Evidence for the incompatibility of age-neutral overweight and age-neutral physical activity standards from runners\textsuperscript{1–3}

Paul T Williams

ABSTRACT In contrast with earlier versions, the 1995 Dietary Guidelines for Americans uses the same definition of overweight for both younger and older adults. These guidelines state that prevention of weight gain at any age is achievable by balancing food intake with physical activity. The purposes of our study were to assess 1) whether vigorous exercise prevents weight gain with age, and 2) whether weight maintenance and an age-neutral adult overweight standard are consistent with a constant activity level over time. These hypotheses were tested in a national cross-sectional survey of 4769 and 2150 male runners aged 18–49 y and > 49 y, respectively. Before age 50 y, the rates at which body mass index (BMI; in kg/m\textsuperscript{2}) and waist circumference increased in association with age were the same in shorter-distance (< 16 km/wk) and longer-distance (> 80 km/wk) runners. Regardless of weekly running distance, before age 50 y, BMI increased at (± SE) 0.045 ± 0.006 kg · m\textsuperscript{-2} · y\textsuperscript{-1} and waist circumference increased at 0.186 ± 0.014 cm/y. The percentage of runners who were moderately overweight (BMI ≥ 25) was 21.5% before age 30 y and 30.1% in those between 45 and 49 y old. Men who ran greater distances were nevertheless leaner because weekly running distance was inversely related to BMI (slope ± SE: −0.033 ± 0.002 kg/m\textsuperscript{2} per km/wk) and waist circumference (−0.083 ± 0.004 cm · km\textsuperscript{-1} · wk\textsuperscript{-1}). To be consistent, guidelines should either 1) recommend substantial increases in physical activity over time when promoting an age-neutral adult overweight standard, or 2) accept an age-adjusted overweight standard when recommending a constant level of physical activity over time. Am J Clin Nutr 1997;65:1391–6.

KEY WORDS Exercise, running, physical activity, adiposity, weight gain, regional adiposity, middle aged men

INTRODUCTION

In contrast with earlier versions, the 1995 Dietary Guidelines for Americans uses the same definition of overweight for both younger and older adults\textsuperscript{(1)}. This was done because age-related weight gain is unlikely to be benign. Population studies show that body weight increases in men through late middle age and then decreases with further aging\textsuperscript{(2, 3)}. The middle-age weight gain is coincident with an increase in intraabdominal fat\textsuperscript{(4, 5)}. High intraabdominal fat is associated with major coronary artery disease risk factors, including insulin resistance, high plasma concentrations of total cholesterol and low-density-lipoprotein (LDL) cholesterol, high blood pressure, and low plasma concentrations of high-density lipoprotein (HDL) cholesterol\textsuperscript{(6, 7)}.

The 1995 guidelines state that prevention of weight gain at any age is achievable by balancing food intake with physical activity\textsuperscript{(1)}. Their recommendations for physical activity correspond with those advocated by the Centers for Disease Control and Prevention\textsuperscript{(8)}, ie, that the majority of health benefits can be achieved by walking 10–14 miles/wk [the energy equivalent of running 8–12 km (9)]. The dietary guidelines recommend that sedentary individuals become more active and that very active individuals maintain the same level of activity as they age. They state that weight achievement at any level is a more important goal than the achievement of a healthy weight. The purposes of our study were to assess 1) whether vigorous exercise prevents weight gain with age, and 2) whether weight maintenance and an age-neutral adult overweight standard are consistent with a constant activity level over time. Running promotes weight loss\textsuperscript{(10)}. Middle-aged men who are long-distance runners are leaner than their sedentary counterparts\textsuperscript{(11)}. It is unclear whether this is because running prevents age-related weight gain or because exercise-induced weight loss offsets weight gain during middle age\textsuperscript{(12)}. If running prevents age-related weight gain, then the same exercise recommendations may be appropriate for both younger and older adults. If running is compensatory (ie, if exercise-induced weight loss offsets age-related weight gain, the two effects being additive and independent), then an age-neutral physical activity guideline may be inadequate for the prevention of age-related weight gain, ie, the recommended level of physical activity may need to be increased with increasing age.

