Fatness Is a Better Predictor of Cardiovascular Disease Risk Factor Profile Than Aerobic Fitness in Healthy Men

Demetra D. Christou, PhD; Christopher L. Gentile, MS; Christopher A. DeSouza, PhD; Douglas R. Seals, PhD; Phillip E. Gates, PhD

Background—The prevalence of cardiovascular disease (CVD) is partly attributable to an inactive and/or overweight population. However, the independent association of body fatness and aerobic fitness with CVD risk factors is uncertain. We sought to determine whether fatness or fitness better predicted traditional CVD risk factors in men with broad fatness, aerobic fitness, and age ranges using 3 expressions of adiposity.

Methods and Results—In 135 carefully screened healthy men, we measured 18 established CVD risk factors, body mass index, total percent body fat, waist circumference, and maximal aerobic capacity. Body mass index, percent body fat, and waist circumference were consistently associated with all metabolic risk factors \((r = -0.44 \text{ to } 0.51, P < 0.05)\) after partialling out the effects of aerobic fitness and age. Body mass index and waist circumference were also independently associated with selective hemodynamic risk factors \((r = 0.20 \text{ to } 0.30, P \leq 0.01)\). In contrast, aerobic fitness was independently associated with only selective metabolic risk factors \((r = -0.21 \text{ to } 0.19, P < 0.05)\) and was not associated with any hemodynamic risk factors \((P > 0.05)\). Both aerobic fitness and body fatness were independently associated with selective hemostatic risk factors \((r = -0.22 \text{ to } -0.26, P \leq 0.01; r = -0.32 \text{ to } 0.48, P < 0.05, \text{ respectively})\). Overall, fatness was more strongly and consistently associated with CVD risk factors than aerobic fitness.

Conclusions—Body fatness is a better predictor of CVD risk factor profile than aerobic fitness in healthy men. Although habitual physical activity is an effective strategy for preventing CVD, elevated body fatness is associated with an adverse CVD risk factor profile independently of aerobic fitness. (Circulation. 2005;111:1904-1914.)

Key Words: blood pressure | fibrinolysis | exercise | obesity

Recent emphasis has been placed on the importance of risk factors in predicting morbidity and mortality from cardiovascular disease (CVD) and understanding disease progression and natural history. In addition, there is a need to understand how CVD risk is influenced by physical characteristics that are modified by lifestyle behaviors. Low aerobic fitness and increased body fatness are of particular interest, given that the prevalence of CVD in the United States is at least partly attributable to a largely inactive and/or overweight population.

It is well established that aerobic exercise is cardioprotective, and that being overweight increases the risk of CVD. However, because low physical activity and increased adiposity often occur in combination, masking their independent effects, it is unclear whether lower aerobic fitness or higher body fatness exerts a greater influence on CVD risk factors. With more adults becoming overweight or obese, this issue is increasingly important for the implementation of effective public health policy, prevention strategies, and patient management.

The limited available data on the importance of body fatness compared with aerobic fitness to specific CVD risk factors are equivocal. These discrepancies likely are attributable to the use of different expressions of body fatness and aerobic fitness, the grouping of subjects according to body fatness/aerobic fitness, and the use of different markers of CVD risk. Moreover, many studies have focused on a single risk factor despite the multifactorial nature of CVD and the common "clustering" of CVD risk factors. As such, it is difficult to draw conclusions about the relative contributions of body fatness and aerobic fitness to the CVD risk factor profile.

Therefore, a clear need exists to determine whether aerobic fitness or body fatness contributes more to intermediary phenotypic CVD risk factors in healthy adults. Moreover, it is critical to conduct such an analysis in a subject cohort with a
broad range of body fatness and aerobic fitness. Accordingly, the purpose of the present study was to determine comprehensively whether fatness or fitness better predicted traditional metabolic, hemodynamic, and hemostatic risk factors for CVD in a cohort of healthy men with broad body fatness, aerobic fitness, and age ranges through the use of 3 different expressions of adiposity.

