Serial Changes in Body Composition Throughout Adulthood and Their Relationships to Changes in Lipid and Lipoprotein Levels

The Fels Longitudinal Study

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Abstract—Few studies have examined the relationships between measures of body composition and lipid and lipoprotein levels in long-term serial data from individuals unselected for cardiovascular disease– or obesity-related variables, and none have considered such extensive serial data as used in the current study. The aim was to examine in such individuals the associations between annual changes in lipid and lipoprotein levels and concurrent changes in total body fat, fat-free mass, percent body fat, and body mass index. Serial data from 1304 examinations of 423 adult white participants in the Fels Longitudinal Study were analyzed sex-specifically in 2 age groups, 18 through 44 years and 45 to 65 years. A regressive analytic approach utilized the long-term (4 to 20 years) serial data of individuals. Annual changes in adiposity, independent of levels of lean tissue changes, before and after age 45 for men and women were significantly correlated with corresponding annual changes in cholesterol and low density lipoprotein cholesterol. In men before age 45, changes in triglycerides and high density lipoprotein cholesterol were also significantly associated with changes in adiposity, with the relationship remaining after age 45 in high density lipoprotein cholesterol. Increases in adiposity in individuals are associated with changes in lipid and lipoprotein levels in the direction of increased risk for cardiovascular disease. Adult levels of total cholesterol and low density lipoprotein cholesterol across age and sex and high density lipoprotein cholesterol in men are responsive to changes in adiposity, independent of initial adiposity or lipid and lipoprotein levels. (Arterioscler Thromb Vasc Biol. 1998;18:1759-1764.)

Key Words: body composition ■ fat-free mass ■ lipids ■ lipoproteins ■ serial

Cross-sectional population studies in the United States have clearly demonstrated age-associated increases in serum lipid and lipoprotein levels, body weight, and indices of body fatness in adults.1,2 In addition to adiposity, elevated levels of total (TC) and LDL cholesterol (LDL-C) are risk factors for coronary heart disease, as is a reduced level of HDL cholesterol (HDL-C).3-5 In both obese and nonobese individuals, weight loss over short periods of time is commonly associated with a decrease in TC levels.6-8 Cross-sectional relationships between lipids and lipoproteins and body composition in young, middle-aged, and older adults have shown that adiposity and adipose tissue distribution are related to lipid and lipoprotein levels.9-13 In addition, a few follow-up studies have shown relationships between changes in adiposity and changes in lipids and lipoproteins over some age ranges.14-16 However, in the United States, there is relatively little information about the relationships between changes in body composition throughout adulthood and concurrent changes in lipid and lipoprotein levels in individuals unselected for variables related to cardiovascular disease or obesity. The aim of the current study was to examine in such individuals the associations between average annual changes in plasma lipid and lipoprotein levels and concurrent changes in total body fat, fat-free mass (FFM), percent body fat (%BF), and body mass index (BMI).

Methods

Data recorded since 1976 from 1304 examinations of a subset of 423 white adults (202 men, 221 women) enrolled in the Fels Longitudinal Study17 were analyzed. Participants in this study have been enrolled between 1929 to the present, typically near the time of their birth. Most are white, were residing in southwestern Ohio at the time of their enrollment, and were selected for enrollment on the basis of the willingness of their parents to allow them to participate in a long-term serial study. The National Center for Health Statistics’ United States growth charts for children from birth to 36 months are based exclusively on data from participants in the Fels Longitudinal Study.18 Adult participants between the ages of 25 and 40 are scheduled for examinations every 5 years, and those residing out of state are also scheduled at 5-year intervals regardless of age. All other adults are examined every 2 years.

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Adult Changes in Adiposity and Lipid/Lipoprotein Levels

Body composition measures of total body fat (TFB, kg), %BF, and FFM (kg) were calculated by using Lohman’s multicomponent model over a wide age range. This approach allows for age and sex variation in the composition of FFM up to age 25 years and, in a comparison of several body composition methodologies in this population, it performed well across the adult age range considered here. BMI (kg/m²) was calculated from weight and stature. Plasma levels of fasting TC (mmol/L), HDL-C (mmol/L), LDL-C (mmol/L), and triglycerides (TG, mmol/L) were measured according to standard procedures. All data collection procedures were approved by the Institutional Review Board of Wright State University, and the participants in this study gave their informed consent to be involved in the research.

