4 times higher (for 2hPI) than in the respective low-ITR group. In Figure 2, CHD mortality rate appeared more or less equal in the high-ITR-low-2hPI group and the low-ITR-high-2hPI group; this result indicates the possibility that both variables are independent CHD risk factors.

The results of several multivariate analyses are given in Table 2. The four major risk factors of CHD were added as explanatory variables to ITR and PI levels with four modalities (FPI taken continuously, FPI in two classes as defined above, 2hPI taken continuously, and 2hPI in two classes as defined above). In all four models, ITR appeared as an independent predictor of CHD death. FPI level, whether continuous or dichotomized, did not reach statistical significance as an independent predictor of CHD death when ITR was taken into account. However, the dichotomized (but not the continuous) 2hPI level retained a significant predictive power together with ITR. BMI, plasma glucose, and triglyceride levels never reached a significant probability value in any of the models. The results were similar at 15-year follow-up.
To complete this analysis, a multivariate stepwise logistic regression was performed with an interaction variable between insulin (in the four previously described modalities) and ITR. In no model was the interaction variable entered, and it never affected the coefficient for ITR and insulin.

To find some explanation for the independent predictive roles of 2hPI level and fat distribution, we compared the values of various parameters in quintiles of 2hPI and ITR (Tables 3 and 4, respectively). For BMI, systolic blood pressure, plasma cholesterol level, proportion of diabetes cases, and CHD mortality, there was a steady significant increase of values along the quintiles of both 2hPI and ITR. By contrast, cigarette use and MCV increased with increasing ITR, whereas they decreased with increasing 2hPI.

**Discussion**

The present analysis confirms a previous analysis of the Paris Prospective Study that showed an association of 2hPI level with CHD mortality risk.\(^1\) However, upper-body fat distribution estimated by the ITR is shown here to be another powerful independent predictor of CHD mortality. It even replaces FPI, which was a steady significant increase of values along the quintiles of both 2hPI and ITR. In contrast to those of the iliac and thigh. Nevertheless, ITR can be considered a good marker of upper-body obesity.\(^2\) This ratio is clearly related to BMI (Table 4) and to skinfold thicknesses.\(^3\) Within this male population the iliac circumference must be influenced more by differences in fat deposition rather than by different skeletal characteristics. Moreover, if differential muscle mass in the thigh can also be suspected to contribute to CHD prediction with this index,\(^4\) we found that iliac circumference alone was strongly predictive of CHD death (p<0.0001), whereas the thigh circumference was not (p=0.30). Using the ratio of the two circumferences greatly enhanced the predictive power.

The correlation of hyperinsulinemia and upper-body (or male-type) fat distribution is well established\(^12-15,22\) and was also confirmed in the present study. In contrast to what had been found previously,\(^1\) FPI did not reach a significant probability value as a predictor of CHD in multivariate analyses after ITR was entered in the model. Because it has been hypothesized that hyperin-
Fat Distribution, Hyperinsulinemia, and Coronary Risk

Table 4. Mean Values (±SD) of Baseline Variables According to Quintiles of Iliac-to-Thigh Ratio at Entry to Follow-up and Univariate Correlation Coefficients Between These Variables and Iliac-to-Thigh Ratio

<table>
<thead>
<tr>
<th>Quintiles of iliac-to-thigh ratio</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>48.7±2</td>
<td>48.8±2</td>
<td>48.9±2</td>
<td>48.9±2</td>
<td>48.9±2</td>
<td>0.02</td>
<td>NS</td>
</tr>
<tr>
<td>Cig (No./day)</td>
<td>7.8±10</td>
<td>9±10</td>
<td>9±10</td>
<td>10.2±10</td>
<td>10.8±11</td>
<td>0.08</td>
<td>0.0001</td>
</tr>
<tr>
<td>SBP (mm Hg)</td>
<td>137±18</td>
<td>140±20</td>
<td>145±22</td>
<td>147±22</td>
<td>154±26</td>
<td>0.22</td>
<td>0.0001</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.3±3</td>
<td>25.3±3</td>
<td>26.2±3</td>
<td>27.0±3</td>
<td>28.0±4</td>
<td>0.33</td>
<td>0.0001</td>
</tr>
<tr>
<td>Chol (mmol/l)</td>
<td>5.29±0.93</td>
<td>5.52±1.06</td>
<td>5.58±1.06</td>
<td>5.68±1.08</td>
<td>5.73±1.08</td>
<td>0.12</td>
<td>0.0001</td>
</tr>
<tr>
<td>FPI (pmol/l)</td>
<td>65.9±50</td>
<td>78.2±57</td>
<td>91.1±65</td>
<td>103.2±100</td>
<td>119.7±86</td>
<td>0.22</td>
<td>0.0001</td>
</tr>
<tr>
<td>2-Hour postload insulin (pmol/l)</td>
<td>229.4±179</td>
<td>279.6±251</td>
<td>329.8±294</td>
<td>372.8±323</td>
<td>415.9±387</td>
<td>0.18</td>
<td>0.0001</td>
</tr>
<tr>
<td>MCV (fl)</td>
<td>96.5±5</td>
<td>96.8±5</td>
<td>96.8±5</td>
<td>97.2±6</td>
<td>97.4±6</td>
<td>0.05</td>
<td>0.0007</td>
</tr>
<tr>
<td>Diabetes prevalence (%)</td>
<td>0.99</td>
<td>1.9</td>
<td>3.38</td>
<td>5.68</td>
<td>8.89</td>
<td>0.12</td>
<td>0.0001</td>
</tr>
<tr>
<td>CHD mortality (%)</td>
<td>0.67</td>
<td>1.35</td>
<td>2.07</td>
<td>1.98</td>
<td>3.91</td>
<td>0.06</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Cig: cigarette smoking; SBP, systolic blood pressure; BMI, body mass index; ITR, iliac-to-thigh ratio; Chol, plasma cholesterol level; FPI, fasting plasma insulin level; MCV, mean corpuscular volume; CHD, coronary heart disease.

Hyperinsulinemia is a feature of syndrome X as described initially by Reaven and that this syndrome could be the explanation of the epidemiological finding of the relation between insulin levels and CHD, then it is probably correct to think, as was suggested by Zimmet, that upper-body fat distribution should be added to the metabolic syndrome. This latter variable, as another indicator of the same syndrome, could then replace insulin level as a predictor of future CHD death. If this hypothesis is true, then fat distribution could represent the clinical parameter and PI level the biological marker of the same CHD risk syndrome. Actually, several authors have proposed physiological explanations to account for the role of abdominal fat deposits in hepatic insulin resistance first and hyperinsulinemia second. Our results support the idea of a greater predictive power for ITR, which may involve alcohol consumption and cigarette use, because they increase with increasing PI, whereas they decrease with increasing PI level.

However, a second important finding of this analysis is the independent predictive power of dichotomized 2hPI level even when a marker of fat distribution and the four major coronary risk factors (blood pressure, smoking, age, and plasma cholesterol level) are controlled for in the model. This latter result could be consistent with a direct effect of the highest PI levels on the vessel walls, as was previously proposed, or with other specific metabolic effects, such as a possible relation to very low density lipoprotein triglyceride, that are independent of fat distribution.

Thus, our analysis confirms that hyperinsulinemia and male-type fat distribution are two interrelated predictors of CHD mortality. This may be explained in part because both factors are markers of a metabolic syndrome associated with insulin resistance. However, some part of their predictive power seems to be independent. Pathophysiological explanations are still needed to account for this fact.

References

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