Relation of speed of a mile run, maximum energy cost of running, and maximum oxygen consumption: a field study

Sunil Kumar Das and Abhijit Dutta

Exercise, Sports and Cardiorespiratory Physiology Laboratory, Department of Physiology, University Colleges of Science and Technology, Calcutta, India

Objective—To compare the maximum energy cost of running (MECR) estimated from the speed of a mile run and the maximum oxygen consumption (VO\textsubscript{max}) with a field step test.

Methods—MECR was defined as the maximum VO\textsubscript{2}, derived from the equation VO\textsubscript{2} = 5.3 mph + 3.9 (ml \cdot min\textsuperscript{-1} \cdot kg\textsuperscript{-1}), when the subject performs a maximal, exhausting run and attains maximum speed. The equation is based on a straight line relation between speed and VO\textsubscript{2}. In this study MECR was obtained from a mile run and was compared with VO\textsubscript{max} by extrapolation using a step test. Both tests were performed in the field.

Results and Conclusions—The variation in the MECR with VO\textsubscript{max} was within ±10%. It therefore appears that the speed of a mile run is a good criterion of VO\textsubscript{max} or estimated MECR for the measurement of physical fitness, and for the selection, recruitment, and assignment of an individual in field sports.

Methods

Eighty three subjects ranging in age from 13 to 17 years volunteered for the present study. Most of the subjects were physically active and usually participated in school games and sports. They were selected from a school situated in a suburban area of Calcutta. A 400 metre grass track was marked out in a football ground and the subjects were given an initial trial of both a step test and a mile run to familiarize them with the nature of the experiment several days before the actual day of estimation.

VO\textsubscript{max} was determined by extrapolation using the step test as described earlier. The step test was done on a 40 cm step, with step rate varying from 15 to 30 up/down steps per minute in accordance with a metronome. Step frequencies were 15, 17.5, 20, 22.5, 25, 27.5, or 30 per min and the VO\textsubscript{2} values (ml \cdot min\textsuperscript{-1} \cdot kg\textsuperscript{-1}) obtained at these rates were 22.5, 24.5, 27.5, 32.5, 35.5, and 38.5 ml \cdot min\textsuperscript{-1} \cdot kg\textsuperscript{-1}, respectively, from the nomogram of Margaria et al. Exercise heart rate was recorded using an electronic stop watch as the time taken for 5 beats, which was then converted to beats \cdot min\textsuperscript{-1}. This heart rate was taken immediately after the end of each 5 min step, when it is almost equal to the exercise heart rate. At the end of four or five step test sessions, when heart rate reached 150–160 beats \cdot min\textsuperscript{-1}, all the subjects rested for half an hour. After resting the subjects ran on the track and the timing of a mile run was recorded with an electronic stop watch. The subjects were motivated to exert maximum effort in the run and showed excellent cooperation. From the timing of the mile run, their speed was calculated in mph. MECR was calculated from the speed.

VO\textsubscript{max} was predicted by plotting the several pairs of heart rate and VO\textsubscript{2} values as a straight line and extrapolating to maximum heart rate (MHR), which on average was 205 beats \cdot min\textsuperscript{-1} at a mean age of 15 years (MHR = 220 — age in years). The VO\textsubscript{2} corresponding to 205 beats \cdot min\textsuperscript{-1} is said to be the VO\textsubscript{max} (extrapolated). No individual age-predicted maximum heart rate was considered. This study was done in the winter season between 7 am and 9 am when the temperature varied between 20 and 25 °C, relative humidity was 30–65 %, and barometric pressure was 760–766 mm Hg.

