Visceral Adipose Tissue Accumulation, Cardiorespiratory Fitness, and Features of the Metabolic Syndrome

Benoit J. Arsenault, MSc; Dominique Lachance, BSc; Isabelle Lemieux, PhD; Natalie Alméras, PhD; Angelo Tremblay, PhD; Claude Bouchard, PhD; Louis Pérusse, PhD; Jean-Pierre Desprès, PhD, FAHA

Background: It has been suggested that overweight and obese individuals with an adequate level of cardiorespiratory fitness (CRF), the so-called fat and fit, are at reduced risk of coronary heart disease and type 2 diabetes mellitus.

Methods: To determine whether individuals with low CRF have more visceral adipose tissue (AT) accumulation compared with individuals with high CRF and to verify whether low CRF is associated with a poorer metabolic profile, we performed a cross-sectional study of 169 asymptomatic men without diabetes mellitus (mean±SD body mass index [calculated as weight in kilograms divided by height in meters squared], 25.9±4.4; and mean±SD age, 37.1±14.0 years). Abdominal AT accumulation, CRF, and indexes of plasma glucose-insulin homeostasis and of the lipoprotein-lipid profile were measured.

Results: More visceral AT accumulation was observed among men in the lowest tertile of CRF compared with men in the highest tertile of CRF (mean±SD, 139.6±70.2 cm² vs 74.7±41.6 cm²; P<.001). Overall, the plasma lipoprotein-lipid profiles were more favorable in men with a high CRF compared with individuals with a low CRF, as men with a low CRF had higher triglyceride (mean±SD, 161±73 mg/dL vs 99±45 mg/dL; P<.001) and apolipoprotein B (mean±SD, 106±23 mg/dL vs 89±24 mg/dL; P<.009) levels and an increased total cholesterol–high-density lipoprotein cholesterol ratio (mean±SD, 5.27±1.00 vs 3.96±1.17; P=.002) than men with high CRF. After matching individuals with similar body mass index values but with high or low CRF, men with low CRF were characterized by more visceral AT accumulation than men with high CRF (mean±SD, 114.4±59.9 cm² vs 87.8±49.1 cm²; P<.007) and by a poorer metabolic profile. However, when matched for visceral AT accumulation, such differences were no longer statistically significant.

Conclusion: This study underlines the importance of visceral AT accumulation in the previously reported association between CRF and metabolic complications predictive of coronary heart disease and type 2 diabetes mellitus.

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It is well recognized that an excess accumulation of body fat in the abdominal cavity (visceral adipose tissue [AT] accumulation), is associated with a cluster of metabolic abnormalities often referred to as the metabolic syndrome. To prevent visceral obesity and related metabolic abnormalities, increasing energy expenditure with regular exercise could help reduce risk factors for coronary heart disease (CHD) and type 2 diabetes mellitus.

The lower CHD risk observed among physically active persons compared with sedentary individuals could be related to the beneficial effects of regular exercise on glycemic control, insulin sensitivity, and plasma lipoprotein-lipid levels. Regular physical activity has also been shown to induce substantial mobilization of atherogenic visceral AT.

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dependent of body weight. The investigators found that overweight and obese subjects with high CRF were at reduced CHD risk compared with subjects with normal body weight and low CRF. Based on these observations, the authors pioneered the theory that one could be “fat and fit” and at reduced CHD risk compared with nonobese unfit individuals. However, little is known about the body fat distribution and visceral AT mass of fat and fit subjects. Therefore, we first tested the hypothesis that individuals with high CRF may have less visceral AT accumulation compared with individuals with low CRF, regardless of body mass index (BMI [calculated as weight in kilograms divided by height in meters squared]). We then examined the contribution of such reduced visceral AT accumulation to the more favorable metabolic risk profile of fit compared with unfit individuals.

