Greater rate of decline in maximal aerobic capacity with age in physically active vs. sedentary healthy women

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1Human Cardiovascular Research Laboratory, Center for Physical Activity, Disease Prevention, and Aging, Department of Kinesiology, University of Colorado, Boulder 80309; and 2Divisions of Cardiology and Geriatric Medicine, Department of Medicine, Center on Aging, University of Colorado Health Sciences Center, Denver, Colorado 80262

Tanaka, Hirofumi, Christopher A. DeSouza, Pamela P. Jones, Edith T. Stevenson, Kevin P. Davy, and Douglas R. Seals. Greater rate of decline in maximal aerobic capacity with age in physically active vs. sedentary healthy women. J. Appl. Physiol. 83(6): 1947–1953, 1997.—Using a meta-analytic approach, we recently reported that the rate of decline in maximal oxygen uptake (V\textsubscript{O2\text{max}}) with age in healthy women is greatest in the most physically active and smallest in the least active when expressed in milliliters per kilogram per minute per decade. We tested this hypothesis prospectively under well-controlled laboratory conditions by studying 156 healthy, nonobese women (age 20–75 yr): 84 endurance-trained runners (ET) and 72 sedentary subjects (S). ET were matched across the age range for age-adjusted 10-km running performance. Body mass was positively related with age in S but not in ET. Fat-free mass was not different with age in ET or S. Maximal respiratory exchange ratio and rating of perceived exertion were similar across age in ET and S, suggesting equivalent voluntary maximal efforts. There was a significant but modest decline in running mileage, frequency, and speed with advancing age in ET. V\textsubscript{O2\text{max}} (ml·kg\textsuperscript{-1}·min\textsuperscript{-1}) was inversely related to age (P < 0.001) in ET (r = −0.82) and S (r = −0.71) and was higher at any age in ET. Consistent with our meta-analytic findings, the absolute rate of decline in V\textsubscript{O2\text{max}}, greater in ET (−5.7 ml·kg\textsuperscript{-1}·min\textsuperscript{-1}·decade\textsuperscript{-1}) compared with S (−3.2 ml·kg\textsuperscript{-1}·min\textsuperscript{-1}·decade\textsuperscript{-1}; P < 0.01), but the relative (%) rate of decline was similar (−9.7 vs. −9.1%/decade; not significant). The greater absolute rate of decline in V\textsubscript{O2\text{max}} in ET compared with S was not associated with a greater rate of decline in maximal heart rate (−5.6 vs. −6.2 beats·min\textsuperscript{-1}·decade\textsuperscript{-1}), nor was it related to training factors. The present cross-sectional findings provide additional evidence that the absolute, but not the relative, rate of decline in maximal aerobic capacity with age may be greater in highly physically active women compared with their sedentary healthy peers. This difference does not appear to be related to age-associated changes in maximal heart rate, body composition, or training factors.

METHODS

Subjects. We studied 156 women: 84 endurance-trained athletes (age range 21–73 yr) and 72 nonobese sedentary subjects (age range 20–75 yr). All subjects were apparently healthy and free of overt coronary artery disease as assessed...
by medical history questionnaire. Irrespective of training status, women over 50 yr of age were further evaluated by physical examination and by resting and maximal exercise electrocardiograms. None of the subjects were smokers or were taking medications, other than hormone replacement, that could affect circulatory function. To eliminate the potentially confounding influence of severe obesity, only subjects with a body mass index of <35 kg/m² were included in the study. At least 10 subjects were included in each 10-yr age period for each group. The endurance-trained women had been training for at least the past 2 yr and were actively competing in road-running races. To ensure that the endurance-trained subjects were homogeneous with regard to relative competitiveness, they were matched across the entire age range for age-adjusted world-best 10-krn running times (Masters Age-Graded Tables, 1994 "National Masters News," Van Nuys, CA) as described previously in detail (10). The women in the sedentary group performed no regular physical exercise. Before participation, verbal and written explanations of the procedures and potential risks were administered. In turn, the subjects gave their written informed consent to participate in this investigation. This study was reviewed and approved by the Human Research Committee of the University of Colorado at Boulder.

