Maximal heart rates and plasma lactate concentrations observed in middle-aged men and women during a maximal cycle ergometer test

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Summary. The purpose of this study was to investigate criteria for maximal effort in middle-aged men and women undertaking a maximal exercise test until they were exhausted if no measurements of oxygen uptake are made. A large group of 2164 men and 975 women, all active in sports and aged between 40 and 65 years, volunteered for a medical examination including a progressive exercise test to exhaustion on a cycle ergometer. In the 3rd min of recovery a venous blood sample was taken to determine the plasma lactate concentration ([lactic acid]p,3min). Lactate concentration and maximal heart rate (f_c,max) were lower in the women than in the men (P<0.001). Multiple regression analyses were performed to assess the contribution of sex to [lactic acid]p,3min, independent of age and forms. It was found that [lactic acid]p,3min was about 2.5 mmol·l⁻¹ lower in women than in men of the same age and f_c,max. In our population 88% of the men and 85% of the women met a combination of the following f_c,max and [lactic acid]p,3min criteria: f_c,max equal to or greater than 220 minus age·min⁻¹ and/or [lactic acid]p,3min equal to or greater than 8 mmol·l⁻¹ in the men and f_c,max equal to or greater than 220 minus age·min⁻¹ and/or [lactic acid]p,3min equal to or greater than 5.5 mmol·l⁻¹ in the women.

Key words: Lactate – Heart rate – Exercise tests – Sex difference – Maximal exercise

Introduction

In maximal exercise testing it is always difficult to judge whether a subject has really performed up to his or her true maximum. There are several more or less objective criteria that may be used to judge the level of exhaustion in progressive exercise testing. It has been generally accepted that maximal effort is confirmed by a levelling-off of the oxygen consumption with increasing power output (Åstrand and Rodahl 1986). Other parameters which have been used are respiratory exchange ratios above 1.00, 1.05 or 1.10, a respiratory equivalent above 30 or combinations of these and other criteria (Froberg and Pedersen 1984; Kuipers et al. 1985; Løllgen and Ulmer 1985; Saris et al. 1985).

If no gas analysis equipment is available the maximal heart rate and the peak blood lactate concentration have often been used. Maximal heart rate (f_c,max) has often been assumed to be 220 minus age (beats·min⁻¹) on average, with a standard deviation of 10 beats·min⁻¹ at a given age, for men as well as women. As a minimal criterion of maximal effort, therefore, 200 minus age [220 minus (age+2SD)] beats·min⁻¹ for f_c,max has been used (Åstrand and Rodahl 1986; Løllgen and Ulmer 1985). Astrand and Rodahl (1986) have suggested using a peak lactate concentration of 8 mmol·l⁻¹ or higher as a criterion for maximal effort. They did not mention the existence of a difference in peak lactate concentrations between men and women. However, Jacobs et al. (1983) have found significantly lower muscle lactate concentrations after maximal exercise in women than in men, suggesting that there may be sex differences in peak blood lactate concentration. Other authors have indeed found significantly different peak plasma lactate concentrations (Åstrand et al. 1973; Froberg and Pedersen 1984; Verstappen et al. 1989).

In this study the difference in plasma lactate concentration between men and women was quantified to set a criterion for maximal effort based on lactate concentration after maximal exercise in women similar to that used for men.

Methods

Subjects. All volunteers were aged 40 years or older and active in sports [participation rate of 4.0 (SD 3.4) h·week⁻¹]. They performed a progressive maximal exercise test, as part of a sports-medical examination. Tests of subjects using cardiovascular medication were excluded from the analysis. Only subjects with complete data regarding maximal heart rate (f_c,max), plasma lactate
between the sexes was found (Table 1). More-

to the men. Only 40°70 of the women reached a
beats.min -1 , P< 0.0011. The
[168.4 (SD 13.5) versus 173.0 (SD 13.6)
A small, but significant, difference in age (0.9 year,
was considered to be f¢ .... . In the 3rd min of recovery, a blood
plasma lactate concentration at 3rd min of recovery
concentration in the third minute of recovery (ln...min) and
and/or [la-
]p,3min equal to or greater than
220 minus age beats.min-1 and/or [la--
]p,3min -> 8 (men) or -> 5.5 (women) mmol·l-1; E, f¢,max -> 220 minus age
women mmol·l-1; definitions as in Tables 1 and 2. ■ Men; ■ women