Methods

Subjects
A total of 135 men who were 20 to 79 years of age were studied. Subjects were sedentary (no regular physical activity), recreationally active, or aerobically exercise trained (vigorous endurance exercise >5 times per week). The aerobically exercise–trained subjects were recruited from local running clubs. All subjects were normotensive (<140/90 mm Hg) and free of overt coronary artery disease as assessed by medical history, physical examination, resting ECG, blood chemistries, and hematological evaluation (eg, plasma glucose concentration <3.6 mmol/L and total cholesterol <6.2 mmol/L). Men >40 years of age were further evaluated with ECG and blood pressure responses to incremental treadmill exercise performed to exhaustion. None of the subjects demonstrated significant carotid plaque plaque formation or ankle-brachial blood pressure index <0.9. Subjects were not smoking nor taking any medications. The Human Research Committee of the University of Colorado at Boulder approved all procedures. The nature, benefits, and risks of the study were explained to the volunteers, and their written informed consent was obtained before the study.

Study Procedures
All measurements were performed while subjects abstained from caffeine and after they had fasted for ≥4 hours. (A 12-hour overnight fast was required for determination of metabolic and hemostatic risk factors.) In addition, all measurements were performed 24 to 48 hours after the last exercise session to avoid the acute effects of a single bout of exercise. Immediately before the experimental sessions, each subject rested supine for at least 15 minutes in a quiet, temperature-controlled, semidarkened room.

Body Composition
Body weight was measured to the nearest 0.1 kg with a physician’s balance scale (Detecto). Subjects were weighed barefoot wearing light clothing. Height was measured to the nearest 1 mm with a stadiometer. Body mass index (BMI) was determined as weight divided by height squared (kg/m²). Waist circumference was measured in duplicate to the nearest 1 mm with a nonstretchable tape (Lafayette Instruments). Measurement was taken at the smallest horizontal narrowing between the ribs and iliac crest with the subject in the standing position. Waist circumference is associated with visceral adiposity.

Whole-body composition was determined with dual-energy x-ray absorptiometry (DPX-IQ, Lunar Radiation Corp; software version 4.1) with subjects in the supine position. With the standard soft-tissue analysis, we measured fat, lean, bone, and total mass using standard cut lines. Total adiposity (%) was determined as the portion of total fat to total body mass. All scans were analyzed by the same investigator (C.L.G.). To assess intraobserver reliability, the scans of 10 representative subjects were analyzed 3 times for total body fat content. The coefficient of variation was 0.4%, with an intraclass correlation of 0.9998.

Aerobic Fitness
Aerobic fitness was assessed using maximal oxygen consumption (V̇O₂max). Online computer-assisted open-circuit spirometry during incremental treadmill exercise was used as previously described. Briefly, after a 6- to 10-minute warm-up period, each subject ran or walked at a comfortable speed that corresponded to 70% to 80% of age-predicted maximal heart rate. The treadmill grade was increased 2.5% every 2 minutes until volitional exhaustion. To ensure that each subject attained a valid V̇O₂max, ≥3 of the following 4 criteria were met by each subject: (1) plateau in V̇O₂max with increasing exercise intensity, (2) a maximal respiratory exchange ratio of ≥1.15, (3) achievement of age-predicted maximal heart rate (±10 bpm), and (4) a rating of perceived exertion of ≥18 on the Borg scale.

Metabolic Risk Factors
An intravenous glucose tolerance test was performed, and measurements of plasma lipids, lipoproteins, and insulin concentrations were obtained as described previously. The intravenous glucose tolerance test was performed according to the method of Bergman. Glucose (0.3 g/kg) was injected intravenously at time 0, and insulin (0.025 U/kg) was injected at 20 minutes. Twenty-eight samples were obtained between 0 and 180 minutes for glucose and insulin measurements. Insulin sensitivity was calculated by computer analysis using Bergman’s minimal model of insulin action. Plasma insulin was determined by a solid-phase radioimmunoassay. Plasma total cholesterol (TC) and triglyceride (TG) levels were analyzed with conventional enzymatic methods. Plasma HDL cholesterol concentration was determined by the dextran precipitation technique. LDL cholesterol was subsequently determined from the following equation: LDL=TC−HDL−TG/5.