Measurements. VO₂max was determined by a continuous incremental treadmill protocol by using an online computer-assisted open-circuit spirometry as described in detail previously (10, 30). Expired air volume was measured with a turbine (model VMM-2, Interface Associates, Laguna Niguel, CA) previously calibrated against a Hans Rudolph 7-liter syringe (Kansas City, MO). Gas fractions were analyzed either with a Perkin-Elmer MGA-1100 mass spectrometer (Pomona, CA) or with an Applied Electrochemistry 5-3A oxygen analyzer (Pittsburgh, PA) and a Beckman LB-2 carbon dioxide analyzer (Schiller Park, IL). There were no differences between these two systems when gas fractions, oxygen uptake, and carbon dioxide production were analyzed simultaneously. Before each trial, these analyzers were calibrated with standard gases of known concentrations. Heart rates were continuously monitored with an electrocardiogram.

After a 6- to 10-min warm-up period, each subject ran or walked at a comfortable speed that corresponded to 70–80% of maximal oxygen uptake, and carbon dioxide production were analyzed by an electrocardiogram.

<table>
<thead>
<tr>
<th>Variable</th>
<th>20–29</th>
<th>30–39</th>
<th>40–49</th>
<th>50–59</th>
<th>&gt;60</th>
<th>r With Age</th>
<th>P Value</th>
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<tr>
<td>Sedentary subjects</td>
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<td></td>
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<td>20</td>
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<td></td>
<td></td>
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<tr>
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<td>45 ± 1</td>
<td>54 ± 1</td>
<td>64 ± 1</td>
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<tr>
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<td>165 ± 2</td>
<td>163 ± 2</td>
<td>167 ± 2</td>
<td>161 ± 2</td>
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<tr>
<td>Body mass, kg</td>
<td>61 ± 2</td>
<td>65 ± 4</td>
<td>66 ± 3</td>
<td>67 ± 2</td>
<td>70 ± 3</td>
<td>0.27</td>
<td>&lt;0.05</td>
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<td>Fat-free mass, kg</td>
<td>44 ± 1</td>
<td>46 ± 1</td>
<td>43 ± 1</td>
<td>44 ± 1</td>
<td>46 ± 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body fat, %</td>
<td>27 ± 2</td>
<td>28 ± 3</td>
<td>34 ± 1</td>
<td>33 ± 1</td>
<td>34 ± 1</td>
<td>0.38</td>
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<td>Endurance-trained subjects</td>
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<td>34 ± 1</td>
<td>45 ± 1</td>
<td>54 ± 1</td>
<td>66 ± 1</td>
<td></td>
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<tr>
<td>Height, cm</td>
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<td>167 ± 1</td>
<td>163 ± 2</td>
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<td>53 ± 2</td>
<td>56 ± 1</td>
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<tr>
<td>Fat-free mass, kg</td>
<td>46 ± 1</td>
<td>47 ± 1</td>
<td>45 ± 1</td>
<td>46 ± 1</td>
<td>44 ± 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body fat, %</td>
<td>14 ± 1</td>
<td>15 ± 1</td>
<td>16 ± 2</td>
<td>19 ± 1</td>
<td>22 ± 1</td>
<td>0.51</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Values are means ± SE; n, no. of subjects. NS, not significant.
of age-predicted maximal heart rate. Treadmill grade was increased 2.5% every 2 min until volitional exhaustion. At the end of each stage, the subjects were asked to rate their perception of effort by using a Borg scale (6–20 scale). Each treadmill test lasted between 8 and 12 min. Maximal heart rate was defined as the highest value recorded during the test. To ensure that each subject attained a valid \( \dot{V}_\text{O}_2\text{max} \), at least three of the following four criteria were met by each subject: 1) a plateau in oxygen uptake with increasing exercise intensity, 2) a respiratory exchange ratio of at least 1.15, 3) achievement of age-predicted maximal heart rate [\([\pm 10 \text{ beats/min (bpm)}]\)], and 4) a rating of perceived exertion of at least 18 units (17).

