Maximal Aerobic Power in Cycle Ergometry in Middle-Aged Men and Women, Active in Sports, in Relation to Age and Physical Activity

Institute of Sports Medicine Limburg, Departments of Human Biology and Movement Sciences, State University of Limburg, Maastricht, The Netherlands

Abstract


Accepted after revision: October 23, 1992

Reliable standards of maximal power output in middle-aged and physically active men and women are desirable in sports-medical practice. For this purpose maximal cycle ergometer tests were evaluated in 2036 men and 898 women over 40 years of age (46.8 ± 6.1 years (mean ± SD) and 47.5 ± 6.6 years), who volunteered in a sports-medical check-up and all of whom were active in sports for at least three months in the year preceding the screening (4.3 ± 3.1 hours/week respectively 3.6 ± 2.5 hours/week). The range of maximal values for power output (Wmax), heart rate (HRmax), systolic blood pressure (SBPmax) and peak plasma lactate concentrations (PPLa) during progressive cycle ergometer testing are presented for males and females who were divided into groups with 5-year age difference. Wmax varied with sex (male = 1, female = 0), age (year) and height (cm): Wmax = 6.53 x (sex) + 2.0 x (height) - 1.9 x (age) - 67.9 (See = 38.2, r = 0.76). The weighing of different factors that influence performance was also studied by multiple regression analysis to provide improved precision in standards used to interpret exercise tests. In both men and women about half of the variation of Wmax could be explained by the independent variables age, body mass, body fat, smoking habits, vital capacity, heart rate, and physical activity parameters. It is concluded that active involvement in endurance sports and/or the use of the bicycle for transport, contributed substantially to cardiovascular fitness in healthy, middle-aged men and women.

Key words

Maximal exercise, exercise test, maximal aerobic power, maximal heart rate, maximal systolic blood pressure, physical activity, reference values

Introduction

In medical practice progressive maximal exercise tests are often used for diagnostic purposes in patients with cardio-pulmonary complaints as well as for reasons of screening for potential risk factors in healthy persons. Maximal exercise testing for screening or for preventive purposes is often performed in persons who are physically active in their occupation or leisure time. This is certainly the case in sports-medical practice, where maximal exercise tests are also used to judge the aerobic power in relation to training activities.

Measurement of the maximal oxygen consumption (VO₂max) is the most commonly preferred index of performance in progressive maximal exercise testing. It is clear that measurements of oxygen consumption are limited by expense, time and technical assistance and therefore not attractive to use on a large scale. Several investigators introduced an equation to predict VO₂max based on treadmill endurance time (3) or maximal power output (Wmax) achieved during a standard cycle ergometer test (7,17). Storer et al. (17), who developed prediction equations of VO₂max from Wmax (cycle ergometry), suggested that VO₂max is more closely related to Wmax in cycle ergometry than to treadmill time till exhaustion. Wmax achieved during a progressive maximal cycle ergometer test therefore is an attractive alternative index of the cardiopulmonary functional capacity, when direct VO₂max measurement is not feasible. It has also been shown that the intra-individual variation of Wmax is lower than the intra-individual variation of VO₂max (11).

Reference values of progressive maximal exercise testing in middle-aged, active subjects, especially in women are scarce. Therefore, the purpose of this study was to obtain reference values of maximal power output during cycle ergometry (Wmax) in men and women older than 40 years and active in sport. The relation between maximal power output and variables such as age, anthropometric parameters, physical activity parameters, smoking habits, vital capacity and heart rate was studied as well.