Hemodynamic Risk Factors
Casual blood pressure was measured with a random-zero sphygmomanometer (Hawksley & Sons) according to guidelines established by the American Heart Association while subjects were in the upright-seated position. For each measurement described below, the analysis was performed by the same investigator, who was blinded to the identity of the subject. Carotid augmentation index and aortic pulse wave velocity (PWV) were used as conventional measures of arterial stiffness. For carotid augmentation index, the pressure waveform and amplitude were obtained from the right common carotid artery with a pencil-type probe incorporating a high-fidelity strain-gauge transducer (model TCB-500, Millar Instruments), as previously described by Kelly et al. The reliability of the augmentation index measurement in our laboratory was established by sequential measurements on 2 separate days on 8 adult men and women of various ages. Carotid augmentation was 5.0±3.2% versus 4.8±2.9% for trial 1 versus 2 (not significantly different); the mean coefficient of variation was 7%.

For aortic PWV, pressure waves were recorded at the aortic arch and femoral artery with 2 identical transcutaneous Doppler flowmeters (model 810-A, Parks Medical Electronics, Inc). Arterial pressure waves were digitized for offline analysis with signal-processing software (WINDAQ, Dataq Instruments, Inc). PWV was calculated from the distance (cm) traveled between the 2 recording sites divided by pulse transit time (or time delay). Transit time was determined from the time delay between the proximal and distal foot waveforms.

### TABLE 1. Subject Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean±SE</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>48±1</td>
<td>20–79</td>
</tr>
<tr>
<td>V̇O₂max, ml·kg⁻¹·min⁻¹</td>
<td>42.2±1.0</td>
<td>21.6–69.1</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>80.3±1.2</td>
<td>56–135</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>25.5±0.3</td>
<td>20–39</td>
</tr>
<tr>
<td>Total body fat, %</td>
<td>19.4±0.6</td>
<td>6.2–37.9</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>89.9±1.0</td>
<td>69.7–131.5</td>
</tr>
</tbody>
</table>
The foot of the wave was identified as the beginning of the sharp systolic upstroke. Distance traveled by the pulse wave was assessed in duplicate with a random-zero length measurement over the surface of the body with a nonelastic tape measure. The test-retest reliability of our PWV measurements was established using the experimental approach described for augmentation index above. The coefficient of variation of aortic PWV measurements was approximately 8%.

Carotid and femoral artery intima-media thicknesses (IMTs) were measured from the images derived from an ultrasound machine (Toshiba SSH-140A) equipped with a high-resolution linear-array transducer as described originally by Pignoli and Longo.28 For carotid IMT, longitudinal 2D ultrasound images were obtained at the proximal 1- to 2-cm straight portion of the common carotid artery. For the femoral IMT, longitudinal 2D ultrasound images were obtained below the inguinal ligament, ~2 to 3 cm above its bifurcation into the profundus and superficial branch. These images were recorded on a super VHS recorder (Panasonic VCR AG7350) for later offline analysis, digitized with a video-frame grabber (DT-3152, Data Translation), and stored on a personal computer. All scans were performed by the same sonographer. IMT was defined as the distance from the leading edge of the lumen-intima interface to the leading edge of the media-adventitia interface.28 These measurements were made at end diastole. At least 10 measurements of IMT were taken at each segment. The mean values of these 10 measurements were used for analysis. In our laboratory, this technique has been used for analysis. In our laboratory, this technique has excellent day-to-day reproducibility (coefficient of variation, 3%).