METHODS

POPULATION

Subjects in this study were asymptomatic men without diabetes mellitus who participated in phase 2 of the Quebec Family Study. Briefly, the Quebec Family Study is a population-based study of French Canadian families living in and around Quebec City, Quebec. The Quebec Family Study was approved by the Medical Ethics Committee of Universite´ Laval, Quebec. Subjects were recruited through the media and gave their written informed consent to participate in the study. Only healthy nonsmoking men aged between 18 and 65 years who were not receiving treatment for CHD, diabetes mellitus, dyslipidemias, or endocrine disorders were considered for the present analyses. Further details about the Quebec Family Study have been previously reported.16

ANTHROPOMETRIC AND BODY COMPOSITION MEASUREMENTS

Height, body weight,17 and waist circumference18 were measured following standardized procedures. The measurement of cross-sectional areas of abdominal AT accumulation was performed by computed tomography (between L4 and L5 vertebrae) as previously described.19 Fat mass and fat-free mass (FFM) were derived from the measurement of body density assessed by underwater weighing.20

PLASMA LIPOPROTEIN-LIPID PROFILE

Following a 12-hour overnight fast, blood samples were collected from an antecubital vein into vacuum tubes (Vacutainer; Becton, Dickinson and Co, Franklin Lakes, New Jersey) containing EDTA (Miles Pharmaceuticals, Rexdale, Ontario) for the measurement of plasma lipid and lipoprotein levels. Plasma cholesterol and triglyceride levels were analyzed in plasma and lipoprotein fractions (Technicon RA-500; Bayer Corporation, Tarrytown, New York) using enzymic reagents (Randox Laboratories Ltd, Crumlin, England). Plasma very LDL (density, <1.006 g/mL) was isolated by ultracentrifugation,21 and the high-density lipoprotein fraction was obtained after precipitation of LDL in the infranatant (density, ≥1.006 g/mL) with heparin and manganese chloride.22,23 The cholesterol content of the infranatant fraction was measured before and after the precipitation step, allowing the calculation of LDL cholesterol levels. Apolipoprotein B levels were measured in plasma using the rocket immunoelectrophoretic method of Laurell.24 Lyophilized serum standards for apolipoprotein B measurements were prepared in our laboratory and were calibrated using reference standards (Centers for Disease Control and Prevention, Atlanta, Georgia). The LDL peak particle size was measured by 2% to 16% nondenaturing polyacrylamide gradient gel electrophoresis performed on whole plasma as previously described.24

ORAL GLUCOSE TOLERANCE TEST

A 3-hour 75-g oral glucose tolerance test was performed in the morning after an overnight fast. Blood samples were collected in EDTA-containing tubes through a venous catheter placed in an antecubital vein for the determination of plasma glucose and insulin levels. Plasma glucose levels were measured enzymatically, whereas plasma insulin levels were measured by radioimmunoassay with polyethylene glycol separation.25,26 The total glucose and insulin areas under the curve during the oral glucose tolerance test were determined using the trapezoid method.

CARDORESPIRATORY FITNESS

Cardiorespiratory fitness of each participant was assessed by a progressive submaximal physical working capacity (PWC) test performed on a cycle ergometer (Monark, Vansbro, Sweden). Heart rate was measured through a single electrocardiogram derivation and was recorded during 3 consecutive 6-minute workloads, each separated by a 1-minute rest. The test was designed to reach a target heart rate of 150 beats/min at the end of the last workload. The PWC150, which is the power output at 150 beats/min, was then calculated. To consider the individual differences in body weight, PWC150 was expressed as kilograms of body weight (PWC150/kg).

STATISTICAL ANALYSIS

Data are expressed as mean±SD in the tables and as mean±SE in the figures. Unpaired t-tests were performed to compare men with high vs low CRF. One-way analyses of covariance using the general linear model with adjustment for age were performed to evaluate the effect of CRF on anthropometric and metabolic risk variables. Stepwise multiple regression analyses were computed to sort out the independent contribution of anthropometric and body composition variables to the variance of CRF. The 50th percentile for PWC150/kg in the present study sample corresponded to a value of 10.7 kiloponds/min (kpm) per kilogram. Therefore, subjects with a PWC150/kg of 10.7 kpm/kg or less were defined as being unfit (low CRF), and subjects with a PWC150/kg of greater than 10.7 kpm/kg were defined as being fit (high CRF). Finally, the logistic regression analysis was performed using CRF and visceral AT accumulation to predict the presence of the atherogenic metabolic triad. All statistical analyses were performed using commercially available software (SAS version 8.02; SAS Institute, Cary, North Carolina).

