# Waist and hip circumferences have independent and opposite effects on cardiovascular disease risk factors: the Quebec Family Study[1–3]

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**ABSTRACT**

**Background:** A high waist-to-hip ratio is associated with unfavorable cardiovascular disease risk factors. This could be due to either a relatively large waist or a small hip girth.

**Objective:** We sought to define the separate contributions of waist girth, hip girth, and body mass index (BMI) to measures of body composition, fat distribution, and cardiovascular disease risk factors.

**Design:** Three-hundred thirteen men and 382 women living in the greater Quebec City area were involved in this cross-sectional study. Percentage body fat, anthropometric measurements, and abdominal fat distribution were obtained and BMI (in $kg/m^2$) and waist-to-hip ratio were calculated. Serum blood lipids were determined from blood samples collected after subjects had fasted overnight

**Results:** A large waist circumference in men and women (adjusted for age, BMI, and hip circumference) was associated significantly with low HDL-cholesterol concentrations ($P < 0.05$) and high fasting triacylglycerol, insulin, and glucose concentrations ($P < 0.01$). In women alone, a large waist circumference was also associated with high LDL-cholesterol concentrations and blood pressure. A narrow hip circumference (adjusted for age, BMI, and waist circumference) was associated with low HDL-cholesterol and high glucose concentrations in men ($P < 0.05$) and high triacylglycerol and insulin concentrations in men and women ($P < 0.05$). Waist and hip girths showed different relations to body fat, fat-free mass, and visceral fat accumulation.

**Conclusions:** Waist and hip circumferences measure different aspects of body composition and fat distribution and have independent and often opposite effects on cardiovascular disease risk factors. A narrow waist and large hips may both protect against cardiovascular disease. These specific effects of each girth measure are poorly captured in the waist-to-hip ratio. *Am J Clin Nutr* 2001;74:315–21.

**KEY WORDS** Waist circumference, hip circumference, waist-to-hip ratio, body mass index, cardiovascular disease risk factors, fat distribution, cholesterol, insulin, blood pressure, Quebec Family Study

## INTRODUCTION

Waist circumference and the waist-to-hip ratio are widely used as indicators of abdominal obesity in population studies. It is increasingly clear that the waist circumference may be a better reflection of the accumulation of intraabdominal or visceral fat than the waist-to-hip ratio (1, 2). Because of the postulated role of the visceral fat depot in health risks associated with obesity (3, 4), waist circumference is now the preferred measure in the context of population studies. The waist-to-hip ratio is, however, a robust measure of risk in many population studies and it has been proposed that an increased waist-to-hip ratio may reflect both a relative abundance of abdominal fat (increased waist circumference) and a relative lack of gluteal muscle (decreased hip circumference) (5, 6). In a small study of Swedish men, it was observed that a high waist-to-hip ratio, after adjustment for age and body mass index (BMI), was associated with an increased visceral fat area and a decreased thigh muscle area (7). In another study that compared Indian and Swedish males of similar age, height, and weight, it was found that Indian males had high glucose, insulin, and triacylglycerol concentrations. It was shown by use of multiscan computed tomography (CT) that the Indian subjects had proportionally less leg muscle, but no ethnic differences were observed with regard to visceral fat concentrations (5).

The high waist-to-hip ratio in clinical subgroups, eg, alcoholic men (8) and women with Cushing syndrome (9), has been attributed to the wasting of leg muscle and an increased visceral fat area. Increased cortisol secretion was postulated as the underlying cause for these variations in fat and muscle distribution (10). Behavioral factors associated with a high waist-to-hip ratio (eg, high alcohol consumption, physical inactivity, and smoking)

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[2] Supported by in part by contributions of the Donald B Brown Research Chair on Obesity, Laval University, Quebec City, Canada, and the RIVM, Bilthoven, Netherlands. CB is partially supported by the George A Bray Chair in Nutrition. The Quebec Family Study is funded by a Group Grant from the Medical Research Council of Canada (GR-15187).

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Received March 6, 2000.

Accepted for publication December 22, 2000.