Material and Methods

All subjects volunteered to participate in an experimental sports-medical examination. They were all over 40 years of age and had been active in sports for at least one hour per week over a period of more than 3 months in the year preceding the screening. The examinations took place at three Centers for Public Health where similar equipment and protocol

© Georg Thieme Verlag Stuttgart · New York
were used by three specially trained physicians. Throughout the study 48 volunteers were examined at all three locations for a reliability study of the measurements. A detailed medical and family history was taken in a standardized manner. The physician interviewed the subjects on age (year), alcohol consumption (yes/no), smoking habits (yes/no), medication and physical activity. Physical activity included occupational activity (yes/no), use of the bicycle for transport purposes (yes/no) and sport activities. The number of sports (one, two or more), type of sport, frequency (times/week) and duration (hours/week) of participation were recorded. A subject was classified as performing an endurance sport (yes/no) if he/she was active in any sport that uses large muscle groups, that can be maintained for a prolonged period of time and is rhythmical and aerobic in nature, like long distance running, jogging, cycling, ice-skating, or rowing.

Anthropometric measurements included height (cm), weight (kg) and body fat (%) estimated from the sum of 4 skinfolds (4). Body mass index was calculated from weight and height (kg/m²). Supine blood pressure was measured from the right upperarm by standard sphygmomanometry and supine heart rate was measured by palpation. The vital capacity (VC) was measured by automated equipment (Discom, Chest Corporation, Tokyo, Japan). To judge if there were any contraindications for the exercise test, information was obtained from medical history, physical examination and a 12-lead resting ECG in each subject. Criteria to exclude subjects from the exercise test were based on recommendations by the American College of Sports Medicine (1).

The exercise test was performed on an electrically braked cycle ergometer (Lode, the Netherlands) with the subject seated upright. The pedal frequency was kept between 60 and 80 rpm. Men started for 5 min at a power output of 100 W and women at 50 W as warming-up. Thereafter, power output was increased by 50 W/2.5 min until a heart rate between 140 and 150 beats/min was reached. Then the increment was 25 W/2.5 min until exhaustion. Maximal power output (Wmax) was the highest power output that could be maintained for 2.5 min.

If the final increment was not fully completed, Wmax was calculated with a correction for the completed time of that increment (5 watt per 30 seconds). In the third minute of recovery, a blood sample was drawn from a cubital vein for measurement of the plasma lactate concentration (PPLa). Heart rate was determined from a 3-lead (II, V1 and V5) ECG, the highest rate recorded was considered as maximal heart rate (HRmax). Tests of subjects who did not meet criteria for maximal effort were excluded. Criteria for maximal effort were a HRmax ≥ 220 minus age and/or PPLa ≥ 8 mmol/l for men and a HRmax ≥ 220 minus age and/or PPLa ≥ 5.5 mmol/l for women. Selection of these criteria was based on the finding that, when maximal heart rate was equal in men and women, a peak plasma lactate concentration of 8 mmol/l in men (which has been suggested as a criterion for maximal effort) corresponded with a concentration of 5.5 mmol/l in women. A considerable percentage of the men (88%) and the women (85%) reached these criteria. Tests of 2038 men and 898 women, not using cardiovascular medication, were analysed. In 1996 men and 826 women venous blood samples for the determination of the peak plasma lactate concentration (PPLa) were analysed. Samples were frozen and analysed later using one lactate analyzer (640 Lactate Analyzer, Roche). Analysis of the other samples was not possible because of technical problems. Maximal systolic blood pressure (SBPmax) was only recorded if the final work load lasted long enough and accurate measurement was possible. SBPmax data were obtained in 742 men and 306 women. The reliability study showed inter-center reliability coefficients of .95 for maximal power output, .51 for maximal systolic blood pressure and .76 for maximal heart rate.

Means and standard deviations of variables were calculated for men and women separately. Differences between groups were tested by Student's t-tests and Mann-Whitey U-tests. Differences between different age groups were tested by an analysis of variance. Correlation coefficients between Wmax and independent variables were calculated and scatter diagrams were inspected. Simple and multiple regression analyses were performed with Wmax as dependent variable. The decision on how many factors to retain in the final form of the regression model presented in Table 4 was made by using the all-possible subset method. That subset with the largest number of prognostic factors with regression coefficients significantly different from zero (p<0.001) was selected and considered to be the best-fitted model.