Body mass was measured with a physician’s balance scale (Detecto, Webb City, MO) to the nearest 0.1 kg. Body fat percent was estimated from the sum of five-site skinfold measurements with a Lange caliper (19). Fat-free mass was subsequently calculated as the difference between total body mass and estimated fat mass.

Statistics. One-way analysis of variance was used to determine differences in the dependent variables among age groups. When indicated by a significant \( F \)-value, a post hoc test using the Newman-Keuls method was performed to identify significant differences among group means. Univariate correlations and regression analyses were performed to determine the relations among the dependent variables and the proportion of variance in \( \dot{V}_\text{O}_2\text{max} \) explained by selected predictor variables, respectively. Stepwise multiple-regression analyses were used to identify significant, independent determinants for the age-related declines in \( \dot{V}_\text{O}_2\text{max} \). All data are reported as means \( \pm \) SE. Statistical significance was set a priori at \( P < 0.05 \).

RESULTS

Subject characteristics. Table 1 presents mean values for selected subject characteristics. In the sedentary women, no significant relations were observed between age and height or fat-free mass, whereas body mass and body fat percent increased (\( P < 0.05 \)) with advancing age. In the endurance-trained women, height, body mass, and fat-free mass did not decline with age, whereas body fat percent was positively related to age (\( P < 0.001 \)).

Maximal exercise responses. Table 2 presents values obtained during maximal exercise. Irrespective of the expression, \( \dot{V}_\text{O}_2\text{max} \) declined with advancing decades of age in both groups (\( P < 0.0001 \)). Similarly, maximal heart rate, pulmonary ventilation, and oxygen pulse were inversely related to age (\( P < 0.0001 \)). In both groups, respiratory exchange ratio and rating of perceived exertion at \( \dot{V}_\text{O}_2\text{max} \) were not different across age, suggesting consistently similar voluntary maximal efforts.

Rate of decline in \( \dot{V}_\text{O}_2\text{max} \). Figure 1 illustrates the decline in \( \dot{V}_\text{O}_2\text{max} \) in the sedentary and endurance-trained women. \( \dot{V}_\text{O}_2\text{max} \) was strongly inversely related to age in both the endurance-trained (\( r = -0.82 \)) and sedentary (\( r = -0.71 \)) women. At any age, \( \dot{V}_\text{O}_2\text{max} \) was higher in the endurance-trained compared with the sedentary women.

When expressed in absolute terms (e.g., ml·kg\(^{-1}\)·min\(^{-1}\)·decade\(^{-1}\)), the rate of decline in \( \dot{V}_\text{O}_2\text{max} \)
in $\dot{V}O_2_{max}$, the age-related declines in maximal heart rate were greater over 50 yr of age. In contrast to the rate of decline in maximal heart rate, there were no group differences in rate of decline in maximal heart rate with advancing age. bpm, Beats/min.

was greater ($P < 0.01$) in the endurance-trained (−5.7 ml·kg$^{-1}$·min$^{-1}$·decade$^{-1}$) compared with sedentary (−3.2 ml·kg$^{-1}$·min$^{-1}$·decade$^{-1}$) women (Figs. 1 and 2A). Similar group differences in the rate of decline persisted when $\dot{V}O_2_{max}$ was expressed in absolute terms (l/min) and relative to fat-free mass. In contrast, the relative (%) rate of decline in $\dot{V}O_2_{max}$ from mean levels at age −25 yr was similar in the endurance-trained (9.7%·decade$^{-1}$) and sedentary (9.1%·decade$^{-1}$) women (Fig. 2B).