**TABLE 1**
Characteristics of the study population[1]

| | Men | Women |
|---|---|---|
| Age (y) | 42.6 ± 16.6 (18–84) | 43.1 ± 17.4 (18–94) |
| BMI (kg/m$^2$) | 27.0 ± 6.0 (17.4–57.3) | 27.2 ± 8.0 (16.8–64.9) |
| Waist circumference (cm) | 93.4 ± 16.3 (65.4–164.5) | 83.1 ± 17.9 (57.9–151.0) |
| Hip circumference (cm) | 100.5 ± 11.2 (78.6–169.5) | 104.2 ± 15.9 (79.4–200.0) |
| Waist-to-hip ratio | 0.92 ± 0.08 (0.76–1.14) | 0.79 ± 0.08 (0.53–1.08) |
| Fat mass (kg) | 19.9 ± 12.2 (1.2–92.6) | 24.3 ± 14.1 (2.8–109.3) |
| Fat-free mass (kg) | 60.0 ± 7.8 (41.2–83.5) | 43.8 ± 6.3 (29.3–71.8) |
| Abdominal fat distribution[2] | | |
| Total (cm$^2$) | 341.3 ± 192.3 (46.0–895.0) | 425.5 ± 228.3 (78.8–1066.0) |
| Visceral (cm$^2$) | 125.9 ± 79.8 (18.9–443.0) | 98.7 ± 66.1 (14.9–381.5) |
| Subcutaneous (cm$^2$) | 215.4 ± 132.8 (15.7–681.0) | 326.8 ± 180.0 (60.3–872.0) |
| Total cholesterol (mmol/L) | 5.1 ± 1.0 (2.2–8.6) | 5.2 ± 1.2 (2.0–15.1) |
| HDL cholesterol (mmol/L) | 1.1 ± 0.3 (0.5–2.2) | 1.3 ± 0.3 (0.4–2.5) |
| LDL cholesterol (mmol/L) | 3.2 ± 0.8 (1.1–6.0) | 3.1 ± 0.9 (0.9–8.2) |
| Triacylglycerols (mmol/L) | 1.7 ± 1.1 (0.5–4.5) | 1.5 ± 1.7 (0.3–4.5) |
| Insulin (pmol/L) | 75.5 ± 57.5 (1–329.0) | 76.3 ± 63.9 (1–588) |
| Glucose (mmol/L) | 5.4 ± 1.2 (3.6–13.4) | 5.2 ± 1.4 (3.5–18.5) |
| Systolic BP (mm Hg) | 121.2 ± 17.7 (84–187) | 120.3 ± 21.6 (88–223) |
| Diastolic BP (mm Hg) | 74.6 ± 10.7 (48–111) | 71.9 ± 10.4 (48–115) |

[1] $\bar{x}$ ± SD; range in parentheses. $n$ = 313 men and 382 women. BP, blood pressure.
[2] As measured by computed tomography.

were attributed to both a relatively large waist and relatively narrow hips (11, 12). Subjects with type 2 diabetes had markedly elevated waist-to-hip ratios, which was accounted for by both a larger waist and a smaller hip circumference than what was predicted based on the subject's age and BMI (6). Moreover, insulin clearance was increased with high muscle mass and decreased with high fat mass (13).

In population studies, it is difficult to interpret simple anthropometric measures of fatness and fat distribution and their relations with risk factors for cardiovascular disease and diabetes mellitus. Hence, it is important to explore these issues with laboratory-based studies that incorporate direct measurements of the key variables. In the present study, we try to dissociate the individual contributions of waist and hip circumferences and BMI to the risk factors often associated with fatness and fat distribution.

## SUBJECTS AND METHODS

Subjects were participants in phase 2 the Quebec Family Study (14). Only adult subjects aged ≥18 y were included in the present study. All subjects (313 men and 382 women were of French descent and lived within 80 km of Quebec City. Subjects were recruited through the media. Percentage body fat (underwater weight assessment of body density), anthropometric measurements (weight, height, and waist and hip circumferences), and abdominal fat distribution (visceral and subcutaneous fat areas measured by use of a CT scan at the L4–L5 level) were obtained, the methods of which are described in detail elsewhere (15). BMI (in kg/m$^2$) and waist-to-hip ratio were calculated. Serum blood lipids were determined from blood samples collected at ≈0800 after subjects had fasted for 12 h overnight. Total cholesterol and triacylglycerol concentrations were determined enzymatically by use of commercial kits, as described elsewhere (16). HDL-cholesterol and LDL-cholesterol concentrations were analyzed after precipitation of LDL in the infranatant fluid with heparin and manganese chloride (17). Glucose concentrations were measured enzymatically and serum insulin concentrations were measured by radioimmunoassay (18). Blood pressure was measured with a mercury sphygmomanometer (19).

### Statistical methods

All analyses were done with the use of the statistical software package SAS, version 6.1 (SAS Institute, Cary, NC). Pearson correlation coefficients were calculated and partial Pearson correlation coefficients were calculated and adjusted for BMI and age. Waist and hip circumferences were predicted from age and BMI by using multiple regression equations. Multiple regression was performed by using risk factors as the dependent variables and waist circumference, hip circumference, BMI, and age as the independent variables. In separate analyses, multiple linear regression was performed by using fat mass, fat-free mass, visceral fat area (CT scan), and subcutaneous fat (CT scan) as the dependent models and waist circumference, hip circumference, age, and BMI as the independent variables. In further analyses, risk factors were predicted from fat mass, fat-free mass, and age.

Residuals of waist and hip circumferences were calculated as the difference between observed and predicted values of BMI and age. These residuals were introduced as continuous independent variables in the multiple linear regression model in addition to age, BMI, and residuals of the other circumference. For illustrative purposes (graphic representation in figures), the residuals were divided into quartiles. Differences (adjusted for BMI, age, and the other circumference) between the second, third, and fourth quartile compared with the first quartile (reference category set as zero) were calculated by introducing these quartiles as dummy variables into the multiple regression model with age and BMI as covariates. $P$ values <0.05 were considered to be statistically significant.