Results

Characteristics of study population

The anthropometric, physical activity and maximal exercise characteristics of the study population are shown in Table 1. Almost all differences between men and women are significant. Women are more physically active at work than men (32% versus 24%), mostly in housekeeping activities. Women also more often used the bicycle for transport than men (65% versus 46%). There was no difference between sexes in the number of sports performed and the frequency of sport activities. Men spent more hours in sport activities than women (4.3 ± 3.1 versus 3.6 ± 2.5 hours/week, p<0.001). Men more often performed endurance sports than women (63% versus 47%). These percentages were 41% and 27% respectively in subjects who were active in only one type of sport.

Maximal exercise

In Table 2, reference values for a number of variables measured during maximal cycle ergometer testing of the study population are presented in 5-year age groups for men and women. Maximal exercise variables, except for SBPmax, showed a significant decrease with increasing age. Sex differences in variables of maximal exercise as presented in the total study population (Table 1) were also present in different age groups (Table 2). Table 2 also shows that the age distribution of the subjects was skewed.

Factors influencing Wmax and HRmax

The regression equations of Wmax and HRmax with independent variables sex, age and height are summarized in Table 3. Weight did not exert a significant effect on age and height had been taken into account in stepwise regression. Of the variables measured, the single variable associated with the least variance in both sexes was the VC (1): Wmax = 23.3 × VC + 127.9 (SEE, 42.2; r, 0.41) in men and Wmax = 18.3 × VC + 91.0 (SEE, 25.9; r, 0.39) in women. In Table 4 the results of multiple regression procedures with Wmax as dependent variable and eight different independent variables are presented for men and women. For reasons of
Table 1 Characteristics of the study population (mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n = 2038)</td>
<td>(n = 888)</td>
<td></td>
</tr>
<tr>
<td>Age (year)</td>
<td>48.8 ± 6.1</td>
<td>47.5 ± 6.6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>77.1 ± 8.5</td>
<td>83.4 ± 7.6</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>175.7 ± 6.4</td>
<td>183.5 ± 6.0</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>23.5 ± 5.0</td>
<td>33.1 ± 5.0</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>25.2 ± 2.2</td>
<td>23.7 ± 2.6</td>
</tr>
<tr>
<td>Smokers (%)</td>
<td>26.2</td>
<td>18.9</td>
</tr>
<tr>
<td>Occupational activity (%)</td>
<td>23.9</td>
<td>32.3</td>
</tr>
<tr>
<td>Use of bicycles for transport (%)</td>
<td>48.0</td>
<td>65.0</td>
</tr>
</tbody>
</table>

Sport activity:

- number of sports: 1.9 ± 0.8 ns 2.0 ± 0.8
- frequency (times/week): 3.0 ± 1.9 ns 2.9 ± 1.9
- duration (hours/week): 4.3 ± 3.1 *** 3.6 ± 2.5
- endurance athletes (%): 62.9 *** 47.1
- vital capacity (%): 5.4 ± 0.8 *** 3.9 ± 0.6
- heart rate (beats/min): 62.6 ± 6.0 *** 67.1 ± 9.2
- blood pressure systolic (mmHg): 134.0 ± 13.7 *** 132.6 ± 16.1
- blood pressure diastolic (mmHg): 88.4 ± 8.3 *** 83.5 ± 8.2

Maximal exercise:

- Wmax (W): 254.3 ± 46.1 *** 181.7 ± 28.2
- Wmax/kg body weight (W/kg): 3.3 ± 0.6 *** 2.6 ± 0.5
- Wmax FFM1 (W/kg): 4.3 ± 0.8 *** 3.5 ± 0.6
- heart rate (beats/min): 175.6 ± 11.9 *** 171.6 ± 11.7
- blood pressure systolic (mmHg): 214.1 ± 20.5 *** 180.8 ± 18.5
- peak plasma lactate (mmol/l): 11.2 ± 2.6 *** 8.4 ± 2.7

1 FFM = Fat Free Mass

For equation applicable to both sexes male is coded 1, female is coded 0

Table 2 Reference values in maximal cycle ergometer testing; mean ± SD in 5-year age groups in male (M) and female (F).