Two age groups were analyzed separately, including participants between 18 and 44 years of age and 1 with participants ranging from 45 to 65 years of age. For inclusion within an age group, participants had to have at least 2 examinations within the specified age range, with the first and last examination separated by an interval of at least 4 years. For each individual, interval length was calculated as the difference in years between the first and last examinations within an age range, and median age (midage) was calculated as the mean of the ages at the first and last examinations. For each individual with >2 examinations, a series of linear regressions, with age as the independent variable and with each body composition or lipid and lipoprotein measure as the dependent variable, was used to determine an annualized rate of change, or slope, for each variable. For individuals with exactly 2 examinations within an age group, the difference between last and first examinations divided by interval length was used as a measure of annualized change in each lipid or lipoprotein and body composition variable. The regressive approach maximizes the information in each person’s serial data and should provide better estimates of the rate of change than simply using the end points, as is typically done in studies with a “follow-up” design. The resulting variables for changes were ΔTFB (kg/y), Δ%BF (%/y), ΔFFM (kg/y), ΔBMI (kg · m⁻² · y⁻¹), ΔTC (mmol · L⁻¹ · y⁻¹), ΔHDL-C (mmol · L⁻¹ · y⁻¹), ΔLDL-C (mmol · L⁻¹ · y⁻¹), and ΔTG (mmol · L⁻¹ · y⁻¹).

Tests were performed to determine sex differences and whether or not annualized rates of change were different from zero. Significant differences were defined at the P<0.05 and P<0.001 levels. To account for individual baseline levels, a regression of baseline level for each body composition and lipid and lipoprotein variable on their corresponding annual change was performed within each age and sex group. The corresponding baseline-adjusted variables are identified by a preceding Δ (eg, ΔTFB and ΔTC). The associations between the baseline-adjusted annual rate of change in each body composition measure and the baseline-adjusted annual rate of change in each lipid and lipoprotein measure were described by using Pearson’s product-moment correlations calculated separately for men and women in each age group. To adjust FFM for level of adiposity, a linear regression of TBF on FFM was first performed within each age group, and the individual regressive analytic approach described above was then applied to the residuals.

Results

The number of individuals with each of the various numbers of serial examinations within each age group is given in Table 1. The number of serial examinations for the younger age group ranges from 2 to 7, with ~65% of the individuals in this age group having 3 or more examinations. In the older group, the number of examinations ranges from 2 to 6, with 75% having 3 or more examinations and 18% of the individuals having 5 or more examinations.

The means for the midage, interval, body composition measures, and lipid and lipoprotein levels are given in Table 2. The means of the body composition and lipid and lipoprotein variables within each age group were based on the individual regressions and calculated at the midage. The mean age in each of the 2 age groups was approximately 30 and 54 years, respectively, for both men and women, and the mean age interval was between 9.4 and 11.2 years for each age×sex group. The sex differences observed in the younger age group were consistent with expectations based on the published literature; women had higher levels of TFB, %BF, and HDL-C and men had higher levels of FFM, TC, LDL-C, and TG. BMI values were similar for both sexes. The differences between the means for adiposity and lipid and lipoprotein variables between younger and older men and women were consistent with an increasing risk in each cardiovascular disease risk factor studied, except there were no changes in mean HDL-C for men, and there were only slight increases in mean HDL-C levels for women. FFM (uncorrected for TBF) was not different between younger and older men or women.

The means and SDs for the annual change variables for each age×sex group are given in Table 3. For younger men, all the annual changes in body composition and lipid and lipoprotein levels (except for ΔHDL-C) were positive and significantly different from zero. For younger women, ΔBMI, ΔTFB, Δ%BF, and ΔTG were likewise positive and significantly different from zero. Significant sex differences in annual changes in the younger group were found in ΔTC, ΔTG, and ΔLDL-C, with men exhibiting a greater change in each. The means for ΔBMI, ΔTFB, and Δ%BF in older men and women were positive and significantly different from zero. Also, ΔTC and ΔLDL-C in older men were negative, ΔTG in older women was positive, and all were significantly different from zero. A significant sex difference in the older group was found in ΔTC and ΔLDL-C, with men exhibiting a decrease in each.