## RESULTS

Characteristics of the study population are shown in **Table 1**. There was a considerable proportion of overweight persons in

**TABLE 2**
Correlations between anthropometric variables and body composition[1]

| | Waist circumference | Waist-to-hip ratio | BMI | FM | FFM | Total fat area[2] | Visceral fat area[2] | Subcutaneous fat area[2] |
|---|---|---|---|---|---|---|---|---|
| Waist circumference | | 0.83 | 0.95 | 0.96 | 0.60 | 0.93 | 0.82 | 0.86 |
| Waist-to-hip ratio | 0.75 | | 0.68 | 0.73 | 0.27 | 0.77 | 0.83 | 0.62 |
| BMI | 0.95 | 0.56 | | 0.95 | 0.63 | 0.92 | 0.74 | 0.88 |
| Fat mass | 0.94 | 0.55 | 0.97 | | 0.53 | 0.96 | 0.78 | 0.92 |
| Fat-free mass | 0.63 | 0.32 | 0.65 | 0.60 | | 0.41 | 0.21 | 0.47 |
| Total fat area[2] | 0.94 | 0.60 | 0.93 | 0.95 | 0.50 | | 0.84[3] | 0.94 |
| Visceral fat area[2] | 0.81 | 0.71 | 0.69 | 0.72 | 0.24[3] | 0.80 | | 0.61 |
| Subcutaneous fat area[2] | 0.89 | 0.50 | 0.93 | 0.94 | 0.55 | 0.98 | 0.65 | |

[1] Correlations for men are shown in the upper right of the table, for women in the lower left of the table. All correlations were significant, $P < 0.0001$.
[2] As measured by computed tomography.
[3] $P < 0.001$.

this sample, with an average BMI of ≈27, but there was also considerable variation in both age and degree of obesity.

The interrelations among the anthropometric variables (all except one variable were significant) are shown in **Table 2**. Many of the anthropometric variables were highly correlated, which made it difficult at the group level to establish whether waist circumference, waist-to-hip ratio, and BMI measured distinct aspects of body fat distribution or body composition. In general, when compared with waist circumference and BMI, the waist-to-hip ratio correlations with fat mass and fat-free mass tended to be weaker. In men, BMI was not as closely associated with visceral fat as were waist circumference or waist-to-hip ratio, whereas in women, waist circumference was most closely associated.

The correlations between waist circumference, waist-to-hip ratio, and BMI and cardiovascular disease risk factors are shown in **Table 3**. The correlations were generally of the same order of magnitude, but correlations with most risk factors tended to be somewhat lower for BMI than for waist circumference and waist-to-hip ratio. Waist-to-hip ratio showed relatively strong correlations with total cholesterol, LDL-cholesterol, and triacylglycerol concentrations in both men and women.

In men, after adjustment for age and BMI, associations between waist-to-hip ratio and cardiovascular disease risk factors tended to be stronger than they were for waist circumference (**Table 4**). In women, associations with cardiovascular disease risk factors were similar for waist circumference and waist-to-hip ratio, with the exception of total cholesterol and LDL-cholesterol concentrations, for which the associations tended to be stronger with waist-to-hip ratio than with waist circumference. Correlation coefficients for waist circumference and waist-to-hip ratio did not differ greatly (differences ranged from 0.00 to 0.10). The explained variance for the risk factor by waist circumference and waist-to-hip ratio (independent of age and BMI) was >10% for all risk factors.

The results of simultaneously entering waist circumference and hip circumference when predicting cholesterol concentrations after adjustment for age and BMI are shown in **Table 5**. Waist circumference was independently related to HDL-cholesterol, insulin, and glucose concentrations in men and women and related to LDL-cholesterol concentrations and blood pressure in women alone. Hip circumference had a positive association with HDL-cholesterol concentrations and a negative association with glucose concentrations in men and negative associations with triacylglycerol and insulin concentrations in men and women.

We constructed residuals that were defined as the differences between observed waist and hip circumferences and those predicted from age and BMI. Mean levels ± SE of HDL-cholesterol, triacylglycerol, and insulin concentrations in quartiles of these residuals (after adjustment for each other, age, and BMI) in comparison to the first quartile (set as zero) are shown in **Figures 1** and **2**. When entered as continuous variables into a multiple regression model, the linear correlations of the waist residuals,

**TABLE 3**
Correlations between selected anthropometric variables and cardiovascular disease risk factors[1]

| | Men | | | Women | | |
|---|---|---|---|---|---|---|
| | Waist circumference | Waist-to-hip ratio | BMI | Waist circumference | Waist-to-hip ratio | BMI |
| Total cholesterol | 0.18[2] | 0.32[3] | 0.13[4] | 0.10[4] | 0.24[3] | 0.02 |
| HDL cholesterol | −0.34[3] | −0.32[3] | −0.33[3] | −0.41[3] | −0.33[3] | −0.41[3] |
| LDL cholesterol | 0.08 | 0.21[3] | 0.04 | 0.15[2] | 0.26[3] | 0.06 |
| Triacylglycerol | 0.56[3] | 0.52[3] | 0.41[3] | 0.47[3] | 0.40[3] | 0.14[4] |
| Insulin | 0.71[3] | 0.57[3] | 0.68[3] | 0.68[3] | 0.45[3] | 0.66[3] |
| Glucose | 0.38[3] | 0.41[3] | 0.33[3] | 0.45[3] | 0.40[3] | 0.30[2] |
| Systolic BP | 0.42[3] | 0.39[3] | 0.35[3] | 0.39[3] | 0.43[3] | 0.27[3] |
| Diastolic BP | 0.45[3] | 0.39[3] | 0.39[3] | 0.35[3] | 0.36[3] | 0.31[3] |

[1] BP, blood pressure.
[2] $P < 0.01$.
[3] $P < 0.0001$.
[4] $P < 0.05$.