Rate of decline in maximal heart rate. As illustrated in Fig. 3, maximal heart rate was inversely related to age in both groups ($P < 0.001$). There was substantial variation in maximal heart rate among both young adult and older adult subjects, with the largest interindividual variability observed in endurance-trained subjects over 50 yr of age. In contrast to the rate of decline in $\dot{V}O_2_{max}$, the age-related declines in maximal heart rate were not different in the endurance-trained (−5.6 bpm/decade) and sedentary (−6.0 bpm/decade) women.

Age-related changes in training factors in the endurance athletes. Exercise training data in the endurance-trained women are presented in Table 3 and Fig. 4. Weekly running mileage, frequency, and speed were modestly inversely related to age ($r = −0.29$ to approximately $−0.44$, $P < 0.01$), whereas years of training were positively related to age ($r = 0.35$, $P < 0.001$). Percentages of age-adjusted world-best 10-km running times were similar across the adult age range (75−77%; Table 3).

Correlates of the age-related decline in $\dot{V}O_2_{max}$. Table 4 presents significant predictor variables of the age-related reductions in $\dot{V}O_2_{max}$ as assessed by forward stepwise multiple-regression analysis. Age was the primary predictor of $\dot{V}O_2_{max}$ in both groups, accounting for 69 and 57% of the total variance in the endurance-trained and sedentary women, respectively. The secondary predictor for both groups was body fat percent, which accounted for an additional 10% of the variance in the endurance-trained women and 20% of the variance in the sedentary women. No other variable, including running mileage and running speed, significantly improved the proportion of the variance explained in the age-associated decline in $\dot{V}O_2_{max}$ in the endurance-trained women.

**DISCUSSION**

The primary findings of the present study are as follows. First, consistent with the results of our recent meta-analysis, the absolute, but not the relative, rate of decline in $\dot{V}O_2_{max}$ with age was greater in highly physically active women compared with their sedentary peers. Second, the greater rate of decline in $\dot{V}O_2_{max}$ with age in the endurance-trained women was not related to a greater rate of change in maximal heart rate, body composition, or training factors.

Using the meta-analytic approach, we recently demonstrated that the absolute rate of decline in $\dot{V}O_2_{max}$ with age in healthy women increases with increasing levels of habitual endurance exercise (11). The results of the present study are consistent with these findings, indicating that the absolute rate of decline in $\dot{V}O_2_{max}$ with increasing age is greater in endurance-trained than sedentary women. Moreover, the age-related rates of decline in $\dot{V}O_2_{max}$ in the present study were similar to those observed in our meta-analysis (i.e., −3.2 and −3.5 in sedentary and −5.7 and −6.2 ml·kg$^{-1}$·min$^{-1}$·decade$^{-1}$ in endurance-trained women, respectively). Taken together, these results indicate that endurance-trained women appear to have greater rates of decline in $\dot{V}O_2_{max}$ with advancing age compared with healthy sedentary adult women. The present results also are consistent with recent findings from longitudinal studies in men (14, 24, 32).

**Table 3. Exercise training and performance data of the endurance-trained women**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Age Groups, yr</th>
<th>$r$ With</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20–29</td>
<td>30–39</td>
<td>40–49</td>
</tr>
<tr>
<td>Mileage, km/wk</td>
<td>62 ± 5</td>
<td>59 ± 5</td>
<td>49 ± 7</td>
</tr>
<tr>
<td>Frequency, days/week</td>
<td>5.6 ± 0.3</td>
<td>5.1 ± 0.3</td>
<td>4.8 ± 0.3</td>
</tr>
<tr>
<td>Training speed, m/min</td>
<td>203 ± 9</td>
<td>197 ± 5</td>
<td>194 ± 7</td>
</tr>
<tr>
<td>Length of training, yr</td>
<td>10.2 ± 1.2</td>
<td>12.1 ± 1.3</td>
<td>9.4 ± 1.6</td>
</tr>
<tr>
<td>10-km Time, min</td>
<td>41 ± 1</td>
<td>41 ± 1</td>
<td>45 ± 1</td>
</tr>
<tr>
<td>%Performance</td>
<td>75 ± 1</td>
<td>76 ± 1</td>
<td>77 ± 1</td>
</tr>
</tbody>
</table>