### Hemostatic Risk Factors

Blood samples for tissue plasminogen activator and plasminogen activator inhibitor type-1 were drawn with minimal venostasis between 8 and 11 AM to avoid diurnal variation in fibrinolytic variables as described in detail previously.29 Total tissue plasminogen activator antigen and total plasminogen activator inhibitor type-1 antigen were determined by an ELISA (American Bioproducts). Total tissue plasminogen activator activity and total plasminogen activator inhibitor type-1 activity were determined by an amidolytic method (Chromogenix). Plasma fibrinogen was determined with the Clauss method for clottable fibrinogen.30

### Data Analysis

Statistical analyses were performed with the SPSS (version 11.0.1) statistical package. To determine the independent association of fatness and aerobic fitness with CVD risk factors, we used multiple linear regression analyses. This approach allowed analysis of a broad range of fatness and fitness from the entire cohort of men, avoiding the selection bias associated with grouping subjects in discrete “fatness” and “fitness” categories. Separate regression models were used for each CVD risk factor and each expression of fatness (BMI, total body fat model, and waist circumference). For each model, a CVD risk factor was entered as the dependent variable, whereas aerobic fitness, an expression of fatness, and age were entered as the independent variables. Part (also known as semipartial) correlation coefficients derived from regression analysis were used to determine the independent association of aerobic fitness with CVD risk while controlling for fatness and age. Part correlation coefficients also were used to determine the independent association of fatness to CVD risk while controlling for fitness and age. Residual analyses to test the validity of the regression model assumptions were performed for all the regression models. Statistical significance was set at the P<0.05 level for all analyses.

### TABLE 2. Independent Relation of Aerobic Fitness and Fatness to Metabolic Risk Factors

<table>
<thead>
<tr>
<th>Variable</th>
<th>V̇O₂max, mL·kg⁻¹·min⁻¹</th>
<th>BMI, kg/m²</th>
<th>Total Body Fat %</th>
<th>V̇O₂max, mL·kg⁻¹·min⁻¹</th>
<th>Total Body Fat %</th>
<th>Waist, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cholesterol, mmol/L</td>
<td>NS</td>
<td>0.31‡</td>
<td>NS</td>
<td>0.36‡</td>
<td>NS</td>
<td>0.35‡</td>
</tr>
<tr>
<td>HDL cholesterol, mmol/L</td>
<td>NS</td>
<td>-0.19*</td>
<td>NS</td>
<td>-0.24*</td>
<td>NS</td>
<td>-0.26†</td>
</tr>
<tr>
<td>LDL cholesterol, mmol/L</td>
<td>NS</td>
<td>0.23‡</td>
<td>NS</td>
<td>0.28†</td>
<td>NS</td>
<td>0.27†</td>
</tr>
<tr>
<td>Ratio of total to HDL cholesterol</td>
<td>NS</td>
<td>0.38‡</td>
<td>NS</td>
<td>0.40†</td>
<td>NS</td>
<td>0.44‡</td>
</tr>
<tr>
<td>Triglycerides, mmol/L</td>
<td>-0.16*</td>
<td>0.35‡</td>
<td>NS</td>
<td>0.42‡</td>
<td>NS</td>
<td>0.44‡</td>
</tr>
<tr>
<td>Fasting insulin, pmol/L</td>
<td>-0.21†</td>
<td>0.42‡</td>
<td>NS</td>
<td>0.44‡</td>
<td>NS</td>
<td>0.51‡</td>
</tr>
<tr>
<td>Insulin sensitivity, ×10⁻³·min⁻¹·pmol/L⁻¹</td>
<td>0.19*</td>
<td>-0.40‡</td>
<td>NS</td>
<td>-0.44‡</td>
<td>NS</td>
<td>-0.33‡</td>
</tr>
</tbody>
</table>

Values are part correlation coefficients derived from multiple linear regression analysis. The BMI model included V̇O₂max, BMI, and age as independent variables; the total body fat model included V̇O₂max, total percent body fat, and age; and the waist model included V̇O₂max, waist circumference, and age.

*P<0.05; †P<0.01; ‡P<0.0001.

### TABLE 3. Independent Relation of Aerobic Fitness and Fatness to Hemodynamic Risk Factors

<table>
<thead>
<tr>
<th>Variable</th>
<th>V̇O₂max, mL·kg⁻¹·min⁻¹</th>
<th>BMI, kg/m²</th>
<th>Total Body Fat %</th>
<th>V̇O₂max, mL·kg⁻¹·min⁻¹</th>
<th>Total Body Fat %</th>
<th>Waist, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic BP, mm Hg</td>
<td>NS</td>
<td>0.20*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Diastolic BP, mm Hg</td>
<td>NS</td>
<td>0.24*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Augmentation index, %</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Aortic PWV, cm/s</td>
<td>NS</td>
<td>0.21*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Carotid IMT, mm</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Femoral IMT, mm</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

BP indicates blood pressure. Values are part correlation coefficients derived from multiple linear regression analysis. The BMI model included V̇O₂max, BMI, and age as independent variables; the total body fat model included V̇O₂max, total percent body fat, and age; and the waist model included V̇O₂max, waist circumference, and age.