**TABLE 4**
Partial correlations between waist circumference, waist-to-hip ratio, and risk factors after adjustment for age and BMI[1]

| | Men | | Women | |
|---|---|---|---|---|
| | Waist-to-hip ratio | Waist circumference | Waist-to-hip ratio | Waist circumference |
| Total cholesterol | 0.06 | 0.03 | 0.14[2] | 0.09 |
| HDL cholesterol | −0.16[2] | −0.09 | −0.23[3] | −0.18[3] |
| LDL cholesterol | −0.01 | −0.03 | 0.15[2] | 0.13[2] |
| Triacylglycerols | 0.29[3] | 0.19[3] | 0.27[4] | 0.20[3] |
| Insulin | 0.28[3] | 0.29[3] | 0.18[2] | 0.16[2] |
| Glucose | 0.17[2] | 0.13[4] | 0.23[3] | 0.32[3] |
| Systolic BP | −0.05 | 0.01 | 0.17[3] | 0.17[2] |
| Diastolic BP | −0.02 | 0.03 | 0.11[4] | 0.11[4] |

[1] In women, hip circumference after adjustment correlated with triacylglycerol ($r = -0.13$) and insulin ($r = -0.12$), $P < 0.05$. BP, blood pressure.
[2] $P < 0.01$.
[3] $P < 0.0001$.
[4] $P < 0.05$.

after adjustment for age, BMI, and hip residuals, were significant in men, negative for HDL cholesterol ($P = 0.03$), and positive for triacylglycerol ($P < 0.001$), insulin ($P < 0.001$), and glucose ($P = 0.009$). Hip residuals, after adjustment for waist residuals, BMI, and age were significant and positive for HDL cholesterol ($P = 0.04$) and negative for triacylglycerol ($P = 0.0009$), insulin ($P = 0.035$), and glucose ($P = 0.031$).

In women, waist residuals were independently, negatively correlated with HDL-cholesterol ($P = 0.0002$) and positively correlated with LDL cholesterol ($P = 0.009$), insulin ($P = 0.004$), glucose ($P = 0.0001$), systolic blood pressure ($P = 0.0008$), and diastolic blood pressure ($P = 0.026$). Hip residuals in women were negatively correlated only to triacylglycerol ($P = 0.025$) and insulin ($P = 0.020$).

Increased waist and hip circumferences (adjusted for age and BMI) both reflect increased total body fat mass and increased fat-free mass, although the latter association was particularly strong for hip circumference in men and waist circumference in women, as shown in **Table 6**. These results show that increased hip circumference is associated with decreased visceral fat and increased subcutaneous abdominal fat, especially in men. This suggests that waist and hip circumferences reflect different aspects of body composition and fat distribution in men and women.

The results of the association of fat mass and fat-free mass (adjusted for each other) with cardiovascular disease risk factors adjusted for age are presented in **Table 7**. Increased fat mass is associated with unfavorable risk factors, whereas increased fat-free mass is associated with decreased total and LDL-cholesterol concentrations and increased glucose concentrations in men, and increased insulin concentrations in women.

## DISCUSSION

The results of this study suggest that waist and hip circumferences can be used to measure different aspects of body composition and fat distribution and have independent and often opposite effects on determining cardiovascular disease risk factors. A narrow waist and large hips may protect against cardiovascular disease. The results of this study confirm that interpreting an increased waist-to-hip ratio is more complex than generally assumed. The waist-to-hip ratio does not reflect variations in visceral fat accumulation only.

Anatomically, it makes sense that waist and hip circumferences indicate more than fat distribution. Variation in waist circumference reflects mainly variation in subcutaneous and visceral fat, whereas variation in hip circumference incorporates variation in bone structure (pelvic width), gluteal muscle, and subcutaneous gluteal fat.

Narrow hips may reflect less subcutaneous fat, which could have a favorable effect on risk factors. Alternatively, narrow hip circumferences may reflect gluteal muscle atrophy. Small skeletal frame size is also a possible explanation, although smaller hips than what was predicted from BMI and age were not associated with stature in the present study. The results of the present cohort agree with those of another cross-sectional population study in which subjects with type 2 diabetes had high waist-to-hip ratios, due to an independent contribution of both increased waist and reduced hip circumferences (6).

Both waist and hip circumferences and the tissues contributing to their variation may be influenced by behavioral characteristics (eg, smoking, alcohol consumption, and physical activity; 11, 12) and other factors affecting steroid metabolism (particularly