RESULTS

Anthropometric measurements and metabolic profiles of the sample of 169 men (mean±SD BMI, 25.9±4.4; and mean±SD age, 37.1±14.0 years), classified into tertiles of CRF (PWC150/kg), are given in Table 1. Because men in the low tertile tended to be older, the reported P values are those obtained after adjustment for age. Adiposity indexes decreased across tertiles of CRF, with visceral AT accumulation being lowest among men with the
The highest CRF (P < .001). Accordingly, men in the high CRF tertile had overall better metabolic risk profiles compared with men in the low CRF tertile. For instance, glucose and insulin areas under the curve determined during the oral glucose tolerance test were smallest among men with high CRF (P < .001). Overall, plasma lipoprotein-lipid profiles were more favorable among men with high CRF compared with men with low CRF. Subjects in the high CRF tertile were also characterized by highest FFM (P < .001). Multiple linear regression analyses were performed and revealed that the best predictors of CRF were age, FFM, and visceral AT accumulation (data not shown). The correlation coefficient between BMI and CRF was −0.22 (P = .004) and was not significant after statistical adjustment for visceral AT accumulation (P = .119), whereas the correlation coefficient between visceral AT accumulation and CRF was −0.42 (P < .001) and was unaffected by controlling for BMI.

To control for the decreased adiposity observed in subjects with high CRF, men were then individually matched on the basis of their BMI (within a 1.0 variation) but with high CRF or low CRF. Anthropometric measurements and metabolic profiles of men matched for BMI but with high vs low CRF are given in Table 2 and in Figure 1 and Figure 2. When subjects were matched for BMI, men with low CRF were older and had more visceral AT accumulation than men with high CRF (P < .007) (Table 2). Men with low CRF were characterized by elevated triglyceride and apolipoprotein B levels and by an increased total cholesterol–high-density lipoprotein cholesterol ratio compared with men with high CRF (Figure 1) (P ≤ .02). Figure 2 shows that the plasma glucose (P < .010) and insulin (P = .052) responses to the 75-g oral glucose challenge were higher in subjects with low CRF. Subjects were then matched according to their visceral AT accumulation (within a 5.0-cm² variation). Results given in Table 2 and in Figures 1 and 2 show that subjects with high vs low CRF matched for visceral AT accumulation no longer differed in their plasma lipoprotein-lipid profile and indexes of plasma glucose-insulin homeostasis. Such lack of difference in the cardiometabolic risk profile was observed despite the fact that men with low CRF had a lower FFM than men with high CRF.

Finally, to further explore the respective contributions of visceral AT accumulation and CRF to the metabolic risk profile, subjects were classified according to