Table 1. Characteristics and maximal exercise parameters of the
subjects

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 2164</td>
<td>n = 975</td>
</tr>
<tr>
<td>Age (year)</td>
<td>mean</td>
<td>mean</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>47.0</td>
<td>47.9</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.76</td>
<td>1.64</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>23.5</td>
<td>33.2</td>
</tr>
<tr>
<td>Wmax (W)</td>
<td>250.9</td>
<td>157.8</td>
</tr>
<tr>
<td>Wmax·kg -1 (W·kg -1)</td>
<td>3.3</td>
<td>2.5</td>
</tr>
<tr>
<td>f¢,max (beats·min -1)</td>
<td>173.0</td>
<td>168.4</td>
</tr>
</tbody>
</table>
| [la-
]p,3min (mmol·l -1) | 10.5 | 7.7 | 3.7*** |

** P<0.01 (Mann-Whitney U-test); *** P<0.001 (t-test)

Exercise test. The subjects were seated upright on an electrically braked cycle ergometer (Lode) with 3-lead (II, V1 and V5) electrocardiogram (ECG)-electrodes in place. The test was performed with a pedal frequency between 60 and 80 rpm, starting at a power output of 100 W for the men and 50 W for the women for 5 min. Thereafter, power output was increased by 50 W·2.5 min -1 until a heart rate between 140 and 150 beats·min -1 was reached. Then the increment was 25 W·2.5 min -1 until exhaustion. The Wmax was the highest power output that could be maintained for 2.5 min. If the final increment of power output could not be maintained for 2.5 min, Wmax was calculated with a correction for the completed time of that increment (5 W per 30 s). The test lasted between 12.5 and 15 min for the men and between 11 and 13.5 min for the women. Heart rate was determined from the ECG over the last 30 s of each exercise intensity, and the highest value recorded was considered to be f¢,max. In the 3rd min of recovery, a blood sample was drawn from a cubital vein for measurement of [la-
]p,3min (640 lactate analyzer, Roche) (Geyssaut et al. 1985).

Data analysis. Means and standard deviations of variables were calculated separately for the men and for the women. Differences between the men and the women were tested by two-sample Stu-
dent's t-tests, except for differences in age, which were tested by
Mann-Whitney u-tests because the distribution was not normal.
Correlation coefficients between sex, age, f¢,max and [la-
]p,3min were determined. Multiple linear regression analyses were used to evaluate the influence of the independent variables of sex, age and f¢,max on [la-
]p,3min.

Results

A small, but significant, difference in age (0.9 year, P<0.01) between the sexes was found (Table 1). Moreover, the women reached significantly lower f¢,max than the men [168.4 (SD 13.5) versus 173.0 (SD 13.6) beats·min -1, P<0.0011. The
[la-
]p,3min was 2.8 mmol·l-1 (P<0.001) lower in the women compared to the men. Only 40% of the women reached a

Discussion

If no gas analyses are performed in exercise testing, f¢,max and lactate have often been used as objective crite-
ria of maximal effort. In this study the influence of sex

Fig. 1. Percentages of population meeting different criteria of maximal effort based on f¢,max and [la-
]p,3min: A, f¢,max -> 200 minus age beats·min -1; B, f¢,max -> 220 minus age beats·min -1; C, [la-
]p,3min -> 8 mmol·l-1 (men), [la-
]p,3min -> 5.5 mmol·l -1 (women); D, f¢,max -> 200 minus age beats·min -1 and/or [la-
]p,3min -> 8 (men) or -> 5.5 (women) mmol·l-1; E, f¢,max -> 220 minus age beats·min -1 and/or [la-
]p,3min -> 8 (men) or -> 5.5 (women) mmol·l-1; definitions as in Tables 1 and 2. ■ Men; ■ women