Project 2 -- Oxygen Consumption, Fatigue, and Performance in Exercise[1]

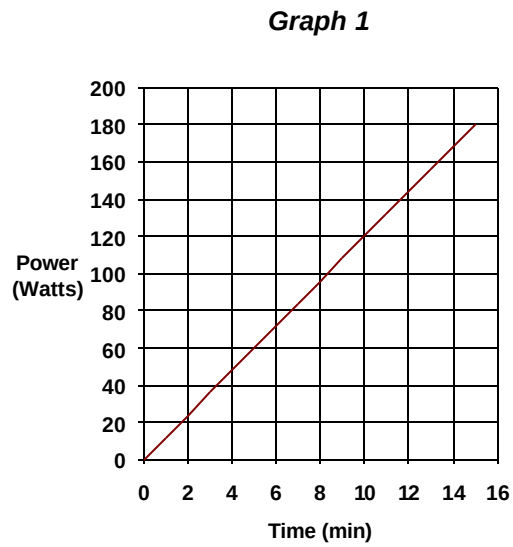
or

"How to Improve Your CPFT Score"

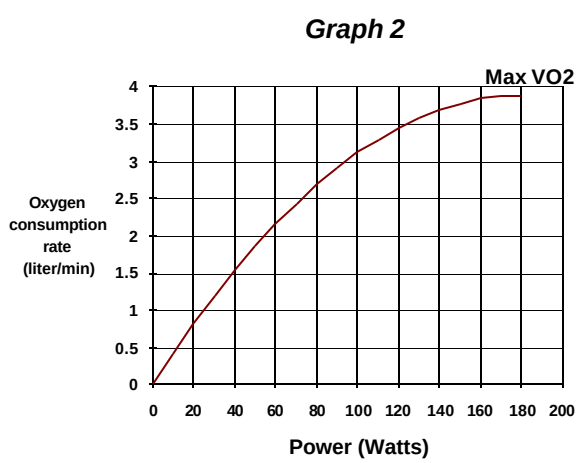
The ability to sustain a high level of physical activity without undue fatigue depends on two factors: (1) oxygen delivery and (2) the capacity of specific muscle cells to generate the cellular fuel adenosine triphosphate, or ATP (McArdle 223). The formation of ATP to be used for muscular energy begins when glucose molecules undergo a chemical transformation in a process known as glycolysis. When the body is subject to light exercise, even of long duration, the ATP generated through glycolysis is produced with an efficient, ***slow glycolysis***. End products from the glycolysis are easily removed from the muscles at about the same rate that they are produced and there is little accumulation. Under conditions of strenuous exercise, the demand for ATP can exceed the cell's ability to produce it efficiently. When this happens, the muscle cells resort to a ***fast glycolysis*** which releases end products faster than they can be removed. The result is an accumulation of end products in the muscle fibers and blood stream. One of these end products is lactic acid. The fast glycolysis **buys time** for the muscles by rapidly producing ATP even if the oxygen supply is inadequate or the exercise too strenuous to produce ATP efficiently through slow glycolysis (McArdle 125). However, using fast glycolysis to meet muscular energy demands is only a temporary situation; the accumulation of lactic acid in the blood stream contributes to muscle fatigue. Effective aerobic conditioning is one way to enhance the capacity of specific muscle cells to generate ATP efficiently and thus delay muscle fatigue. (Crowder)

The capacity for O_2 (oxygen) consumption is a fundamental measure of maximal aerobic power (McArdle 211). The highest value of oxygen consumption during a controlled fitness test is called max VO_2 (i.e., Value of O_2) and is measured in units of liters/minute. No one can operate for long at their max VO_2 level, but there is a significant connection between max VO_2 and the formation of lactic acid in the blood: for people at all levels of fitness who engage in strenuous exercise, there is a certain percentage of max VO_2 where production of blood lactic acid shows a near exponential increase. This point is called the **Onset of Blood Lactic Acid (OBLA)** (McArdle 126). It is the combination of these two important factors that influence endurance performance: (1) the max VO_2 (i.e., the maximal capacity to consume oxygen), and (2) the point where OBLA begins (i.e., the point where lactic acid production exceeds its removal.) These points are shown on *Graphs 2* and *3* below.

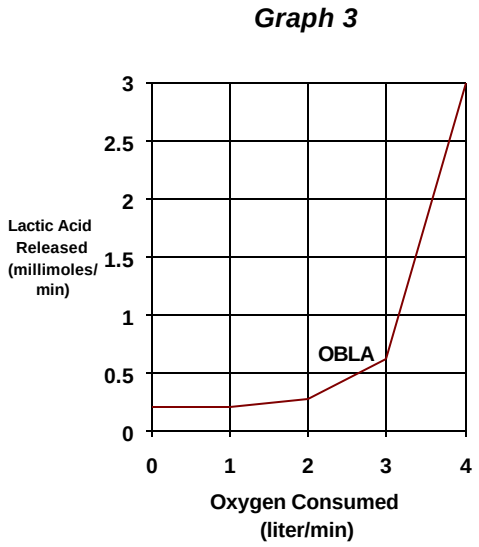
Graph 1: Power expended during the exercise is a function of time. This graph shows a typical laboratory treadmill test. Initially, the treadmill is horizontal and moving at an easy pace. Over time the treadmill is gradually inclined and the runner must provide more and more power to stay on the treadmill. The speed of the treadmill belt is also gradually increased.[2]



Graph 2: The rate of oxygen consumption during an exercise is a function of power expended. Here we see that when power expended is low, then the O_2 consumption rate is also low. As the treadmill test requires a greater expenditure of power, the O_2 consumption rate increases up to a maximum point, the max VO_2. The test is concluded when the runner reaches max VO_2 and can no longer stay on the treadmill.