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**Table 1. Anthropometric and Metabolic Characteristics Among 169 Men in the Study**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Low Tertile</th>
<th>Middle Tertile</th>
<th>High Tertile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>41.2 ± 13.9</td>
<td>35.3 ± 14.2</td>
<td>34.8 ± 13.2</td>
</tr>
<tr>
<td>Physical working capacity, kiloponds/min per kilogram</td>
<td>8.0 ± 1.3</td>
<td>10.6 ± 0.7²</td>
<td>14.9 ± 2.5³⁵¹</td>
</tr>
<tr>
<td>Blood pressure, mm Hg</td>
<td>116.4 ± 12.1</td>
<td>113.3 ± 12.7</td>
<td>112.4 ± 10.9</td>
</tr>
<tr>
<td>Systolic</td>
<td>73.8 ± 8.9</td>
<td>71.0 ± 10.2</td>
<td>70.0 ± 8.1</td>
</tr>
<tr>
<td>Diastolic</td>
<td>27.2 ± 4.9</td>
<td>26.3 ± 4.7⁶⁷</td>
<td>24.0 ± 2.7⁶⁷</td>
</tr>
<tr>
<td>Body mass index¹</td>
<td>47.6 ± 7.2</td>
<td>52.7 ± 10.4⁶⁷³</td>
<td>57.9 ± 9.8⁶⁷³</td>
</tr>
<tr>
<td>Fat-free mass, kg</td>
<td>21.5 ± 10.5</td>
<td>17.9 ± 8.7</td>
<td>12.4 ± 5.7⁶⁷³</td>
</tr>
<tr>
<td>Fat mass, kg</td>
<td>93.7 ± 13.8</td>
<td>89.3 ± 12.6</td>
<td>84.3 ± 9.0³⁶³</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>256.4 ± 4.6</td>
<td>255.6 ± 4.4</td>
<td>255.9 ± 4.3</td>
</tr>
<tr>
<td>Adipose tissue accumulation, cm²</td>
<td>256.4 ± 4.6</td>
<td>255.6 ± 4.4</td>
<td>255.9 ± 4.3</td>
</tr>
<tr>
<td>Total</td>
<td>256.4 ± 4.6</td>
<td>255.6 ± 4.4</td>
<td>255.9 ± 4.3</td>
</tr>
<tr>
<td>Visceral</td>
<td>256.4 ± 4.6</td>
<td>255.6 ± 4.4</td>
<td>255.9 ± 4.3</td>
</tr>
<tr>
<td>Subcutaneous</td>
<td>256.4 ± 4.6</td>
<td>255.6 ± 4.4</td>
<td>255.9 ± 4.3</td>
</tr>
<tr>
<td>Cholesterol level, mg/dL</td>
<td>256.4 ± 4.6</td>
<td>255.6 ± 4.4</td>
<td>255.9 ± 4.3</td>
</tr>
<tr>
<td>Total</td>
<td>256.4 ± 4.6</td>
<td>255.6 ± 4.4</td>
<td>255.9 ± 4.3</td>
</tr>
<tr>
<td>Visceral</td>
<td>256.4 ± 4.6</td>
<td>255.6 ± 4.4</td>
<td>255.9 ± 4.3</td>
</tr>
<tr>
<td>Subcutaneous</td>
<td>256.4 ± 4.6</td>
<td>255.6 ± 4.4</td>
<td>255.9 ± 4.3</td>
</tr>
<tr>
<td>Glucose level, mg/dL</td>
<td>95 ± 9</td>
<td>93 ± 9</td>
<td>93 ± 8</td>
</tr>
<tr>
<td>Insulin level, µIU/mL</td>
<td>10.6 ± 8.0</td>
<td>8.9 ± 5.7</td>
<td>7.0 ± 3.4⁶⁷³</td>
</tr>
<tr>
<td>Adipose tissue accumulation, cm²</td>
<td>256.4 ± 4.6</td>
<td>255.6 ± 4.4</td>
<td>255.9 ± 4.3</td>
</tr>
<tr>
<td>Glucose, mg/dL</td>
<td>256.4 ± 4.6</td>
<td>255.6 ± 4.4</td>
<td>255.9 ± 4.3</td>
</tr>
<tr>
<td>Insulin, µIU/mL</td>
<td>256.4 ± 4.6</td>
<td>255.6 ± 4.4</td>
<td>255.9 ± 4.3</td>
</tr>
<tr>
<td>C-reactive protein level, mg/L</td>
<td>1.46 ± 0.46</td>
<td>1.90 ± 2.00</td>
<td>1.05 ± 1.01⁶⁷³</td>
</tr>
</tbody>
</table>

Abbreviations: HDL, high-density lipoprotein; LDL, low-density lipoprotein.