The correlations between the baseline-adjusted annual changes in body composition measures and those of lipid and lipoprotein levels are presented in Table 4. In the younger men, each of the baseline-adjusted annual changes in lipids and lipoproteins was significantly associated with the corresponding changes in each adiposity measure, ΔTFB, Δ%BF, and ΔBMI, with the absolute value of the correlations ranging from 0.23 to 0.49. Also in the younger men, ΔFFM (uncorrected for TBF) was significantly correlated (0.23) with ΔTG. In the older men, only baseline-adjusted adiposity measures were significantly correlated with any of the baseline-adjusted annual changes in lipids and lipoproteins. The adiposity measures of ΔTFB and ΔBMI were positively associated with ΔTC and ΔLDL-C, with values ranging...
from 0.28 to 0.39. These were not significantly correlated with Δ\text{TG}, however. All adiposity measures, including Δ\text{%BF}, were significantly negatively correlated with Δ\text{HDL-C}. Thus, the pattern of the relationships between changes in adiposity and changes in lipid and lipoprotein levels was similar in the older and younger groups of men, except that Δ\text{TG} was not significantly associated with any of the adiposity variables in older men.

For younger women, each of the adiposity measures was significantly correlated with Δ\text{TC} and Δ\text{LDL-C}, with magnitudes ranging from 0.20 to 0.32. In addition, Δ\text{HDL-C} was significantly correlated with both Δ\text{BMI} and Δ\text{TBF}; Δ\text{TG} was significantly associated with Δ\text{BMI}. In the older women, Δ\text{TC} and Δ\text{LDL-C} were significantly correlated with each measure of adiposity, with Δ\text{LDL-C} exhibiting a stronger relationship. The pattern of the relationships between baseline-adjusted changes in body composition and changes in lipid and lipoprotein levels was similar in the older and younger groups of women.

The relationship between changes in FFM, independent of levels of adiposity, and changes in lipid and lipoproteins in individuals was also investigated. Because levels of lean tissue increase as the level of adiposity increases, FFM was adjusted for levels of TBF within each age range. None of the correlations between the changes in TBF-adjusted level of FFM and changes in lipid or lipoprotein levels in either sex or age group were significant (most correlations were '2 0.10 # P # 0.10).

Thus, the association between the changes in lipids and lipopro-

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**TABLE 2. Means (and SDs) for the 2 Age Groups by Sex**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Men (n=149)</th>
<th>Women (n=159)</th>
<th>Men (n=53)</th>
<th>Women (n=62)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of individuals</td>
<td>149</td>
<td>159</td>
<td>53</td>
<td>62</td>
</tr>
<tr>
<td>No. of examinations</td>
<td>455</td>
<td>460</td>
<td>176</td>
<td>213</td>
</tr>
<tr>
<td>Midage (years)</td>
<td>29.9 (6.5)</td>
<td>30.1 (6.4)</td>
<td>53.9 (3.2)</td>
<td>53.2 (3.2)</td>
</tr>
<tr>
<td>Interval (years)</td>
<td>11.2 (4.6)</td>
<td>19.8 (8.6)</td>
<td>9.4 (4.6)</td>
<td>24.2 (8.6)</td>
</tr>
<tr>
<td>TBF (kg)</td>
<td>14.9 (7.1)</td>
<td>24.3 (8.8)</td>
<td>14.7 (8.6)</td>
<td>27.1 (6.4)</td>
</tr>
<tr>
<td>FBF (kg)</td>
<td>62.6 (7.4)</td>
<td>44.4 (5.8)</td>
<td>62.8 (7.0)</td>
<td>43.4 (5.8)</td>
</tr>
<tr>
<td>%BF</td>
<td>29.7 (7.2)</td>
<td>34.7 (6.9)</td>
<td>37.1 (6.4)</td>
<td>37.2 (6.9)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.9 (3.0)</td>
<td>27.5 (4.0)</td>
<td>27.4 (3.0)</td>
<td>24.7 (4.0)</td>
</tr>
<tr>
<td>TC (mmol/L)</td>
<td>4.81 (0.85)</td>
<td>4.63 (0.71)</td>
<td>5.43 (1.01)</td>
<td>5.64 (0.95)</td>
</tr>
<tr>
<td>LDL-C (mmol/L)</td>
<td>2.95 (0.72)</td>
<td>2.71 (0.63)</td>
<td>3.49 (0.81)</td>
<td>3.31 (0.86)</td>
</tr>
<tr>
<td>HDL-C (mmol/L)</td>
<td>1.28 (0.25)</td>
<td>1.44 (0.28)</td>
<td>1.28 (0.36)</td>
<td>1.62 (0.34)</td>
</tr>
<tr>
<td>TG (mmol/L)</td>
<td>2.95 (1.73)</td>
<td>2.43 (1.44)</td>
<td>3.83 (2.14)</td>
<td>3.54 (1.78)</td>
</tr>
</tbody>
</table>