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Sex</th>
<th>Number</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>Wmax (W)</th>
<th>Wmax/kg (W/kg)</th>
<th>HRmax (b/min)</th>
<th>SBPmax (mmHg)</th>
<th>PPLa (mmol/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-44</td>
<td>M</td>
<td>1057</td>
<td>77.5 ± 8.6</td>
<td>176.5 ± 8.5</td>
<td>283.8 ± 46.1</td>
<td>3.4 ± 0.6</td>
<td>178.2 ± 11.7</td>
<td>211.2 ± 19.2</td>
<td>11.5 ± 2.8</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>426</td>
<td>62.5 ± 7.5</td>
<td>164.5 ± 5.8</td>
<td>171.0 ± 27.1</td>
<td>2.8 ± 0.4</td>
<td>175.2 ± 10.6</td>
<td>186.8 ± 18.1</td>
<td>8.5 ± 2.4</td>
</tr>
<tr>
<td>45-49</td>
<td>M</td>
<td>530</td>
<td>77.2 ± 8.4</td>
<td>176.6 ± 5.9</td>
<td>253.8 ± 43.7</td>
<td>3.3 ± 0.6</td>
<td>175.8 ± 10.9</td>
<td>210.7 ± 20.7</td>
<td>11.4 ± 2.9</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>213</td>
<td>63.9 ± 7.8</td>
<td>163.6 ± 8.4</td>
<td>162.7 ± 24.9</td>
<td>2.6 ± 0.8</td>
<td>171.7 ± 10.1</td>
<td>186.8 ± 18.8</td>
<td>8.5 ± 2.6</td>
</tr>
<tr>
<td>50-54</td>
<td>M</td>
<td>242</td>
<td>76.5 ± 8.3</td>
<td>174.3 ± 6.3</td>
<td>242.5 ± 43.0</td>
<td>3.2 ± 0.4</td>
<td>171.1 ± 11.1</td>
<td>210.6 ± 19.7</td>
<td>10.2 ± 2.6</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>140</td>
<td>64.2 ± 7.4</td>
<td>163.0 ± 6.1</td>
<td>153.3 ± 25.9</td>
<td>2.3 ± 0.4</td>
<td>167.2 ± 11.9</td>
<td>196.1 ± 19.9</td>
<td>8.2 ± 2.5</td>
</tr>
<tr>
<td>55-59</td>
<td>M</td>
<td>128</td>
<td>76.3 ± 7.8</td>
<td>174.4 ± 5.9</td>
<td>232.6 ± 40.4</td>
<td>3.1 ± 0.6</td>
<td>169.3 ± 10.2</td>
<td>213.2 ± 22.5</td>
<td>9.9 ± 2.7</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>76</td>
<td>64.0 ± 7.7</td>
<td>161.4 ± 6.1</td>
<td>143.2 ± 20.8</td>
<td>2.3 ± 0.4</td>
<td>165.6 ± 11.1</td>
<td>195.6 ± 21.6</td>
<td>7.7 ± 2.5</td>
</tr>
<tr>
<td>60-64</td>
<td>M</td>
<td>57</td>
<td>74.0 ± 8.8</td>
<td>172.2 ± 7.1</td>
<td>206.5 ± 32.0</td>
<td>2.8 ± 0.4</td>
<td>165.6 ± 11.7</td>
<td>210.4 ± 32.6</td>
<td>9.9 ± 2.6</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>30</td>
<td>67.6 ± 7.1</td>
<td>161.8 ± 7.1</td>
<td>130.3 ± 23.7</td>
<td>1.6 ± 0.3</td>
<td>161.5 ± 10.8</td>
<td>186.5 ± 18.9</td>
<td>6.5 ± 1.4</td>
</tr>
<tr>
<td>65+</td>
<td>M</td>
<td>24</td>
<td>75.3 ± 7.8</td>
<td>172.0 ± 5.1</td>
<td>193.9 ± 36.3</td>
<td>2.6 ± 0.4</td>
<td>161.7 ± 12.7</td>
<td>228.8 ± 21.5</td>
<td>8.6 ± 3.3</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>12</td>
<td>61.3 ± 4.9</td>
<td>157.3 ± 7.7</td>
<td>117.6 ± 21.6</td>
<td>1.9 ± 0.4</td>
<td>159.9 ± 7.1</td>
<td>200.8 ± 26.9</td>
<td>6.1 ± 2.2</td>
</tr>
</tbody>
</table>

