Analysis of Bicycle Ergometer

Pramar P. Bakane¹, K.S. Zakiuddin², P.B. Khope³

¹Student (M.TECH-MED) Department Of Mechanical Engineering, Priyadarshini College of Engineering, Nagpur, Maharashtra, India.
²Department Of Mechanical Engineering, Priyadarshini College Of Engineering, Nagpur. Maharashtra, India.
³Department Of Mechanical Engineering, Priyadarshini College Of Engineering, Nagpur. Maharashtra, India.

Abstract

This research work, “Analysis of Bicycle Ergometer”, was employed to know human energy during exercise bicycle ergometer by analyzing mechanical energy, biological energy and various parameters when a body undergoes a particular work. This information can be used as a guide for increasing fitness and building muscular endurance. The results obtained from both arm ergometer & bicycle ergometer were compared.

Keywords: Bicycle ergometer, VO2max, AD instruments, indirect calorimetry, open-circuit spirometry method.

1. Introduction

Bicycle ergometer is equipment in human factor engineering for measuring muscle work. In friction-type bicycle ergometer, the subject is made to work against friction created on ergometer flywheel by a brake belt mechanism. As the subject pedals the bicycle, the flywheel rotates against the brake belt around its rim. The brake belt is tensioned by the tension-control knob. With the heart beat type, the bike is pedaled at a constant speed of 18-20 rpm for about 3 minutes. A stop watch is used to measure the time and a stethoscope for the measurement of the heartbeat. The stethoscope is connected to the ear of the subject (human) to measure the time for rotation of the pedal after each set-point. The readings for the 10 heart beats and energy lost are measured.

Following are objectives of the present work-
1. To know human energy during exercise bicycle ergometer.

2. To know that whether leg driven is efficient in human powered machines.

The most important feature of the bicycle ergometer is the ability to set a constant external work rate that is maintained independent of pedaling rhythm; many of the cycling related investigations in the laboratory have involved a manipulation of pedaling rhythms and the result of such research would be much more difficult to interpret if the subjects are working at different power output for each rhythm. The advantage of the bicycle ergometer is the ability to have subjects use their own bicycle frame for testing and also enables the subject to work at a constant work load or power output which is independent of rhythm. This implies that the rhythm and the rear wheel resistance are inversely proportional and this provides a valuable tool for conducting experiments at constant power output laboratories.

The underlying theory is based on the principle that for a rotating flywheel bicycle the difference between the weights added and the spring balance reading when cycling gives the frictional force “F” on the flywheel:

\[ W = F_s = F_r \theta \]

Where \( S = r \theta \), \( r \) = radius of flywheel, \( \theta \) = Angular displacement in radians.

To calibrate a subject on a bicycle ergometer, the subject’s cycle at a given temperature and relative humidity for 3-5mins at different load levels (5N to 40N) from which the work done is calculated is required. The heart rate of the subject is measured after each load level cycling.

2. Materials and Methods

2.1 The Apparatus

The apparatus include the following: bicycle ergometer, stethoscope, stop watch, AD-instruments gas analyzer with a power lab data acquisition system.

- The study encompassed 13 untrained college students (8 male + 5 females)
- Examined group characteristic:
  - Age – 20±5 years.
  - Body height – 140±15 cm.
  - Body weight – 60±15 kg.

In this project, we have adopted the Open-circuit spirometry method.

2.2 Experimental Procedures-

Step 1: Identify the tension-control knob, the bicycle pedal, etc. Notice that the instrument pedal is compact and small and can measure and display multiple variables such as speed, distance, time etc. The reddish-brown knob on the instrument allows users to change the variables (parameters) on display by the instrument. The knob also allows the user to erase or zero the displayed values. Notice also that the tension-control knob has 7 x 360 of freedom.
Step 2: Loosen the bike pedal by turning the tension-control knob anticlockwise until limit is reached. Note that clockwise moment tightens the bike pedal while anticlockwise moment loosens it. Mark a datum line on both the retaining and stationary parts of the knob to allow the determination of 360° rotation during the course of the experiment.

Step 3: At this set point, the subjects are allowed to pedal the bike at speed say 50-60 rpm for about 3-4 minutes for warm-up, maintaining the constant speed using the stop watch and the speedometer provided maintaining the heart beats in the range of 80-90 bpm.

Step 4: Note and record the values of VO2, CO2, Respiratory Quotient, heart beats for every 10 seconds with the help of AD instrument.

3. Data Presentation

Table 1: Measurements obtained for bicycle ergometer.