Graph 3: This graph shows that the release of lactic acid into the blood stream is a function of the O_2 consumption rate. When the O_2 consumption rate is low then lactic acid is slowly released (and subsequently removed). When OBLA begins, the rate of lactic acid release into the blood increases dramatically.



Requirement 1

Compute the total O_2 consumed during the stress test. This will involve several steps.

a. Conjecture functions for *Graph 1* and *Graph 2* on your student data sheet. Turn this requirement in to your instructor on 7 March 1994. (Your instructor will help you reach a class consensus after you have turned in the requirement.)

b. Compose (make a composite function of) the two functions so that you have O_2 consumption rate as a function of time. Plot your function of O_2 consumption rate as a function of time.

c. Compute the total oxygen consumed during this 15 minute treadmill test.

In Requirement 1, we approached the problem rather qualitatively by trying to fit an analytical expression to the curves. We now want to be more accurate, so we will work with the numerical data that was measured during the treadmill test. This data was used to generate graphs 1 and 2 on your student data sheet. Now we will use this numerical data to compute total oxygen consumed during the treadmill test.

Requirement 2

a. Given the following data tables, produce a table of *composite data* for O_2 consumed vs. Time (Table 3). Your instructor will give you data for tables 1 and 2 below.

b. Use this new table to find total O_2 consumed. (Hint: use numerical integration.)

Tabular data from our treadmill test:

Table 1

Time (min)	Power (Watts)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

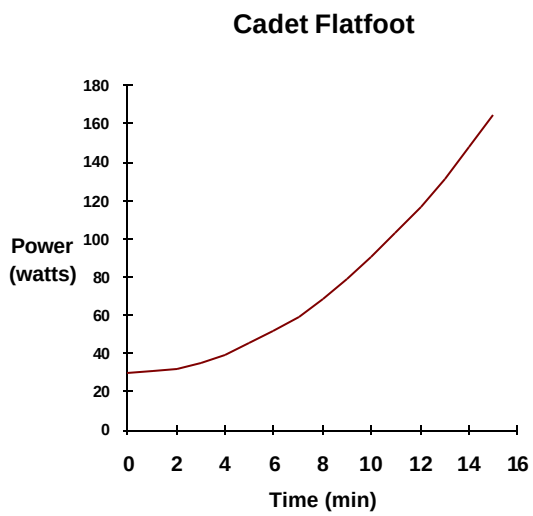
Table 2

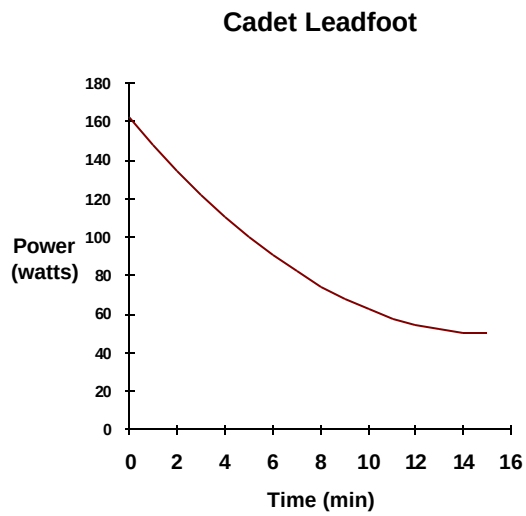
Power (Watts)	O_2 Consumed (liters/min)
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	
110	
120	
130	
140	
150	
160	
170	
180	
190	
200	
210	
220	
230	
240	
250	

Table 3

Time (min)	O_2 Consumed (liters/min)

Cadets Flatfoot and Leadfoot have been training together for the CPFT two mile run and have similar levels of conditioning. They do differ, however, in their race strategy for the actual two mile run event. Cadet Flatfoot likes to start off slowly and then reach a peak effort near the end of the event. Cadet Leadfoot follows a different strategy. He likes to start off the event with a burst of peak energy and then slowly decrease his effort over time as he becomes fatigued. These two strategies are represented graphically below.





Requirement 3

Determine the total O_2 consumed for each of the two strategies. Which strategy consumes the most O_2? Assume that the O_2 vs. Power data (Table 2) from Requirement 2 is valid for this requirement as well. Can you predict which cadet will have the best two mile run time? (Hint: You may want to generate a couple of new Power vs. Time tables by using the graphs given above.)

Requirement 4

In light of requirements 1 - 3, write a short essay describing how you might use the Lactic Acid graph (#3), along with the Power and Oxygen graphs (#1 and #2), to find the total lactic acid which accumulated during an exercise.

NOTES

[1]Dr. Todd Crowder, DPE, helped me compose the description of the physiological processes. He also gave me assistance in obtaining reasonable data to support this project.

[2]The graphs in this project were produced using Microsoft Graph (a part of Word for Windows).

BIBLIOGRAPHY

Crowder, Todd A., Ph.D., Director of Sports Medicine, Department of Physical Education, USMA. Telephone interview.

McArdle, William D., Frank I. Katch, and Victor L. Katch. Exercise Physiology. Malvern, PA: Lea and Febiger, 1991.