*p < 0.001, analysis of variance between age groups

Being active in endurance sports and the use of the bicycle contributed almost equally to Wmax in men (Fig. 1).

Table 3 Predictive equations for maximal power output (Wmax) and maximal heart rate (HRmax) with sex, height and age as independent variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sex</th>
<th>Height (cm)</th>
<th>Age (year)</th>
<th>Constant</th>
<th>SEE</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wmax (W)</td>
<td>M</td>
<td>2.2</td>
<td>-1.95</td>
<td>-39.5</td>
<td>41.7</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>1.3</td>
<td>-1.57</td>
<td>+32.7</td>
<td>24.8</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>M + F</td>
<td>65.3</td>
<td>2.0</td>
<td>-1.86</td>
<td>-67.9</td>
<td>38.2</td>
</tr>
<tr>
<td>HRmax (beats/min)</td>
<td>M</td>
<td>-0.90</td>
<td>+203.6</td>
<td>11.3</td>
<td>0.31</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>-0.85</td>
<td>+202.6</td>
<td>10.9</td>
<td>0.37</td>
<td></td>
</tr>
</tbody>
</table>

1 For equation applicable to both sexes male is coded 1, female is coded 0
r = correlation coefficient
SEE = standard error of estimate

In women, the use of the bicycle for transport had a more important influence on W\text{max} than endurance sports (Fig. 2). It appears from Table 4 that the frequency of sport activities made a small but significant contribution to W\text{max} in women, but not in men. Smoking habits were included in the regression model in men, but in women smoking habits did not contribute significantly.

**Table 4** Multiple regression models (regression coefficients (r.c.) and corresponding t-ratios) with W\text{max} as dependent variable in men (n = 1142) and women (n = 880). Units of independent variables as in Table 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r.c.</td>
<td>t-ratio</td>
</tr>
<tr>
<td>Constant</td>
<td>251.49</td>
<td>21.0</td>
</tr>
<tr>
<td>Age</td>
<td>-1.76</td>
<td>-13.4</td>
</tr>
<tr>
<td>Cycling</td>
<td>21.12</td>
<td>13.9</td>
</tr>
<tr>
<td>Endurance sport</td>
<td>23.55</td>
<td>14.5</td>
</tr>
<tr>
<td>Frequency sport</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Smoker</td>
<td>-15.40</td>
<td>-8.9</td>
</tr>
<tr>
<td>Heart rate</td>
<td>-1.27</td>
<td>-14.5</td>
</tr>
<tr>
<td>Vital capacity</td>
<td>11.24</td>
<td>10.0</td>
</tr>
<tr>
<td>Weight</td>
<td>1.32</td>
<td>11.4</td>
</tr>
<tr>
<td>Body fat</td>
<td>-0.76</td>
<td>-4.1</td>
</tr>
</tbody>
</table>

Multiple r  | 0.69 | 0.66 |
SEE          | 33.7 | 21.3 |

Users of the bicycle for transport (cycling), athletes active in an endurance type of sport (endurance sport) and smokers are coded 0 or 1 depending on a negative resp. positive reaction. All t-ratios are significant at 0.001 level.