Midage and interval were based on the number of individuals, body composition, and lipid and lipoprotein variables calculated at midage. Midage (years) is the age at the midpoint of the interval. Interval (years) is the duration from the first examination to the last examination. Other variables considered include TBF (kg), %BF, FFM (kg), BMI (kg/m²), TC (mmol/L), HDL-C (mmol/L), LDL-C (mmol/L), and TG (mmol/L).

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**TABLE 3. Means and (SDs) for Estimated Annual Changes**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Men (n=149)</th>
<th>Women (n=159)</th>
<th>Men (n=53)</th>
<th>Women (n=62)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔTBF (kg/y)</td>
<td>0.57† (0.72)</td>
<td>0.44† (1.09)</td>
<td>0.37† (0.70)</td>
<td>0.52† (1.05)</td>
</tr>
<tr>
<td>Δ%BF (%)</td>
<td>0.55† (0.74)</td>
<td>0.41† (1.17)</td>
<td>0.34‡ (0.70)</td>
<td>0.47† (0.95)</td>
</tr>
<tr>
<td>ΔFFM (kg)</td>
<td>0.08‡ (0.45)</td>
<td>0.04 (0.57)</td>
<td>0.13‡ (0.63)</td>
<td>0.00 (0.56)</td>
</tr>
<tr>
<td>ΔBMI kg/m²</td>
<td>0.20† (0.26)</td>
<td>0.16† (0.43)</td>
<td>0.12‡ (0.24)</td>
<td>0.18† (0.29)</td>
</tr>
<tr>
<td>ΔTC (mmol/L)</td>
<td>0.049† (0.097)</td>
<td>0.010 (0.093)</td>
<td>0.055† (0.161)</td>
<td>0.009 (0.111)</td>
</tr>
<tr>
<td>ΔLDL-C (mmol/L)</td>
<td>0.024‡ (0.082)</td>
<td>0.003 (0.068)</td>
<td>0.022‡ (0.142)</td>
<td>0.006 (0.104)</td>
</tr>
<tr>
<td>ΔHDL-C (mmol/L)</td>
<td>0.000 (0.031)</td>
<td>0.004 (0.042)</td>
<td>0.006 (0.029)</td>
<td>0.003 (0.043)</td>
</tr>
<tr>
<td>ΔTG (mmol/L)</td>
<td>0.134† (0.250)</td>
<td>0.070† (0.257)</td>
<td>0.040 (0.191)</td>
<td>0.100† (0.232)</td>
</tr>
</tbody>
</table>

**Note:** The variables for changes were ΔTBF (kg/y), Δ%BF (%/y), ΔFFM (kg/y), ΔBMI (kg/m² per year), ΔTC (mmol/L per year), ΔHDL-C (mmol/L per year), ΔLDL-C (mmol/L per year), and ΔTG (mmol/L per year).