SUBJECTS AND METHODS

We examined the association of adiposity with age at different activity levels in participants of the National Runners' Health Study who completed a two-page questionnaire distrib-

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The questionnaire requested permission to obtain participants’ lipoprotein and blood pressure measurements from their physicians. We excluded men for consuming vegetarian diets, smoking, having a prior history of heart disease or cancer, and taking medication to control blood pressure, cholesterol, or thyroid or insulin concentrations. Nonwhite male runners were excluded because they were too few for meaningful analysis. The remainder included 4769 male runners aged 18-49 y and 2150 runners > age 49 y.

The average distance run per week was computed by averaging the reported yearly distance over the preceding 5 y. Self-reported distance run per week was found to be reproducible over repeated measurements (r = 0.89): unpublished data from 110 lean [mean body mass index (BMI; in kg/m²) of 23.2 ± 0.13] middle-aged (46.2 ± 0.7 y) men recruited into the running (66%) or sedentary (33%) arm of a study on lipoprotein concentrations versus adiposity (Table 1). The data were also stratified by weekly running distance when estimating the regression slope for blood pressure and lipoprotein concentrations versus adiposity (Table 2). Multiple-regression analyses were used to evaluate the significance of the relations of adiposity with age and weekly running distance. Two approaches were used to test whether the effects of age and running distance on adiposity were independent and additive: 1) a three-term multiple-linear-regression model with coefficients for age, distance run, and the product of age and distance run as a test for significant interaction; and 2) stepwise regression with age and running distance forced into the model as independent variables followed by stepwise selection of separate age coefficients for each running category (ie, the selection of one or more separate age coefficients would demonstrate the inadequacy of a common slope for all distance groups). When age and running distance were found to be independent and additive, a two-variable model was fitted (ie, BMI = \( \alpha + \beta_1 \) age + \( \beta_2 \) distance; waist circumference = \( \alpha + \beta_1 \) age + \( \beta_2 \) distance; hip circumference = \( \alpha + \beta_1 \) age + \( \beta_2 \) distance).

RESULTS

The mean BMI by age when stratified by weekly running distance in 4769 men between 18 and 49 y of age is shown in Figure 1. (The corresponding regression slope for each distance category is given in Table 1.) The figure shows that BMI and waist circumference decreased with weekly running distance in all age categories. It also shows that BMI and waist circumference increased in association with age in all distance categories. (The significance of the trends toward increased adiposity with age was verified by the regression analyses of

<p>| Table 1 Calculated increase in body mass index and waist circumference per year of age in men 18–49 y old by weekly running distance† |</p>
<table>
<thead>
<tr>
<th>Running distance (km)</th>
<th>BMI (in kg/m²)</th>
<th>Increase per year of age</th>
<th>Waist circumference (cm)</th>
<th>Hip circumference (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unadjusted regression slopes</td>
<td></td>
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<tr>
<td>0–16 (n = 501)</td>
<td>0.048 ± 0.021</td>
<td>0.21 ± 0.05</td>
<td>0.28 ± 0.07</td>
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</tr>
<tr>
<td>16–32 (n = 1452)</td>
<td>0.029 ± 0.012</td>
<td>0.20 ± 0.03</td>
<td>0.23 ± 0.04</td>
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<tr>
<td>32–48 (n = 1518)</td>
<td>0.041 ± 0.010</td>
<td>0.17 ± 0.03</td>
<td>0.17 ± 0.04</td>
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<tr>
<td>48–64 (n = 768)</td>
<td>0.063 ± 0.012</td>
<td>0.18 ± 0.03</td>
<td>0.19 ± 0.05</td>
<td></td>
</tr>
<tr>
<td>64–80 (n = 356)</td>
<td>0.062 ± 0.017</td>
<td>0.16 ± 0.04</td>
<td>0.39 ± 0.07</td>
<td></td>
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<tr>
<td>&gt;80 (n = 174)</td>
<td>0.069 ± 0.022</td>
<td>0.18 ± 0.06</td>
<td>0.57 ± 0.13</td>
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<tr>
<td>Regression slopes adjusted for education, diet, alcohol intake, and parents’ adiposity</td>
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<tr>
<td>0–16 (n = 501)</td>
<td>0.045 ± 0.022</td>
<td>0.21 ± 0.05</td>
<td>0.26 ± 0.08</td>
<td></td>
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<tr>
<td>16–32 (n = 1452)</td>
<td>0.035 ± 0.012</td>
<td>0.21 ± 0.03</td>
<td>0.26 ± 0.05</td>
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</tr>
<tr>
<td>&gt;80 (n = 174)</td>
<td>0.076 ± 0.024</td>
<td>0.21 ± 0.06</td>
<td>0.55 ± 0.14</td>
<td></td>
</tr>
</tbody>
</table>