**Discussion**

**Reference values in maximal exercise testing**

Relation with study population

This report presents reference values for maximal power output for progressive maximal aerobic exercise testing on a cycle ergometer in a healthy and active middle-aged population. The importance of cardiovascular fitness is pointed out by several investigators (2,5) who stated that a lower level of cardiovascular fitness is associated with a higher risk of death from coronary heart disease and cardiovascular disease in clinically healthy men, independent of conventional risk factors. Cardiovascular fitness in our study population was assessed by measurements of maximal aerobic power output on a cycle ergometer which is a good parameter for aerobic power (1,7,17).

As a result of promoting physical activity in order to gain higher fitness levels, exercise testing in active, older men and women is becoming more popular and so is the need for reference values. Accepting the idea that reference values should give information about desired levels of a certain tested functional variable, it is reasonable to select a group of physically fit subjects, active in sports, as a reference group in order to make a fair comparison if individuals are tested on this particular function.

**Maximal power output**

Jones et al. (7,8) and Nordenfelt et al. (14) found lower values of W\text{max} in similar age groups compared to results of Weeds (18) and the present study. Differences in selection criteria such as age and the level of physical activity are factors that may explain these findings. Jones et al. (7,8) studied a selection, although not randomly selected, comparable to the general population with an age range of 15 to 71 years.

**Fig. 1** W\text{max} and age in relation with physical activity in men according to the regression analysis in Table 4. All other predicting factors are held constant.

**Fig. 2** W\text{max} and age in relation with physical activity in women according to the regression analysis in Table 4. All other predicting factors are held constant.
The study population of Nordenfelt et al. (14) was a randomly selected group between 20 and 79 years. Therefore, it can be assumed that in these two studies there was no selection bias related to physical activity. Compared with mean values in similar age groups of men in the study of Weed (18), the men of the present study population reached slightly higher values of \( W_{\text{max}} \) in the age group of 40 to 44 year and slightly lower values in older age groups. Weed (18) studied healthy male employees working in the steel industry, with a relatively great percentage of volunteers who were also physically active in leisure time. His cycle ergometer tests were performed with a comparable protocol (30 W/3 min and starting at 90 W for 5 min) until exhaustion according to objective criteria (18). It is obvious that in studies on a relatively active population, and also using criteria for maximal effort, as was done in the present study and in the study of Weed (18), higher levels of \( W_{\text{max}} \) are to be expected. As can be concluded from above, the maximal power output in a study population is dependent on the selection criteria for this population. In our population the selection did not reveal significant differences in anthropometric and physical activity parameters between the subjects who met the criteria and those who were excluded.

Maximal systolic blood pressure

In groups of men of comparable age SBPmax values presented by Weed (18) were 20 to 30 mm Hg lower whereas values of \( W_{\text{max}} \) and HRmax were slightly higher than in the present study. The values measured in the present study are somewhat lower (5 to 10 mm Hg) than the values of SBPmax measured during a near maximal cycle ergometer test (>90% of the maximal predicted heart rate) in apparently healthy middle-aged Norwegian men (6). It is likely that technical measurement problems when the subjects become exhausted attributed to differences between values of maximal SBP of the present study and other studies (7,18). This can also explain the fair but not excellent inter-center reliability coefficients of SBPmax. However, a more physiological explanation cannot be excluded.

Prediction equations

In order to collect more information on the influence of different variables on the variation of \( W_{\text{max}} \), multiple regression analysis was performed. Age was an important independent factor influencing maximal power output. In the studies of Jones et al. (7,8) and Weed (18) the influence of body height on \( W_{\text{max}} \) was more pronounced than that of body weight, independent of age. Similar regression procedures revealed also better correlations of \( W_{\text{max}} \) with height than with weight in the population in this study. The correlation coefficients as presented in Table 3 were lower than those found by Jones et al. (7), who found a coefficient of 0.86 for \( W_{\text{max}} \) with sex, age, and height as independent variables, and 0.72 and 0.67 respectively in men and women for \( W_{\text{max}} \) with age and height as independent variables. These differences in correlations can be explained by differences in distributions of age, height and as mentioned before, physical activity.