†P < 0.001, ‡P < 0.05.
§Significant sex difference in 18–45-year-olds.
||Significant sex difference in 45–65-year-olds.
TABLE 4. Correlation Between Baseline-Adjusted Changes ($\Delta_a$) in Body Composition and Baseline-Adjusted Changes in Lipids and Lipoproteins*

<table>
<thead>
<tr>
<th></th>
<th>Men 18–45 Years</th>
<th>Men 45–65 Years</th>
<th>Women 18–45 Years</th>
<th>Women 45–65 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta_{TBF}$</td>
<td>0.36*</td>
<td>0.28†</td>
<td>0.24†</td>
<td>0.28†</td>
</tr>
<tr>
<td>$\Delta_{TC}$</td>
<td>0.34*</td>
<td>0.31†</td>
<td>0.32*</td>
<td>0.34†</td>
</tr>
<tr>
<td>$\Delta_{LDL-C}$</td>
<td>0.28*</td>
<td>0.29†</td>
<td>-0.18†</td>
<td>-0.13</td>
</tr>
<tr>
<td>$\Delta_{TG}$</td>
<td>0.36*</td>
<td>0.13</td>
<td>0.15</td>
<td>-0.04</td>
</tr>
<tr>
<td>$\Delta_{%BF}$</td>
<td>0.36*</td>
<td>0.21</td>
<td>0.21†</td>
<td>0.29†</td>
</tr>
<tr>
<td>$\Delta_{LDL-C}$</td>
<td>0.35*</td>
<td>0.23</td>
<td>0.25†</td>
<td>0.36†</td>
</tr>
<tr>
<td>$\Delta_{HDL-C}$</td>
<td>-0.23†</td>
<td>-0.31†</td>
<td>-0.15</td>
<td>-0.07</td>
</tr>
<tr>
<td>$\Delta_{TG}$</td>
<td>0.30*</td>
<td>0.03</td>
<td>0.13</td>
<td>-0.10</td>
</tr>
<tr>
<td>$\Delta_{BMI}$</td>
<td>0.15</td>
<td>0.10</td>
<td>0.00</td>
<td>-0.07</td>
</tr>
<tr>
<td>$\Delta_{TC}$</td>
<td>0.03</td>
<td>0.13</td>
<td>0.10</td>
<td>-0.14</td>
</tr>
<tr>
<td>$\Delta_{LDL-C}$</td>
<td>-0.04</td>
<td>-0.08</td>
<td>-0.10</td>
<td>-0.19</td>
</tr>
<tr>
<td>$\Delta_{TG}$</td>
<td>0.23†</td>
<td>0.19</td>
<td>0.14</td>
<td>0.26</td>
</tr>
</tbody>
</table>

*P < 0.001, †P < 0.05.

The age groupings used in the current study were determined in part from comparison of lipid and lipoprotein data from the Fels Longitudinal Study with cross-sectional data from the second US National Health and Nutrition Examination Survey (NHANES II). As shown in the Figure, NHANES II data for white adults show approximately linear increases in mean TC, LDL-C, and TG levels until approximately 45 years of age, after which there seems to be a sex-specific difference in the pattern of lipid and lipoprotein levels across age. The mean levels of HDL-C remain relatively constant from 20 to 74 years. For the purpose of comparison with NHANES II data, the Fels Longitudinal Study data were separated into age groups 18 to 24, 25 to 34, 35 to 44, 45 to 54, and 55 to 64 years. These age groups matched those used in describing the NHANES II distributions, except that the youngest NHANES group was 20 to 24 years of age. Mean lipid and lipoprotein levels within these age groups were calculated with all available data from the sample described in the current investigation. Although mean levels of plasma lipids and lipoproteins of the Fels participants were slightly lower than the national averages, data from the Fels Longitudinal Study show a pattern across age similar to that of the NHANES II data, with approximately linear increases until age 45 years and sex-specific differences in patterns of change across age after 45 years. Because the analytic methods used in the current study assume linear changes across age, the age ranges of 18 to 44 years and 45 to 65 years were selected to best correspond to periods of approximately linear cross-sectional change with age. In addition to comparison with national data, the assumption of linearity in each of the age ranges and the dichotomization of age groups at 45 years were also based on scatterplots of the Fels Longitudinal Study body composition and cardiovascular disease risk factor data against age.