Values are means ± SE. %Performance, % of age-adjusted world-best 10-km running times.
It is not clear as to why endurance-trained women exhibit a greater rate of decline in \( \dot{V}O_2max \) with increasing age. The results of some earlier studies indicate that changes in body composition play an important role in the age-related decline in \( \dot{V}O_2max \) (8, 12, 20, 23). In the present study, body mass and fat-free mass were maintained across age in the endurance-trained women, whereas the sedentary women demonstrated a significant increase in body mass and body fat across age without a change in fat-free mass. The age-related increase in fat and total body mass in the sedentary women should act to increase their rate of reduction in \( \dot{V}O_2max \) with age when expressed in milliliters per kilogram per minute per decade compared with the active women. It is also plausible to speculate that the greater rate of decline in maximal aerobic capacity in the endurance-trained women may be due to larger age-related reductions in maximal heart rate because of its effect on maximal cardiac output and, in turn, \( \dot{V}O_2max \) via the Fick equation (13, 15). However, the rates of decline in maximal heart rate were similar between the endurance-trained and sedentary women.

Thus these results suggest that factors other than body composition and maximal heart rate (namely age-related changes in maximal stroke volume and arteriovenous oxygen difference) were responsible for the greater rate of decline in \( \dot{V}O_2max \) in the endurance-trained women.

Because of the major role that habitual physical activity plays in determining \( \dot{V}O_2max \) (23, 25, 28), we speculated in our previous meta-analytic study that the greater rate of decline in \( \dot{V}O_2max \) with age in the endurance-trained women could be explained in part by a marked age-related decline in their levels of training. Although the limited database of studies reporting training mileage suggested that this might have been the case, the lack of complete data precluded us from drawing any definite conclusions. In the present study, running mileage and frequency declined significantly, albeit only modestly, with age in the endurance-trained women. Thus the magnitude of decline in physical activity was greater in the endurance-trained than in the sedentary women and, therefore, could have contributed to the greater rate of decline in \( \dot{V}O_2max \) in the former group. However, several lines of evidence suggest that reductions in exercise volume did not exert a major effect. First, the univariate correlations between \( \dot{V}O_2max \) and both weekly training mileage \((r = 0.47)\) and frequency \((r = 0.21)\) were modest. Second, changes in training volume with age did not explain a significant proportion of the variance in the age-related declines in \( \dot{V}O_2max \) in the endurance-trained women, as assessed by the stepwise multiple-regression analysis. Third, a recent study in men reported that, despite a substantially smaller age-related rate of decline in \( \dot{V}O_2max \) compared with sedentary or fitness-

### Table 4. Stepwise multiple-regression analysis for predicting factors responsible for age-related reduction in \( \dot{V}O_2max \)

<table>
<thead>
<tr>
<th>Group</th>
<th>Predictor 1 ((R^2))</th>
<th>Predictor 2 ((\text{cumulative}R^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endurance trained</td>
<td>Age ((0.69))</td>
<td>%Body fat ((0.79))</td>
</tr>
<tr>
<td>Sedentary</td>
<td>Age ((0.57))</td>
<td>%Body fat ((0.77))</td>
</tr>
<tr>
<td>Combined</td>
<td>%Body fat ((0.74))</td>
<td>Age ((0.82))</td>
</tr>
</tbody>
</table>
trained men, elite middle-age runners experienced a 43% reduction in training volume in the 20-yr follow-up period (32). In the present study, the reduction in training volume across a similar time period was only 21%, suggesting the likelihood of an even smaller effect of reductions in training on VO2max.