† Slope ± SE. In men aged ≥50 y each additional year of age was associated with a decrease of 0.057 ± 0.008 in BMI (P < 0.0001) and no change in the waist (0.009 ± 0.020 cm) and hip (0.036 ± 0.029 cm) circumferences when adjusted for weekly running distance.

‡,‡ Significantly different from zero: ‡P < 0.05, ‡P < 0.0001, ‡P < 0.001, ‡P < 0.01.
Our analyses suggest that weight maintenance is unlikely with advancing age (≤ age 49 y) if physical activity remains constant in persons on ad libitum diets. Male runners who maintain constant weekly distances through middle age are expected to increase total weight and waist circumference (−0.024 ± 0.006/km, \( P < 0.0001 \)) but showed no significant relation to age (−0.026 ± 0.021/y, \( P = 0.21 \)).

The clinical significance of higher weights in all distance categories is shown by the significant positive regression slopes in Table 2. Men who ran greater distances were not exempt from clinical consequences of greater weight and upper-body adiposity. Greater adiposity, as measured by higher BMI or higher waist circumference, was associated with a higher LDL cholesterol, higher ratio of total cholesterol to HDL cholesterol, and higher blood pressure regardless of running distance.

In 2150 male runners who were aged ≥ 50 y, we found that age was associated with decreasing BMI, which is consistent with studies on older sedentary men (2, 3). As in younger men, weekly running distance did not significantly affect the inverse relations between age and adiposity. When adjusted for age, each kilometer run per week was associated with a 0.023 ± 0.004 decrease in BMI (\( P < 0.0001 \)) and a 0.074 ± 0.008 decrease in BMI (\( P < 0.0001 \)). Each additional year of aging was associated with a decrease of 0.057 ± 0.008 in BMI (\( P < 0.0001 \)). There was no significant relation between age and waist or hip circumference in older men.
FIGURE 1. Cross-sectional relations of mean body mass index and waist circumference versus age, stratified by weekly running distance. The 64–80 and > 80-km/wk categories were combined because of the small sample sizes that result when stratified by age. In men aged ≥ 50 y, each additional year of age was associated with a calculated decrease of 0.057 ± 0.008 in BMI (P < 0.0001).

(presumably intraabdominal fat). Men who run greater distances appear to be no different from their shorter-distance counterparts with respect to their rate of age-related weight gain. However, the coefficients from the multiple-regression analyses suggest that male runners who annually increase their distance run by 2.24 km/wk (1.39 miles/wk) are expected to compensate for the anticipated weight gain during middle age. After middle age, a decline in BMI in the absence of a reduction in waist circumference reflects a loss in lean body mass that persists when adjusted for physical activity levels (15). Thus, age-neutral adult overweight standards may not be compatible with an age-neutral physical activity guideline.

Age-related increases in visceral fat have been attributed to behavior, environment, and physiologic changes. Cross-sectional studies of men show that plasma testosterone and growth hormone concentrations are inversely correlated with both age and adiposity (16). Age-related declines in these hormones may curtail lipid metabolism and permit the lipid-accumulating and -immobilizing effects of cortisol and insulin to dominate, causing visceral fat to accumulate (17). Administering testosterone to middle-aged men reduces the ratio of waist-to-hip circumference (18). This may be due to increased lipolytic responsiveness to norepinephrine and decreased abdominal lipoprotein lipase activity (18). These changes represent a shift in the abdominal fat metabolism of middle-aged men toward that of younger men. Reductions in abdominal adiposity also occur in men who receive growth hormone (19).