The current study is atypical, in that all available serial data within the specific age ranges of each age group were utilized in the analyses. Previous studies investigating changes in lipids and changes in body composition have used a follow-up approach, wherein the differences between measurements taken at 2 points in time were used as measures of change, eg, the Québec Family Study and a study using data from western Samoans. Although rates of change can be calculated from the values obtained at the first and last examinations for individuals, all intermediate data for each individual are ignored in this approach. In the current study, 65% of the younger group and 75% of the older group had at least 3 measurements, and the intermediate data points comprised 35% of the 1304 total examinations of 423 individuals. Also, the individual regressive approach used in these analyses assumes a linear trend within each age group and therefore minimizes the effects of aberrant values due to measurement error or short-term biological variation.

Differences in the number of measurements for each individual were primarily a function of the study design rather than loss due to participant dropout. Adult participants...
of the Fels Longitudinal Study are scheduled for examinations at 2- or 5-year intervals depending on age and geographic location. Also, because the study has added new participants at a relatively constant rate over the years, some of the younger participants may have fewer examinations than older participants, or in fact, may have more examinations than slightly older participants owing to the study design. The age distribution of participants when hydrodensitometry was implemented into the Fels Longitudinal Study in 1976 also accounts for some variation in the number of examinations. The length of follow-up was affected somewhat by the number of examinations. Participants with only 2 measurements had a significantly shorter interval length than did those with >2 examinations, ~8 years compared with 11 years for younger males and females and ~7 years compared with 11 years in older males and females. In addition, the midage of younger females having 2 examinations (31.8 years) was significantly older than that of those with >2 examinations (29.4 years). None of the other change variables in either the younger or the older groups were significantly different with regard to number of examinations.

In the current investigation, correlation coefficients between baseline-adjusted changes in BMI and changes in TC, LDL-C, TG, and HDL-C were examined. The baseline adjustment made for each of the change variables allows for associations to be determined independent of initial adiposity, leanness, or general atherogenic profile. These correlations ranged from −0.33 to 0.49 and were generally greater in younger men than in younger women and similar between the sexes in the older group, suggesting that lipid and lipoprotein levels in young to middle-aged men were more susceptible to biological changes affecting BMI.

Although BMI is often used as an indirect index of adiposity, the body compartments of TBF and FFM are often confounded in associations between BMI and lipids and lipoproteins. The current study indicates that the correlations between both ΔBMI and ΔTC and ΔBMI and ΔLDL-C reflect a relationship between the specific cholesterol variable and ΔTBF for younger and older men and women. Only in younger men was the FFM compartment of BMI associated with changes in lipid or lipoprotein levels; ΔFFM was significantly correlated with ΔTC. The other adiposity measure, Δ%BF, was significantly correlated with ΔTC and ΔLDL-C in the younger men and in both younger and older women. In addition, ΔHDL-C was significantly related, albeit negatively, to all of the adiposity measures in the younger and older men. Not addressed in this study is which relationships, if any, may exist between changes in adipose tissue distribution independent of overall adiposity and changes in lipid and lipoprotein levels in individuals. Although some investigators have reported independent effects of abdominal obesity on lipid and lipoprotein levels after adjustment for BMI or other measures of adiposity, Jakicic and associates concluded that obesity was necessary for the relationships between various anthropometric measures of fat distribution and lipids and lipoproteins to exist. Likewise, Couillard and colleagues reported that 12-year changes in the distribution of subcutaneous fat were not independently correlated with lipid and lipoprotein profiles after controlling for variation in TBF.