**TABLE 5**
Independent contributions of waist and hip circumference to cardiovascular disease risk factors (adjusted for age and BMI)[1]

| | Waist circumference | Hip circumference | Percentage of variance explained[2] |
|---|---|---|---|
| | | | % |
| Total cholesterol | | | |
| Men | 0.008 ± 0.012[3] | −0.006 ± 0.013 | 23.3 |
| Women | 0.019 ± 0.010 | −0.013 ± 0.010 | 22.2 |
| HDL cholesterol | | | |
| Men | −0.008 ± 0.003[4] | 0.008 ± 0.004[4] | 11.3 |
| Women | −0.010 ± 0.003[5] | 0.005 ± 0.003 | 22.9 |
| LDL cholesterol | | | |
| Men | −0.007 ± 0.010 | 0.004 ± 0.012 | 21.5 |
| Women | 0.021 ± 0.008[6] | −0.004 ± 0.008 | 18.1 |
| Triacylglycerols | | | |
| Men | 0.043 ± 0.010[5] | −0.039 ± 0.011[5] | 31.1 |
| Women | 0.024 ± 0.006[5] | −0.017 ± 0.006[6] | 23.5 |
| Insulin | | | |
| Men | 2.995 ± 0.571[5] | −1.364 ± 0.644[4] | 53.8 |
| Women | 1.320 ± 0.454[6] | −1.021 ± 0.438[4] | 50.3[7] |
| Glucose | | | |
| Men | 0.042 ± 0.016[6] | −0.039 ± 0.018[4] | 16.8 |
| Women | 0.069 ± 0.012[5] | −0.002 ± 0.011 | 23.2[7] |
| Systolic BP | | | |
| Men | −0.052 ± 0.205 | 0.310 ± 0.233 | 25.4 |
| Women | 0.432 ± 0.128[6] | −0.222 ± 0.125 | 40.1 |
| Diastolic BP | | | |
| Men | 0.035 ± 0.127 | 0.127 ± 0.144 | 22.5 |
| Women | 0.180 ± 0.080[4] | −0.086 ± 0.079 | 25.4 |

[1] BP, blood pressure. Age had a significant contribution to all variables except glucose and HDL-cholesterol concentrations in women, and triacylglycerol and glucose concentrations in men.
[2] Variance explained by age, BMI, and waist and hip circumferences.
[3] $\beta \pm$ SEM.
[4] $P < 0.05$.
[5] $P < 0.001$.
[6] $P < 0.01$.
[7] Independent, significant contribution of BMI, $P < 0.05$.

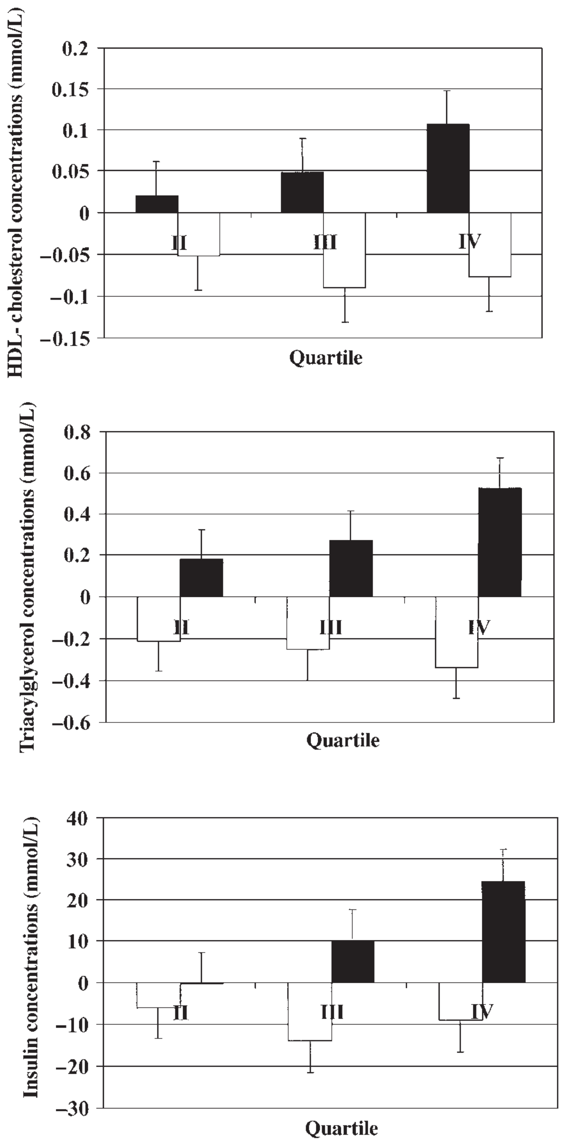


**FIGURE 1.** Mean differences in men (±SE) in concentrations of HDL cholesterol, triacylglycerol, and insulin in comparison with the first quartile of waist (□) and hip (■) circumferences (individual differences in observed circumferences minus those predicted from BMI and age).Values adjusted for age, BMI, and the other circumference residual.

sex steroids and cortisol). Thus, it is wise to practice caution when interpreting BMI as an indicator of body fatness alone and when using the waist-to-hip ratio as an indicator of upper body fat or visceral fat accumulation. For instance, it was previously shown that body composition rather than BMI is related to cardiovascular disease risk (20). This is concordant with the observation that there are changes in body composition with aging, particularly in fat and skeletal muscle mass, and in the skeletal muscle tissue itself. BMI and hip circumferences increase in persons aged ≤60–65 y and then decline, whereas waist circumference continues to increase until very old age (21). In particular, peripheral muscle mass and subcutaneous fat decrease with age, whereas visceral fat increases with age (22, 23). Simple indexes based on weight, height, and circumference ratios do not index these changes properly.