*P<0.01; †P<0.0001.
Results

Subject characteristics are presented in Table 1. Subjects varied widely in age, \( V\dot{O}_2\max \), body weight, BMI, total percent body fat, and waist circumference. The cohort included men who were aerobically fit but had higher levels of adiposity. For example, 40 men (about one third of the entire percent body fat, and waist circumference. The cohort included men who were aerobically fit but had higher levels of adiposity. For example, 40 men (about one third of the entire

Table 1. Independent Relation of Aerobic Fitness and Fatness to Plasma Hemostatic Risk Factors

<table>
<thead>
<tr>
<th></th>
<th>BMI Model</th>
<th>Total Body Fat Model</th>
<th>Waist Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V\dot{O}_2\max ), mL \cdot kg(^{-1}) \cdot min(^{-1})</td>
<td>BMI, kg/m(^2)</td>
<td>( V\dot{O}_2\max ), mL \cdot kg(^{-1}) \cdot min(^{-1})</td>
<td>Total Body Fat, %</td>
</tr>
<tr>
<td>PAI-1 activity, IU/L</td>
<td>NS</td>
<td>0.31†</td>
<td>NS</td>
</tr>
<tr>
<td>PAI-1 antigen, ng/L</td>
<td>−0.22†</td>
<td>0.36‡</td>
<td>NS</td>
</tr>
<tr>
<td>tPA activity, IU/L</td>
<td>−0.26†</td>
<td>NS</td>
<td>−0.23*</td>
</tr>
<tr>
<td>tPA antigen, ng/L</td>
<td>−0.26‡</td>
<td>0.37‡</td>
<td>NS</td>
</tr>
<tr>
<td>Fibrinogen, ( \mu )mol/L</td>
<td>NS</td>
<td>0.31‡</td>
<td>NS</td>
</tr>
</tbody>
</table>

PAI-1 indicates plasminogen activator inhibitor-1; tPA, tissue-type plasminogen activator. Values are part correlation coefficients derived from multiple linear regression analysis. The BMI model included \( V\dot{O}_2\max \), BMI, and age as independent variables; the total body fat model included \( V\dot{O}_2\max \), total percent body fat, and age; and the waist model included \( V\dot{O}_2\max \), waist circumference, and age.

*\( P \leq 0.05; † P \leq 0.01; ‡ P \leq 0.0001."

Figure 1. Relation between total cholesterol and body fatness (BMI, top; waist, bottom). Dashed line represents bivariate unadjusted relation of body fatness to total cholesterol; solid line, same relation after partialling out effect of aerobic fitness and age.
cohort) who were aerobically trained had a broad range of body fatness (mean, 16±1%; range, 6% to 32%).

Fatness, Fitness, and Metabolic Risk Factors
All 3 expressions of fatness (BMI, total percent body fat, and waist circumference) were consistently associated with all metabolic factors even after partialling out the effect of aerobic fitness and age (Table 2). In contrast, aerobic fitness was independently associated with only selective metabolic risk factors after controlling for fatness and age.

Fatness, Fitness, and Hemodynamic Risk Factors
BMI and waist circumference were independently associated with selective hemodynamic risk factors, whereas total percent body fat was not associated with any of these factors (Table 3). Aerobic fitness was not independently associated with any hemodynamic risk factors.

Fatness, Fitness, and Hemostatic Risk Factors
Total percent body fat was consistently and independently associated with all plasma hemostatic factors (Table 4). BMI and waist circumference were independently associated with most plasma hemostatic factors. Aerobic fitness was independently associated only with selective plasma hemostatic factors.