The average interval of ~10 years within each age and sex group in the Fels Longitudinal Study sample was long enough for significant changes in the measured variables to occur. In men, the rate of increase in adiposity was more pronounced before age 45 compared with those observed at older ages, whereas in women, the rate of increase was similar both before and after age 45. In men, mean rates of change in TC levels increased to middle age, after which a decreased rate of change was noted. In women, the rate of increase was considerably slower and continued after age 45 years. Because the individuals enrolled for these analyses were unselected with regard to disease and generally represent a “normal” sample, the strong, positive correlations between the baseline-adjusted annual change in adiposity and change in cholesterol levels suggest that cholesterol levels appear to change with corresponding changes in adiposity over the whole range of body composition variation and not just in overweight individuals.

The current findings were compared with those of the Québec Family Study, which examined concurrent relationships between changes in body fatness and changes in lipid and lipoprotein levels over a similar time interval (12 years) as that used in this investigation. Whereas the investigators of the Québec Family Study concluded that a significant association existed between changes in fat indices and changes in TC in women, they did not find significant associations in men. Although this result may be a function of the considerably smaller sample sizes used in the Québec Family Study, it is more likely to be a function of the age range studied. The mean ages at baseline and follow-up for men were 43 and 55 years, respectively, and 41 and 53 years for women, and thus, bridge the break point at 45 years of age used in the current analysis. As seen in the Figure and other sources, the rates of change in lipids and lipoproteins before and after age 45 years differ. In the Québec Family Study, the mean change in TC levels over the entire 12-year follow-up period for men was 0.02 mmol/L. Because the current study found that TC levels increased before age 45 years at a rate similar to the rate of decrease after this age, this result is not surprising, and the lack of association between changes in TC and changes in body composition in men could be attributed to this fact.

Other follow-up studies of similar duration have used indirect measures of adiposity rather than hydrostatic weighing to determine the effects of changes in body composition on changes in lipid profiles in both young and old adults. In a study of young Samoan men with a mean baseline age of 26 years, 10-year changes in abdominal adiposity were positively associated with changes in TC and non-HDL–C, with correlations near 0.38. These correlations were similar to those reported in the current investigation for the baseline-adjusted changes in the direct measures of adiposity with baseline-adjusted changes in TC and LDL-C. In a study of elderly Dutch men >58 years of age, Weijenberg and associates reported a decrease in levels of TC of 0.04 mmol \cdot L^{-1} \cdot y^{-1}, as well as relatively stable levels of HDL-C over a 15-year follow-up period. This Dutch sample had a mean midage of ~70 years and was thus considerably older than the present 45- to 65-year age group. However, the findings of Weijenberg and associates are concordant with the serial
decreases in TC of older men that were observed in the current study, as well as with the cross-sectional decreases observed in TC levels in men as reported by others, and suggest that these decreases continue into the eighth decade of life.

Existing parallels were noted between the findings of the current investigation and those designed to examine the effects of weight loss. Intervention studies have shown that weight loss for obese individuals over short periods of time results in an improved atherogenic profile. The lengths of these studies were short, though (<2 years), and the samples were not representative of the general population. However, in a normal Australian sample, 2-year changes in weight showed relationships generally similar to those observed in the younger adults of the current study; ie, weight changes were significantly associated with changes in all lipid and lipoprotein variables in men and were significantly associated with changes in TC, LDL-C, and TG in women.

The current study has provided strong evidence that there is a positive relationship between changes in TC and LDL-C and concurrent changes in measures of adiposity in young to middle-aged and middle-aged to older groups of white men and women. In addition, young to middle-aged men showed a strong relationship with HDL-C and TG, with this strong relationship in HDL-C continuing into older age. The annual rate of change in adiposity over an average 10-year interval can explain from 4% to 25% of the variation in the annual rate of change in specific lipid or lipoprotein levels. This is somewhat remarkable, considering that these relationships exist irrespective of consideration of the underlying mechanisms (eg, diet, physical activity, etc) that may be involved in specific changes in individuals. Nevertheless, the findings clearly demonstrate that consistent increases in adiposity in individuals are associated with changes in lipid and lipoprotein levels in the direction of increased risk for cardiovascular disease. Adult levels of TC and LDL-C across age and sex and of HDL-C in men are responsive to changes in adiposity, independent of initial adiposity or lipid and lipoprotein levels.

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