Residual scores are often used to dissociate specific effects among highly correlated variables (eg, to dissociate the contribution of fat intake from energy intake; 24). In the present study, residual scores were used to verify whether weight and hip circumferences contribute to risk factors other than the effect of BMI. It was shown that, after adjustment for BMI and age, a large waist circumference in men and women was associated with an increased visceral fat area and much less with an increased subcutaneous fat area. An large hip circumference is associated with less visceral fat in men and no change in visceral fat in women, but a notable increase in subcutaneous fat area. In addition, an increased hip circumference in men and women is associated with increased body fat mass, especially fat-free mass in men. An increased waist circumference is more closely associated with increased fat mass than with an increased fat-free mass in both men and women.

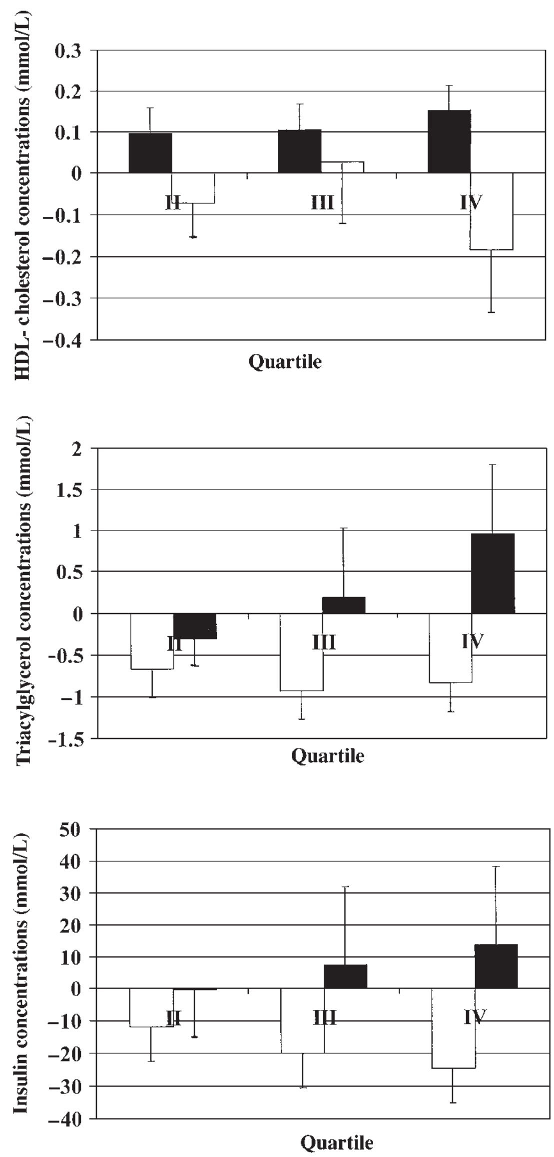


**FIGURE 2.** Mean differences in women (±SE) in concentrations of HDL cholesterol, triacylglycerol, and insulin in comparison to the first quartile of residuals of waist (□) and hip (■) circumferences (individual differences in observed circumferences minus those predicted from their BMI and age). Values adjusted for age, BMI, and the other circumference residual.

**TABLE 6**
Independent contributions of waist and hip circumference to fat mass, fat-free mass, and visceral and subcutaneous fat areas[1]

| | Waist circumference | Hip circumference | Proportion of variance explained[2] |
|---|---|---|---|
| Fat mass (kg) | | | |
| Men | 0.381 ± 0.047[3,4] | 0.303 ± 0.053[4] | 93.9 |
| Women | 0.159 ± 0.032[4] | 0.199 ± 0.030[4] | 95.1 |
| Fat-free mass (kg) | | | |
| Men | 0.158 ± 0.075[5] | 0.526 ± 0.085[4] | 61.3 |
| Women | 0.183 ± 0.039[4] | 0.076 ± 0.037[5] | 64.0 |
| Visceral fat area (cm) | | | |
| Men | 5.189 ± 0.670[4] | −3.244 ± 0.838[4] | 75.4 |
| Women | 4.232 ± 0.317[4] | −0.271 ± 0.302 | 79.1 |
| Subcutaneous fat area (cm) | | | |
| Men | 2.568 ± 1.013[5] | 4.879 ± 1.219[4] | 81.2 |
| Women | 1.570 ± 0.642[5] | 2.005 ± 0.612[6] | 88.4 |

[1] BMI independently contributed to fat mass and subcutaneous fat area in men and women ($P < 0.001$) but not to fat-free mass and visceral fat area. Age was independently associated with all dependent variables ($P < 0.001$) except for fat mass in men and subcutaneous fat area in women.
[2] Variance explained by waist and hip circumferences, BMI, and age.
[3] β ± SEM.
[4] $P < 0.001$.
[5] $P < 0.05$.
[6] $P < 0.01$.