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Sex</th>
<th>Time (Sec)</th>
<th>Age (Years)</th>
<th>Height (Cm)</th>
<th>Weight (Kg)</th>
<th>VO2 In 3 Minute (L/Min)</th>
<th>Predicted VO2 In 3 Minute (L/Min)</th>
<th>Heart Rate (Bpm)</th>
<th>Work (Kcal)</th>
<th>Input Energy (Kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>180.00</td>
<td>22.00</td>
<td>146.00</td>
<td>52.00</td>
<td>2.424</td>
<td>2.200</td>
<td>120.000</td>
<td>2.11</td>
<td>12.16</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>180.00</td>
<td>24.00</td>
<td>140.00</td>
<td>50.00</td>
<td>1.626</td>
<td>1.500</td>
<td>97.000</td>
<td>2.11</td>
<td>8.128</td>
</tr>
<tr>
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<td>146.00</td>
<td>52.00</td>
<td>2.343</td>
<td>1.900</td>
<td>110.000</td>
<td>2.11</td>
<td>11.71</td>
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<tr>
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<td>22.00</td>
<td>142.00</td>
<td>49.00</td>
<td>1.305</td>
<td>1.500</td>
<td>95.000</td>
<td>2.11</td>
<td>6.527</td>
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<td>151.00</td>
<td>65.00</td>
<td>2.255</td>
<td>2.000</td>
<td>113.000</td>
<td>2.11</td>
<td>11.27</td>
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<tr>
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<td>M</td>
<td>180.00</td>
<td>22.00</td>
<td>145.00</td>
<td>55.00</td>
<td>1.305</td>
<td>1.500</td>
<td>90.000</td>
<td>2.11</td>
<td>6.524</td>
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<td>146.00</td>
<td>54.00</td>
<td>1.626</td>
<td>1.900</td>
<td>102.000</td>
<td>2.11</td>
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<tr>
<td>9</td>
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<td>138.00</td>
<td>49.00</td>
<td>0.475</td>
<td>0.900</td>
<td>70.000</td>
<td>2.11</td>
<td>2.376</td>
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<tr>
<td>10</td>
<td>F</td>
<td>180.00</td>
<td>22.00</td>
<td>146.00</td>
<td>52.00</td>
<td>0.473</td>
<td>0.900</td>
<td>70.000</td>
<td>2.11</td>
<td>2.364</td>
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</table>
Table 2: Comparison between Arm & Bicycle ergometer power.

<table>
<thead>
<tr>
<th>Bicycle Ergometer Power (Watt)</th>
<th>Efficiency %</th>
<th>Input Energy (Kcal) For Arm Ergometer</th>
<th>Arm Ergometer Power (Watt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>848.257</td>
<td>17.346</td>
<td>0.694</td>
<td>48.379</td>
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<tr>
<td>566.806</td>
<td>26.000</td>
<td>0.762</td>
<td>53.165</td>
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<td>816.876</td>
<td>18.000</td>
<td>0.665</td>
<td>46.398</td>
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<td>455.160</td>
<td>32.300</td>
<td>0.873</td>
<td>60.898</td>
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<td>786.332</td>
<td>18.763</td>
<td>0.859</td>
<td>59.930</td>
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<td>454.951</td>
<td>32.347</td>
<td>1.081</td>
<td>75.397</td>
</tr>
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<td>26.000</td>
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<td>165.690</td>
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<td>454.812</td>
<td>32.300</td>
<td>0.495</td>
<td>34.500</td>
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</tbody>
</table>

Figure 1: Graph showing various measurable quantities.
4. Data Analysis and Application

Applying basic work equation is
\[ \text{Work} = \text{force} \times \text{distance} \]
\[ \text{Work (in Kg*m)} = \text{resistance force (in kg)} \times \left( \frac{\text{m/rev}}{\text{rev/min}} \times \text{min} \right) \text{(in m)} \]

Open-circuit spirometry method determines VO₂ by measuring amount of O₂ consumed.

1 liter of oxygen =5 kcal=21KJ of energy.

Energy (Kcal/min) =Net VO₂ (L/min) x caloric equivalent (Kcal/L).

Input Energy = VO₂ L/min x 5 kcal/L O₂.

The person’s overall or gross mechanical efficiency during exercise is 15%-27%.

Power output = (F x d) / time = 2.5 kg x (6 m/rev) x (60 rev/min) = 900 kgm/min.

This power output is equivalent to 2.1 kcal/min (900 kgm x 0.0023 kcal/kgm).

Power input = (1.91 LO₂/min) x (5 kcal/L O₂) = 9.6 kcal/min.

Efficiency = (Pout / Pin) x 100 = (2.1/9.6) x 100 = 22%.

Note what this efficiency value of 22% means: Of the total energy turned over in metabolism (i.e.9.6 kcal/min), only 22% (i.e.2.1 kcal/min) was transformed to useful external work, in this case turning the flywheel of the bicycle. The rest of the 78% energy was wasted in terms of doing work on the bike. Another way of looking at this is to do the equivalent of 2.1 kcal/min of external work on the bicycle ergometer; the exerciser had to turn over a total of 9.6 kcal / min in metabolism more than four times as much energy.

5. Conclusion

This study shows that there is a relationship between the rate of energy expenditure and heartbeat rate. The higher the energy expenditure, the higher the heartbeat recorded. It therefore could be said that the energy expenditure is directly proportional to the rate of heartbeat. There is a minimum tension required in the bicycle ergometer with the help of tension knob for its time scale to correspond with that of the stop watch. There is always a critical time for each tension for this synchronism to obtain when riding at a constant speed.

From the results presented in this work we can conclude that:

1. In normal, untrained, co-operative subjects the V0₂ max can be obtained directly using tests on a cycle ergometer at constant or progressively increasing power.
2. The VO₂ values obtained during this study do not differ with respect to the predicted values.
3. In the progressive tests a delay in VO₂ was seen. This explains why the V0₂ was the same in the various tests where there were important and significant differences in maximal powers.
4. The VO₂ values, in absolute terms, were significantly lower for the women.
5. The power calculated from bicycle ergometer is more comparatively arm ergometer. Thus we can say that leg driven is efficient in human powered machines.

References