Address for correspondence: Dr Sumil Kumar Das, Department of Physiology, University Colleges of Science and Technology, 92 Acharya Prafulla Chandra Road, Calcutta 700009, India

Keywords: mile run; energy cost of running; running speed; maximum oxygen consumption; step test; field study

We estimate the maximum energy cost of running (MECR) from the straight line relation between speed (in mph) and its energy cost (as VO\textsubscript{2} in ml \cdot min\textsuperscript{-1} \cdot kg\textsuperscript{-1}), that is, the greater the speed, the greater is the VO\textsubscript{2}; thus maximum speed is equivalent to maximum energy cost. MECR may therefore be defined as the VO\textsubscript{2} at which speed is the maximum that can be sustained for at least a mile run. Speed expressed in mph is linear with VO\textsubscript{2} (in ml \cdot min\textsuperscript{-1} \cdot kg\textsuperscript{-1}) at 0% treadmill inclination, and the latter may be derived by the point slope method as VO\textsubscript{2} = 5.3 mph - 3.9. Thus MECR = 5.3 mph + 3.9 when the speed is maximum. VO\textsubscript{max} is defined as maximum VO\textsubscript{2} (ml \cdot min\textsuperscript{-1} \cdot kg\textsuperscript{-1}) obtained by work to exhaustion and is also known as the aerobic capacity of the maximum physical work capacity, which is measured by extrapolation in the field with the step test protocol.

The aim of the present study was to compare the MECR estimated from the speed of a mile run with VO\textsubscript{max} extrapolated from step testing in the field.
Energy cost of running and VO\textsubscript{2\text{max}}: S. Kumar and A. Dutta

Table 1. Physical characteristics, speed, maximum energy cost of running (MECR), and VO\textsubscript{2\text{max}}. Values are means (SD)

<table>
<thead>
<tr>
<th>n</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Speed (mph)</th>
<th>MECR* (ml·min(^{-1}·kg)^{-1})</th>
<th>VO\textsubscript{2\text{max}}* (ml·min(^{-1}·kg)^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>83</td>
<td>15 (1.7)</td>
<td>163 (6.1)</td>
<td>48.2 (7.3)</td>
<td>8.4 (1)</td>
<td>48.4 (5.6)</td>
<td>48.0 (6.2)</td>
</tr>
</tbody>
</table>

\*MECR = 5.3 mph + 3.9 (ml·min\(^{-1}·kg\)^{-1}).

![Graph showing the relation between VO\textsubscript{2\text{max}} and MECR](image)

Figure 1.

Statistical analysis of the data was performed by a statistical calculator for determination of product moment correlation (r) and mean (SD).

Results

The results are shown in Table 1 and Figure 1. Table 1 shows mean and SD of the physical characteristics, MECR, and VO\textsubscript{2\text{max}}. Figure 1 shows the relation between MECR and VO\textsubscript{2\text{max}} with the line of best fit and the 10% deviation. The product moment correlation was highly significant (r = 0.923, P < 0.001). There was no significant difference between MECR and VO\textsubscript{2\text{max}} when compared using a t test.

Discussion

The distance run in 12 minutes or time of 1.5 mile run have been shown to be highly correlated with VO\textsubscript{2\text{max}}\* and various studies had been carried out to establish the relation between distance run and VO\textsubscript{2\text{max}}\* in the present study VO\textsubscript{2\text{max}} and MECR were almost identical and the correlation did not vary by more than ±10%. We have therefore established that MECR calculated from the speed of a mile run is almost same as VO\textsubscript{2\text{max}}. Thus this study simplifies the field test determination of VO\textsubscript{2\text{max}} from the speed of a mile run. This will be of value for coaches, who need to know the maximum speed of athletes under training or of competitors in various sports and games in which endurance is a good criterion for selection, training, and improvement. The greater the cardiorespiratory fitness, the greater is the speed of a mile run. The speed of a mile run is a good measure of physical fitness and it may be expressed as MECR. Extrapolated VO\textsubscript{2\text{max}} was almost same when determined from treadmill exercise, and this has been verified recently in eight young male and female subjects (Das SK, Bhattacharya G, Mahapatra S, unpublished data).

References