**TABLE 7**
Independent contributions of fat mass and fat-free mass to cardiovascular disease risk factors[1]

| | Fat mass | Fat-free mass | Percentage of variance explained[2] |
|---|---|---|---|
| Total cholesterol | | | % |
| Men | 0.014 ± 0.005[2,4] | −0.028 ± 0.008[5] | 31.0 |
| Women | −0.009 ± 0.006 | −0.022 ± 0.014 | 21.0 |
| HDL cholesterol | | | |
| Men | −0.006 ± 0.002[5] | −0.002 ± 0.003 | 9.5 |
| Women | −0.010 ± 0.002[5] | −0.002 ± 0.004 | 21.5 |
| LDL cholesterol | | | |
| Men | 0.004 ± 0.005 | −0.020 ± 0.007[6] | 28.4 |
| Women | 0.010 ± 0.005[4] | −0.014 ± 0.011 | 16.1 |
| Triacylglycerols | | | |
| Men | 0.036 ± 0.004[5] | −0.015 ± 0.006[4] | 33.9 |
| Women | 0.013 ± 0.003[5] | 0.005 ± 0.008 | 16.2 |
| Insulin | | | |
| Men | 2.948 ± 0.246[5] | −0.152 ± 0.381 | 51.4 |
| Women | 2.233 ± 0.301[5] | 1.891 ± 0.694[4] | 43.1 |
| Glucose | | | |
| Men | 0.015 ± 0.006[4] | 0.022 ± 0.009[4] | 20.6 |
| Women | 0.020 ± 0.007[6] | 0.023 ± 0.016 | 12.1 |
| Systolic BP | | | |
| Men | 0.423 ± 0.091[5] | −0.104 ± 0.136 | 22.8 |
| Women | 0.282 ± 0.076[5] | 0.117 ± 0.176 | 33.3 |
| Diastolic BP | | | |
| Men | 0.257 ± 0.084[5] | −0.088 ± 0.087 | 24.5 |
| Women | 0.182 ± 0.050[5] | −0.063 ± 0.115 | 24.2 |

[1] Adjusted for age. Age had an independent significant contribution to all variables except to HDL cholesterol in men and to insulin in women. BP, blood pressure.
[2] Variance explained by fat mass, fat-free mass, and age.
[3] β ± SEM.
[4] $P < 0.05$.
[5] $P < 0.001$.
[6] $P < 0.01$.

Other studies showed that the wasting of leg muscle or low leg muscle mass may be associated with an increased risk of cardiovascular disease and diabetes (5). Increased waist-to-hip ratios were shown to reflect both increased visceral fat mass and reduced peripheral muscle mass in very specific populations, such as patients with Cushing syndrome (9) and alcoholics (8). These observations suggest that glucocorticoids may play a role in determining a high waist-to-hip ratio because of both peripheral wasting of muscle and the accumulation of visceral fat, as is typically seen in patients with Cushing syndrome. In the general population, mildy increased cortisol (25), stress-related cortisol, and diurnal cortisol secretion patterns were associated with increased waist-to-hip ratios (26). Increased concentrations of glucocorticoids were also implicated in insulin resistance and atherogenic lipid profiles (4).

An increased waist circumference is most likely associated with elevated risk factors because of its relation with visceral fat accumulation, and the mechanism may involve excess exposure of the liver to fatty acids (3), although this issue is a matter of debate (27). The reasons relatively narrow hip circumferences are related to unfavorable concentrations of insulin, HDL cholesterol, and triacylglycerol are not known. There are several possibilities. Narrow hips may reflect peripheral muscle wasting or low muscle mass, which may contribute to both a low insulin clearance from the muscle (13) and low muscle lipoprotein lipase mass and activity with a concomitant reduction in the capacity of muscle to use fatty acids. Williams et al (28) and Hunter et al (29) showed that the total amount of fat in legs and hips (assessed by dual-energy X-ray absorptiometry) was negatively associated with risk of cardiovascular disease. They speculated that increased leg fat may reflect underlying hormonal factors (eg, estrogens) that regulate preferential deposition of fat in the hip and thigh area (30). The protective effect of a large hip circumference may, alternatively, be due to the high lipoprotein lipase activity and low fatty acid turnover of gluteofemoral adipose tissue (31).

In summary, we observed in the present study that larger waist and smaller hip circumferences than what was predicted on the basis of BMI and age are both independently related (but in opposite directions) to risk factors such as low HDL-cholesterol, high triacylglycerol, and high insulin concentrations. The independent effects of these 2 girth measures are confounded in the waist-to-hip ratio. Further research on the protective effect of relatively large hips with respect to cardiovascular disease risk is warranted.

We thank Germain Theriault and Angelo Tremblay for their contribution to the Quebec Family Study; Andre Nadeau for the glucose and insulin assays; Guy Faurnier, Louise Allard, and Claude Leblanc for their contributions to the data collection; and the personnel of the Physical Activity Sciences Laboratory and the Lipid Research Center for their help with the data collection and assays.

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# Erratum

Seidell JC, Pérusse L, Després J-P, Bouchard C. Waist and hip circumferences have independent and opposite effects on cardiovascular disease risk factors: the Quebec Family Study. Am J Clin Nutr 2001;74:315-21.

The individual bars in Figures 1 and 2 are mislabeled. In Figure 1 on page 319, the top panel shows hip (■) and waist (□) residuals, the middle panel shows hip (□) and waist (■) residuals, and the bottom panel shows hip (□) and waist (■) residuals. A revised **Figure 1** in which the shading is the same in all 3 panels is printed below. In Figure 2 on page 319, the top panel shows hip (■) and waist (□) residuals, the middle panel shows hip (□) and waist (■) residuals, and the bottom panel shows hip (□) and waist (■) residuals. A revised **Figure 2** in which the shading is the same in all 3 panels is printed below.