Other physiologic variables associated with both increasing age and increasing abdominal fat, but whose roles as cause or consequence of age-related weight gain require further elucidation, include increased insulin resistance (20), sympathetic nervous system activity (21), luteinizing hormone (22), follicle-stimulating hormone (22), and decreased insulin-like growth factor I (23). Prospective studies show that lower resting metabolic rates (24), higher respiratory quotients [ie, ratio of carbohydrate to fat oxidation (25)], and lower fasting insulin concentrations (26, 27) are predictive of weight gain over time. Behavioral variables, including physical inactivity, diet, marital status, alcohol consumption, and smoking cessation have also been associated with increasing adiposity (28–32). Alcohol, diet, smoking status, and physical inactivity appear unlikely to explain the associations between age and adiposity shown in Figure 1 because the associations persist when adjusted for intakes of red meat, fish, fruit, and alcohol and because none of the runners smoked.

The strong inverse association of running distance with BMI and waist circumference occurred in all age categories (Figure 1). Weight loss occurs when energy expenditure due to basal metabolism, postprandial thermogenesis, and physical activity exceed metabolizable energy intake. Exercise-induced weight loss has been attributed to reduced energy intake (33), increased basal metabolism (34), increased thermic effect of food (34), and energy expenditure during exercise (33, 35). Thus, the effects of energy deficit produced by exercise appear to differ fundamentally from those produced by energy restriction. In contrast with exercise, energy restriction appears to decrease energy expenditure (36, 37), ie, decrease basal meta-
bolic rate and physical activity (37), thereby compensating for the reduction in energy intake and resisting weight change (37). Weight loss during exercise may have an adaptive significance because greater exercise efficiency is achieved with the loss of fat, ie, energy required for running decreases with body weight.

Our data showed little change in the waist-to-hip ratio with age, due presumably to the concomitant increases in both waist and hip circumferences with age. There were no significant inverse relations of hip circumference with systolic blood pressure, LDL cholesterol, or ratio of total cholesterol to HDL cholesterol (Table 2); therefore, there was no indication that a higher hip circumference was beneficial. In men, the waist circumference has been shown to be more strongly associated with intraabdominal fat mass (38) and the metabolic complications of obesity (39) than with the waist-to-hip ratio. The larger waist circumference presumably reflects abdominal fat accumulation because of adipocyte enlargement rather than an increased fat cell number (40).

We found that the physiologic mechanisms responsible for weight gain from early adulthood to late middle age persist despite considerable physical activity. Within the range of activity levels studied here, the physiologic processes responsible for age-related weight gain appear to be unabated by high physical activity levels. Men appear to be susceptible to some degree of middle-age weight gain and its health consequences regardless of their physical activity level. Age-related weight gain and exercise-induced weight loss appear to be independent, additive effects. Middle-aged runners are leaner than sedentary men not because the processes that promote age-related weight gain are abated, but rather, because exercise-induced weight loss offsets weight gain during middle age.

Our cross-sectional data by themselves do not distinguish age-related weight gain from cohort effects and exercise-induced weight loss from self selection. However, several longitudinal studies have shown increases in body weight with age (2, 3, 12) and decreases in weight with running (10, 41). The lower BMI of the runners studied here is known to be due at least in part to active weight loss rather than to self selection (11). The increases in BMI and waist circumference in these runners are less than those observed in studies of men who are presumably much more sedentary (5, 12), suggesting that in more sedentary populations physical inactivity may contribute to additional weight gain during aging beyond that observed in runners. However, even among high-mileage runners, greater adiposity as measured by BMI or waist circumference is unlikely to be benign given its association with three important coronary artery disease risk factors (42-44). The absence of detailed dietary records in this cohort precludes the analysis of energy intake or composition. However, prior studies in more sedentary populations failed to attribute much of the weight gain to either increased energy intake or change in dietary composition (32).

Our data suggest that the rate of weight gain through middle age is the same in both shorter-distance runners [ie, those who largely meet current physical activity guidelines (8)] and longer-distance runners [ie, those who substantially exceed current guidelines (8)]. The inability of a constant level of physical activity to prevent age-related weight gain is likely to be exacerbated in less active populations. We believe that physical activity guidelines should recommend substantial increases in activity over time when promoting an age-neutral adult overweight standard. The alternative is to return to an age-adjusted overweight standard to accommodate the consequences of age-neutral physical activity guidelines.

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REFERENCES