SI conversion factors: To convert cholesterol to millimoles per liter, multiply by 0.0259; C-reactive protein to nanomoles per liter, multiply by 9.524; glucose to millimoles per liter, multiply by 0.0555; insulin to picomoles per liter, multiply by 6.945; and triglycerides to millimoles per liter, multiply by 0.0113.

1Data are given as mean ± SD.

²Significantly different from low tertile after adjustment for age, P < .05.

³Significantly different from middle tertile after adjustment for age, P < .05.

⁴Calculated as weight in kilograms divided by height in meters squared.

⁵All adipose tissue areas were rounded up to 1 decimal and therefore the total adipose tissue may not directly total the sum of visceral and subcutaneous areas.

⁶On log-transformed values.

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Results of the present study are consistent with the established theory that middle-aged men with low CRF are more likely to have a less favorable anthropometric and metabolic risk profile than men with high CRF. However, to the best of our knowledge, this study is the first to show that the poor metabolic risk profile of men with low CRF is associated with an increased visceral AT accumulation, whereas the prevalences were substantially increased among men with more visceral AT accumulation irrespective of their fitness level (80.0% for high CRF and 85.3% low CRF). The presence of the atherogenic metabolic triad of nontraditional risk markers, which includes hyperinsulinemia, hyperapolipoprotein B, and small LDL particles, has been shown to increase the risk of CHD by more than 20-fold even after controlling for traditional risk factors and lipid variables.28

It is recognized that visceral obesity is a better correlate of insulin resistance and of an atherogenic plasma lipoprotein-lipid profile than total body fat.30 Katzmarzyk et al30 suggest that elevated CRF diminishes the risk of all-cause and cardiovascular deaths associated with the metabolic syndrome, regardless of BMI. Accordingly, LaMonte et al31 note that low CRF is an independent predictor of incident metabolic syndrome in men and women, independent of age and BMI, supporting the notion that fat and fit individuals could be protected against the development of metabolic abnormalities that increase CHD risk. Although the present study was cross-sectional in design and had a limited sample size, we observed that low CRF was associated with a poor metabolic risk profile among subjects matched for BMI, which is consistent with the results of Katzmarzyk et al30 and of LaMonte et al.31 However, in the present study, men with low CRF were also characterized by more visceral AT accumulation than men with high CRF, despite no difference in BMI. Because the excess visceral AT accumulation was a condition likely to explain the altered metabolic risk profile of men with low CRF, further analyses were performed to control for this potentially confounding factor. Because differences in the metabolic risk profile were no longer significant after matching men with high vs low CRF, further analyses were performed to control for this potentially confounding factor. Because differences in the metabolic risk profile were no longer significant after matching men with low CRF, further analyses were performed to control for this potentially confounding factor. Because differences in the metabolic risk profile were no longer significant after matching men with low CRF, further analyses were performed to control for this potentially confounding factor. Because differences in the metabolic risk profile were no longer significant after matching men with low CRF, further analyses were performed to control for this potentially confounding factor. Because differences in the metabolic risk profile were no longer significant after matching men with low CRF, further analyses were performed to control for this potentially confounding factor. Because differences in the metabolic risk profile were no longer significant after matching men with low CRF, further analyses were performed to control for this potentially confounding factor. Because differences in the metabolic risk profile were no longer significant after matching men with low CRF, further analyses were performed to control for this potentially confounding factor.


d Significantly different from the corresponding subgroup, P < .01.