Exercise training intensity has been reported to exert an even stronger effect on VO2max than does training volume (16). Therefore, it is reasonable to speculate that the reduction in training intensity may have contributed to the greater rate of decline in VO2max in the endurance-trained women. However, the univariate correlation between VO2max and training intensity (i.e., running speed), although significant, was modest (r = 0.44). In addition, stepwise multiple regression revealed that the reduction in training intensity did not explain a significant portion of the variance in the age-related reduction in VO2max in the endurance-trained women. Moreover, the rate of reduction in training intensity was relatively small (i.e., approx. −3%/decade). Our results are consistent with those of one recent longitudinal study in men (32) but differ from the findings of another recent longitudinal study by Pollock and colleagues (24), which showed a significant correlation between age-related changes in maximal aerobic capacity and training intensity. Thus our data do not support an obvious relation between measures of training volume or intensity and the rate of decline in VO2max with age. However, it is possible that the combined effects of the modest declines in each of these measures may have contributed significantly to the decrease in VO2max with age in the endurance athletes. Such a combined training stimulus measure cannot be calculated; therefore, we cannot speculate further on this possibility.

As discussed in detail in our previous paper (11), we think that the greater rate of decline in VO2max in endurance-trained women may be due to a baseline effect. That is, individuals with the higher levels of VO2max as young adults demonstrate a greater rate of decline with advancing age. This argument is supported by the observation that, when the baseline effect was removed by expressing the data as relative or percent changes from mean levels at age ~25 yr, the rate of decline in VO2max with age was similar in the two groups. Similar relations between baseline levels and rates of decline in VO2max with age are observed between men and women (7, 11). These results suggest that the greater absolute rate of decline in VO2max in endurance-trained women may be largely attributed to their higher baseline levels as young adults.

A low level of maximal aerobic capacity has recently been identified as an important risk factor for all-cause and cardiovascular disease mortality in both men and women (5, 6). In addition, VO2max is the most frequently used measure of physiological functional capacity. It is important to note that, although endurance-trained women appear to have a greater rate of decline in VO2max with age, their absolute levels are substantially higher than those of their sedentary peers throughout the adult age range studied. Moreover, only a few endurance-trained women had VO2max values lower than 32.5 ml·kg−1·min−1, the level below which age-adjusted mortality starts to increase in women (5, 6). Therefore, we wish to emphasize from the standpoint of preventive gerontology (4) that the endurance-trained women in the present study possess higher levels of physiological functional capacity and, based on recent epidemiological data (5, 6), lower risks of premature mortality than do sedentary women at any age.

The major limitation of the present study is its cross-sectional design. It has been noted previously that data concerning the rate of decline in maximal aerobic capacity with age differ between longitudinal and cross-sectional study designs (7, 24). However, in studies in which cross-sectional and longitudinal analyses are combined in the same subject population (18, 22, 29), the estimation of the average rate of decline in VO2max with advancing age is similar with the two approaches. Nevertheless, we cannot discount the possibility that genetic or other constitutional factors may have influenced the present cross-sectional findings. Longitudinal studies will be necessary to more completely understand the relation between age-related changes in maximal aerobic capacity and habitual exercise status.

We should also emphasize that our subject inclusion criteria (e.g., limits on body mass index) as well as the fact that our subjects were volunteers (i.e., not randomly selected) likely introduced subject selection bias. Therefore, our sedentary subjects may not have been representative of the general population of women over this age range.

In conclusion, the results presented herein support our recent findings (11) that the absolute, but not the relative, rate of decline in VO2max with increasing age appears to be greater in highly physically active women compared with their healthy but sedentary peers. The greater rate of decline in VO2max in endurance-trained women was not associated with greater changes in body mass or composition, maximal heart rate, and/or training factors.

We thank Cyndi Long for assistance in the present study.

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REFERENCES

AGE-RELATED VO₂max DECLINE IN WOMEN