Overall Relation Between Fatness, Fitness, and CVD Risk Factors
Generally, fatness was more strongly and consistently associated with CVD risk factors than aerobic fitness. Figures 1 through 6 illustrate examples of the significant relations between 2 common measures of adiposity (BMI and waist circumference) and selected CVD risk factors from each of the 3 categories studied (ie, metabolic, hemodynamic, and hemostatic). In all figures, the solid line represents the
relation of fatness with the CVD risk factor in question after partialling out the effects of aerobic fitness and age. For comparison, the line representing the bivariate relation of fatness with the CVD risk factor (i.e., unadjusted for age and fitness) is shown as a dashed line. Note that the dashed line is partially or completely overlapped by the solid line in each case. This indicates the strength of the independent association of fatness with CVD risk factors because, even after aerobic fitness and age are controlled for, the bivariate association remains essentially unchanged. No single expression of adiposity (BMI, total percent body fat, or waist circumference) was more consistently associated with CVD risk factors than the others. The outcome of all statistical analyses was similar if absolute (g) total body fat mass was used in place of total percent body fat.

Additional regression analyses were performed with $V_{\text{O2max}}$ expressed relative to fat-free mass. The overall outcome of these analyses was similar to that obtained from the analyses in which $V_{\text{O2max}}$ was traditionally expressed as a function of kilograms of body mass. From the 54 regression models, $V_{\text{O2max}}$ expressed as milliliters per kilogram of fat-free mass per minute accounted uniquely for a significant amount of variance in CVD risk factors in 8 models, whereas fatness accounted uniquely for a significant amount of variance in CVD risk factors in 37 models. $V_{\text{O2max}}$ expressed as milliliters per kilogram of body weight per minute (Tables 2 through 4) accounted uniquely for a significant amount of variance in CVD risk factors in 10 models, and fatness accounted uniquely for a significant amount of variance in CVD risk factors in 39 models. Thus, the independent relations of fatness and fitness to CVD risk factors were largely unaffected when $V_{\text{O2max}}$ was expressed relative to fat-free mass.

**Discussion**

To comprehensively characterize CVD risk, we used 18 established risk factors emphasized in recently published
opinions on surrogate markers for CVD. These included traditional metabolic markers, insulin sensitivity index, hemostatic and thrombolytic factors, and indices of arterial structure and function. Moreover, 3 different measures of body fatness were used to characterize total and abdominal adiposity. We are not aware of any previous studies that have assessed the unique contributions of body fatness and aerobic fitness to CVD risk factors this extensively in healthy men with broad body fatness, aerobic fitness, and age ranges. The primary novel finding of this study is that body fatness is a stronger independent predictor of multiple CVD risk factors than aerobic fitness in healthy men. In addition, we found that the 3 different expressions of body fatness predicted CVD risk factors similarly.

Body Fatness and CVD Risk Factor Profile
Morbidity and mortality from CVD are higher in obese men and are associated with higher blood pressure, arterial stiffening, and less favorable metabolic and hemostatic risk factor profiles. The results of the present study suggest that many of these risk factors are elevated in men with increased body fat, regardless of aerobic fitness. The mechanisms by which body fatness exerts such an aerobic fitness-independent effect on CVD risk factors are incompletely understood, but several possibilities exist. For example, increased adiposity is associated with local activation of the renin-angiotensin system, a low-grade inflammatory state, and chronic oxidative stress. In combination, this state results in reduced nitric oxide bioavailability, increased vascular tone, arterial stiffening, increased systolic and pulse pressures, and an overall atherogenic vascular phenotype.

The finding that fatness is a better predictor of multiple CVD risk factors than aerobic fitness has several important implications. First, men who are overweight or obese should be encouraged to reduce body fatness, regardless of their aerobic fitness. Second, weight management and prevention...
of excess adiposity should be a primary cardiovascular health goal for men. Third, in lean trained men, the cardioprotective influence of habitual physical activity may be mediated in part through the maintenance of optimal body weight and fatness.