All adipose tissue areas were rounded up to 1 decimal and therefore the total adipose tissue may not directly total the sum of visceral and subcutaneous areas.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Matched for BMI</th>
<th>Matched for Visceral AT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High CRF (n = 58)</td>
<td>Low CRF (n = 58)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>34.1 ± 12.8</td>
<td>41.8 ± 15.1³</td>
</tr>
<tr>
<td>Physical working capacity, kiloponds/min per kilogram</td>
<td>13.6 ± 2.9</td>
<td>8.5 ± 1.5³</td>
</tr>
<tr>
<td>BMIb</td>
<td>25.2 ± 3.2</td>
<td>25.1 ± 3.2</td>
</tr>
<tr>
<td>Fat-free mass, kg</td>
<td>62.1 ± 7.1</td>
<td>57.3 ± 6.2²</td>
</tr>
<tr>
<td>Fat mass, kg</td>
<td>14.9 ± 7.2</td>
<td>17.0 ± 7.0</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>86.7 ± 10.4</td>
<td>87.9 ± 9.9</td>
</tr>
<tr>
<td>Adipose tissue accumulation, cm²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>266.7 ± 57.9</td>
<td>298.7 ± 54.4c</td>
</tr>
<tr>
<td>Visceral</td>
<td>87.8 ± 49.1</td>
<td>114.4 ± 59.9d</td>
</tr>
<tr>
<td>Subcutaneous</td>
<td>178.9 ± 96.0</td>
<td>184.2 ± 91.2</td>
</tr>
</tbody>
</table>

Table 2. Anthropometric Characteristics of Men Matched on the Basis of Body Mass Index (BMI) or Visceral Adipose Tissue (AT) Accumulation With High vs Low Cardiorespiratory Fitness (CRF)³

Data are given as mean ± SD.

Calculated as weight in kilograms divided by height in meters squared.

All adipose tissue areas were rounded up to 1 decimal and therefore the total adipose tissue may not directly total the sum of visceral and subcutaneous areas.

Because the presence of the atherogenic metabolic triad (defined by the simultaneous presence of hyperinsulinemia, hyperapolipoprotein B, and small LDL particles) has been reported to be predictive of increased CHD risk,28 the proportions of carriers of 2 or 3 features of this atherogenic metabolic triad were calculated in the 4 subgroups studied. To identify men carrying the atherogenic metabolic triad, previously published cutoff values for fasting insulin and apolipoprotein B levels and LDL peak particle diameter were used and corresponded to 7.0 µIU/mL, 96 mg/dL, and 255.5 Å, respectively.29 The proportion of carriers of 2 or more features of the atherogenic metabolic triad was largely dependent on visceral AT accumulation irrespectively of CRF, with prevalences reaching 37.5% (for high CRF) and 35.0% (for low CRF) among individuals with less visceral AT accumulation, whereas the prevalences were substantially increased among men with more visceral AT accumulation irrespectively of their fitness level (80.0% for high CRF and 85.3% low CRF).
of visceral adiposity and CRF to cardiometabolic risk. Never-
theless, our results suggest that visceral AT accumu-
lation could be a key confounding factor when the rela-
tionship of CRF, CHD risk, and metabolic syndrome is
examined. Results of the present study are consistent with
those of Wong et al, who reported differences in vis-
ceral AT accumulation among subjects with low vs high
CRF in a sample of men slightly older than the men in
the present study. In the present study, the fact that sub-
jects with low CRF had almost twice as much visceral
fat accumulation as subjects with high CRF supports this
theory. Christou et al suggest that aerobic fitness is not
as important as body fatness in explaining individual dif-
fences in the cardiovascular risk profile associated with
fitness. In that study, the potential associations between
fitness, fatness, and metabolic risk markers were evalu-
ated using multiple linear regression analyses with maxi-
mal oxygen uptake and waist circumference as respec-
tive indexes of aerobic fitness and abdominal AT
accumulation. The authors concluded that body fatness
was a stronger predictor of cardiovascular risk markers
than aerobic fitness.
The fact that endurance exercise training is associated with a preferential mobilization of visceral AT suggests that regular exercise may have metabolic benefits even in the absence of body weight loss. In addition, metabolic (and possibly cardiovascular) benefits can be observed without improvement in CRF because regular exercise is associated with increased energy expenditure that in turn promotes negative energy balance and prevents the development of visceral obesity and the associated “dysmetabolic” profile. Although physical activity intensity is associated with energy expenditure, our findings suggest that from a clinical standpoint the emphasis should be placed first on the volume of physical activity, to promote mobilization of visceral AT through increased energy expenditure. In addition to increased visceral adiposity, sedentary older populations are generally characterized by lower FFM. Accordingly, we found that men in the low CRF tertile had significantly lower FFM than subjects in the high CRF tertile. However, when men with low vs high CRF matched for visceral adiposity were compared, differences in the metabolic risk profile were no longer observed, despite the fact that men with low CRF tended to have lower FFM than men with