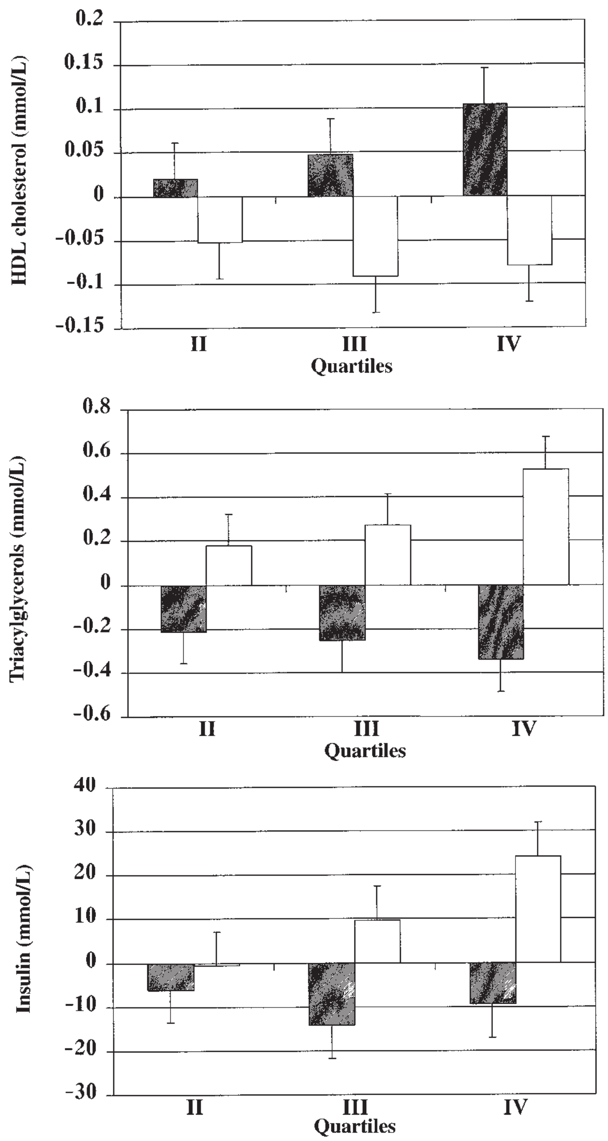


**FIGURE 1.** Mean (±SE) differences in men in concentrations of HDL cholesterol, triacylglycerol, and insulin in comparison with the first quartile of hip (■) and waist (□) residuals (individual differences in observed circumferences minus those predicted from BMI and age). Values were adjusted for age, BMI, and the other circumference residuals.

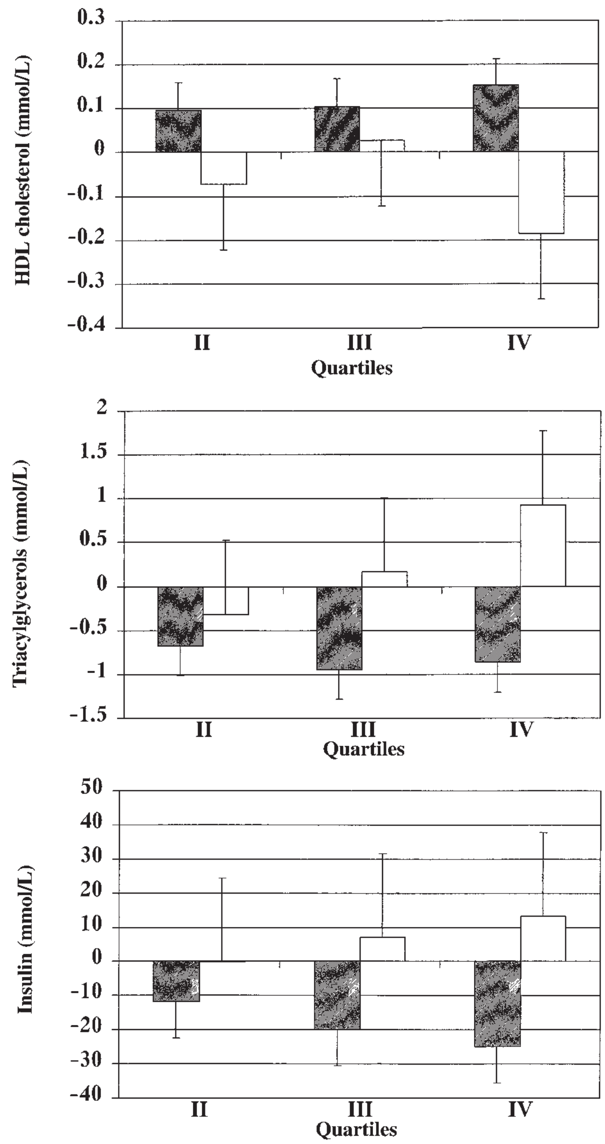


**FIGURE 2.** Mean (±SE) differences in women in concentrations of HDL cholesterol, triacylglycerol, and insulin in comparison with the first quartile of hip (■) and waist (□) residuals (individual differences in observed circumferences minus those predicted from BMI and age). Values were adjusted for age, BMI, and the other circumference residuals.


*Am J Clin Nutr* 2001;74:562. Printed in USA. 