Aerobic Fitness and CVD Risk Factor Profile

The cardioprotective effect of habitual physical activity is well established. Consistent with this, the present study found that when the influence of aerobic fitness was isolated by statistically partialling out the effects of body fatness and age, aerobic fitness was associated with selective metabolic and hemostatic risk factors. In particular, fasting insulin and insulin sensitivity were independently related to aerobic fitness. This is in agreement with the well-documented insulin-sensitizing effect of aerobic exercise. This adaptive response to exercise may have cardioprotective effects by helping to maintain plasma glucose/insulin homeostasis.

These observations support the need for regular aerobic exercise as an important strategy to promote optimal insulin sensitivity.

Aerobic fitness also was independently associated with selective hemostatic risk factors. However, body fatness tended to be more strongly and consistently related to these factors. Together, these results are consistent with previous findings that hemostatic risk factors are more favorable in physically active compared with sedentary women but that percent body fat, BMI, and waist circumference are important physiological predictors of these factors.

Thus, our findings on aerobic fitness support current guidelines emphasizing the need for regular physical activity as an important element of the overall strategy for reducing CVD risk. Independently of the effects of fatness, aerobic fitness was associated with several important risk factors for CVD. Thus, men who are sedentary should be encouraged to increase their physical activity and improve their aerobic fitness, regardless of their body fatness.
Body Fatness, Aerobic Fitness, and Cardiovascular End Points

Some epidemiological studies have reported that body fatness predicts morbidity and mortality end points and that higher levels of physical activity do not negate the risk associated with elevated adiposity. Moreover, removing indices of fitness from statistical analyses does little to weaken the ability of body fatness to predict morbidity and mortality. The intermediary CVD risk factor phenotypic data from the present study are consistent with these findings. In contrast, others have concluded that the health benefits of leanness are limited to fit men and that being fit may reduce the hazards of obesity. This finding has contributed importantly to a current school of thought that the adverse health consequences of obesity are limited largely if not exclusively to physically inactive adults.

The contradictory evidence on this topic may reflect complex genetic, biological, and lifestyle interactions that affect disease progression and subsequent morbidity and mortality in population-based studies. There may also be several methodological influences such as the use of different indices of aerobic fitness and fatness and/or the grouping of subjects into discrete fitness and fatness categories, despite the continuous nature of these factors. Epidemiological studies also are complicated by deaths resulting from uncertain cause, early morbidity resulting from non-CVD events, genetic cardiovascular disorders, and valvular heart disease.

Study Limitations

Our study used a cross-sectional design and lacked cardiovascular morbidity and mortality end points. To gain optimal insight into the pathophysiology and natural history of CVD, further understanding of the complex interactions between genes and environment and their association with body fatness and aerobic fitness should be obtained from longitudinal studies that measure both CVD risk factors and cardiovascular morbidity and mortality end points.
Because our sample consisted of healthy men, our findings are restricted to this population. Although the key results may be generalizable to healthy women and perhaps even to patients with clinical disease, this needs to be confirmed in future investigations.

Conclusions and Clinical Implications

We conclude that body fatness is a better predictor of the general CVD risk factor profile than aerobic fitness in healthy men. Measures of total body and abdominal adiposity were consistently and independently associated with a wide variety of established CVD risk factors, suggesting that both of these adiposity phenotypes may contribute to intermediate CVD risk. Thus, although habitual physical activity is an effective, well-established strategy for preventing CVD, the important message from the present study is that elevated body fatness is associated with an adverse CVD risk factor profile, independently of aerobic fitness.

The present results provide further evidence implicating body fatness as a key public health concern. In particular, our findings provide additional justification for CVD risk factor management strategies that emphasize prevention of weight gain in overweight/obese men and successful long-term weight reduction in overweight and obese men. Most importantly, our results support the position that habitual physical activity/aerobic fitness should be viewed as an effective partner to weight maintenance in the primary prevention of CVD, not as a surrogate approach.

Acknowledgment

This work was supported by National Institutes of Health awards AG06537, AG13038, AG18597, and AG022241.

References


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Circulation. 2005;111:1904-1914
doi: 10.1161/01.CIR.0000161818.28974.1A
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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