Figure 2. Area under the curve (AUC) of plasma glucose and insulin levels measured during a 75-g oral glucose tolerance test among men individually matched for body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared) (A) or for visceral adipose tissue (AT) accumulation (B) with high (open circle) or low (solid circle) levels of cardiorespiratory fitness (CRF) (>10.7 or ≤10.7 kiloponds/minute/kilogram). A. When men with high vs low CRF were matched on the basis of BMI, men with low CRF were characterized by larger glucose and insulin AUCs compared with men with high CRF. B. When men with high vs low CRF were matched on the basis of visceral AT accumulation, these differences were no longer observed. To convert glucose to millimoles per liter, multiply by 0.0555; insulin to picomoles per liter, multiply by 6.945. The open bars indicate the AUC of the open circles; the solid bars, the AUC of the solid circles.

Figure 3. Proportion of carriers of 2 to 3 features of the atherogenic metabolic triad among men classified according to more or less visceral adipose tissue (AT) accumulation (>130 or ≤130 cm²) with high or low levels of cardiorespiratory fitness (CRF) (>10.7 or ≤10.7 kiloponds/minute/kilogram). Men with more visceral AT accumulation were more likely to carry 2 to 3 features of the atherogenic metabolic triad compared with men with less visceral AT accumulation, irrespective of their CRF level (high vs low). 1.2 indicates that the corresponding subgroup is significantly different from subgroups 1 and 2.
high CRF. These results do not exclude an important role for reduced FFM, especially among older populations. In the present study, which included young to middle-aged adult men, visceral AT accumulation seemed to be a more important correlate of the metabolic risk profile than FFM.

Physical fitness was assessed in our study using a submaximal test rather than by the measurement of maximal oxygen uptake. It has been demonstrated that this submaximal test could discriminate highly fit from poorly fit individuals. Submaximal test results are associated with maximal oxygen uptake, and this test has the advantage of not requiring a maximal effort to classify subjects by fitness level, at lower cost and greater safety than maximal oxygen uptake tests.

Our sample included young to middle-aged men of white race/ethnicity. Therefore, we cannot extend these findings to women or to older men, who tend to have a greater visceral AT accumulation as they advance in age. In this regard, prospective studies are needed to evaluate the true relationship between sex, age, CRF, body composition, visceral AT accumulation, and the cardiometabolic risk profile. It would also be relevant to verify whether the protective effect of high physical fitness against the development of the metabolic syndrome is mediated by the maintenance of a low level of visceral AT accumulation.

Results of the present study suggest that the presence of excess visceral adiposity observed in men with low CRF is an important factor associated with their diabetogenic and atherogenic metabolic risk profile. This conclusion was reached at any BMI value studied. This finding supports the notion that visceral obesity is a major correlate of a metabolic risk factor profile that predicts the development of cardiovascular disease and type 2 diabetes mellitus resulting from poor CRF. Although CRF was not the best independent predictor of the metabolic risk profile, physical activity should be promoted irrespective of sex, age, and degree of obesity as a measure to reduce adiposity, increase energy expenditure, and potentially decrease atherogenic visceral AT mass.

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Author Contributions: Mr Arsenault and Drs Lemieux, Bouchard, and Després had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Tremblay, Bouchard, Pérusse, and Després. Acquisition of data: Arsenault, Lemieux, Alméras, and Després. Analysis and interpretation of data: Arsenault, Lachance, Lemieux, and Després. Drafting of the manuscript: Arsenault and Lachance. Critical revision of the manuscript for important intellectual content: Lemieux, Alméras, Tremblay, Bouchard, Pérusse, and Després.

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