Factors influencing \( W_{\text{max}} \)

Vital capacity

In the present study VC was the most powerful predictor of \( W_{\text{max}} \) in correlation analyses of single variables and the relationship was relatively unaffected by age and sex, which is in agreement with findings of Jones et al. (7). Jones concluded that, since the vital capacity is closely related to other size variables, it may represent a reliable predictor of maximal exercise capacity in subjects free from respiratory disease. The relationship between vital capacity and physical fitness variables may be an explanation for the finding of Kannel et al. (9), in the large prospective Framingham study, that VC was a predictive factor for coronary heart disease. Since, in practice, values of the vital capacity are not always available, other factors such as age and height, which show together comparable correlations with \( W_{\text{max}} \), are more useful.

Anthropometric parameters

The occurrence of other predicting variables in Table 4 are in agreement with findings in the literature on the relationships between single variables and maximal power output. Almost half of the variation in \( W_{\text{max}} \) can be predicted from these independent variables. The contribution made by these analyses lies in the weighing of different factors that influence performance. Weight became a more important predictor when vital capacity (related to height) was entered in the analysis. Independent of other anthropometric parameters, body fat was an explaining factor of \( W_{\text{max}} \). It is difficult to explain single contributions of physiological parameters in the total context of all explaining factors in the models in men and women.

Smoking habits

Smoking habit was no explaining factor in women. This may be due to the fact that not only fewer women were smokers but also that female smokers smoked significantly fewer cigarettes than male smokers (data not shown). The findings in men are in agreement with those of other authors (12,13,18), who all reported negative relationships between smoking habits and physical fitness variables (\( V_{\text{O2max}} \) or treadmill endurance time). Since the subjects were not allowed to smoke at least three hours before the exercise test, it can be assumed that cigarette smoking did not directly affect the test outcome.

Supine heart rate

The significant contribution of supine heart rate to the regression equations both in men and women was to be expected. The predicting value of heart rate seems more pronounced in men compared to women. Habitual training enables a person to achieve a certain cardiac output at rest, as well as during exercise, with a lower heart rate and a larger stroke volume. This improves the economy of the heart muscle as far as energy requirement and oxygen demand are concerned (1).

Physical activity parameters

Investigators (16,18) who classified physical activity in different classes ranging from sedentary to strenuous activities found an association between physical activity and
physical fitness. This association was not expected to be so powerful in our population because only subjects who were active in sports were allowed to participate in the study. Still it appears from Table 4 that in women the frequency of sport activities is an independent explaining factor, indicating that considerable variations exist in sport activities of women in this group. Frequency of sport activities showed better correlation with physical fitness variables than hours active in sport (data not shown). In women the contribution of using a bicycle for transport to the variation in maximal power output is greater than for example endurance activities in sport. Compared to men, the difference in contribution of types of physical activities can be explained by more intense use of the bicycle for transport and fewer intensive endurance activities of women in the study population. This may also explain the additional contribution of the frequency of sport activities in the models in women.

Type of sport activity

The impact of the type of physical activity on maximal power output was found to be more important. Higher levels of maximal power output were found in endurance athletes in both sexes. It has been shown that elite ball players, and especially those who played as team members, have lower maximal oxygen uptakes than elite endurance athletes (1). Higher levels of aerobic capacity in endurance athletes may be explained by higher initial levels of VO2max and Wmax by genetic endowment or by a strong hereditary component that influences the functional adaptability (10), resulting in a choice for endurance sports, or simply by more aerobic training.

In summary, the reported values of maximal power output, a suitable indicator of aerobic power, of this study population can be considered as normal standards of middle-aged men and women, in sports-medical practice. About half of the variation of maximal power output could be explained by the independent variables age, anthropometric parameters, smoking habits, vital capacity, heart rate and physical activity parameters. In healthy persons active in sport, physical activities not related to sports like use of the bicycle for transport contribute substantially to cardiovascular fitness. This contribution if more pronounced in women than in men.

References


Dr. A. M. P. M. Bovens
Centre for Public Health
P.O. Box 99
6160 AB Geleen
The Netherlands