Comparative Vertebrate Physiology 2006

ENDURANCE EXERCISE SIMULATION (*web*-HUMAN 6.1)

(short & long write-up versions)

Although we may tend to anthropocentrically think otherwise, endurance exercise is not an activity unique to the human athlete alone. Indeed, eons before the first marathon runner, the problem of how to design a mammal that could, by sustained distance running, wear down a prey item, was successfully solved many times. Animals that hunt in packs (wolves, wild dogs, etc.) all have body physiology adjusted to run down, over long periods of time, weaker prey items (e.g. young or ill caribou). In fact, the two basic mammalian hunting strategies (short fast bursts of speed- the "cats" & long, slow sustained wearing down- the "dogs") have their direct analogs in two types of human running events, the sprint and the marathon.

Recall (SN ch. 1-4) that it is largely the responsibility of two systems, the <u>cardiovascular</u> and the <u>respiratory</u>, to insure adequate <u>O2 flow</u> to the working tissues. Indeed, adjustments are made in all groups of vertebrates (fish<--->mammals & birds) (SN Table 3.3) as the demand for O2 delivery rises. An ultimate goal of the physiology of the organism during endurance exercise is to supply oxygen to the working muscles at a rate sufficient to keep pace with the aerobic O_2 needs of the muscles.

In this experiment, we will have the subject exercise at three levels of intensity (light, moderate and severe). The resulting cardio-respiratory data will enable us to investigate two underlying questions:

1) [Part A] How well are the cardiovascular and respiratory systems of the organism able to supply the needed oxygen and

2) [Part B] What limits an organism's (in *web*-HUMAN, a person's) exercise endurance? That is, what factor(s) of the cardiopulmonary system is (are) the limiting factor(s), the weak link(s)? Which components first fail in the task of providing oxygen at a sufficient rate to meet aerobic muscular demands.

The *web*-HUMAN computer model simulates exercise by specifying exercise as oxygen utilization above resting (basal metabolic) levels. For example, oxygen (**EXER**) use of 2.0 L/min. corresponds to moderate exercise while O2 use of 3.0 L/min. constitutes more severe exercise. Also note that exercise is terminated by the model (i.e. the model quits), even if exercise duration (**XERMIN**) is set to a very large non-limiting amount of time (its default value is only 10 min.), whenever the total oxygen debt (**O2DEBT**) exceeds a total of 10 Liters.*

*Note: With *web*-HUMAN 6.1expanded on screen **Help**, it is now possible to learn on your own or check on 1) how to carry out a procedure (e.g. exercise) and 2) the definitions of variables you are using. Consult the last page for a quick summary of how to use the new Help section tools.

INSTRUCTIONS

Part A - Basic Response of the Cardio-respiratory System to Various Levels of Exercise
(may be run as an interactive class demonstration)

I. Initial Setup

Pick experiment number 1 & Run the subject for 1 hour [1H] with 1 hour between printouts. Use the View Output* pulldown menus to set up Column headings as follows:

Time/Day	UNITS
Arterial Oxygen Content (O2A)	____________
Cardiac output (COL)	____________
Oxygen debt (O2DEBT)	____________
Skeletal muscle blood flow(liters) (MFLOL)	____________
Ventilation (VENT)	____________
Exercise (EXER)	____________

*note- The version of HUMAN you are working in may have experiment numbers with TABLES more conveniently preset for your specific purposes on that run. This may allow you to avoid resetting TABLES each time. Check with your instructor. [For this lab, try the Experiment (E) No. 12].

II. Getting Baseline (non-exercising) values (may be run as an interactive class demonstration)

Establish baseline values for these variables by computing (Go) for 60 minutes with printout intervals of 5 minutes. By circling appropriate printout values record the times and the *initial* and the *final* values for each of the variables [In all work in *web*-HUMAN, you are responsible for taking down your own data for later analysis. Any "checkup data sheets" are intended only for our use in checking and are not data sheets nor are they meant to indicate what data you should be taking down].

III. Exercise at Low & Moderate Levels (may be run as an interactive class demonstration)

Now have the subject exercise at a low and moderate levels for as long as s/he is able. In *web*-HUMAN, the level of exercise is controlled by the variable **EXER**, which specifies the level of exercise in O2 usage above the basal level (i.e. rate of O2 use during exercise). Data from one these runs must be included in the HUMAN "checkup" for this lab (see below).

Set the exercise duration (**XERMIN**) parameter for some very large time (such as 100 minutes) This will allow exercise to proceed until some critical, limiting physiological value has been exceeded. Set EXER = 1.0 L/min. (light exercise) and then on a second run (after reinitializing i.e. Start Over) to 2.0 L/min. (moderate exercise). Compute and record data from the screen as before. Note also how long the subject was able to exercise in each case. Try Your 'Patient's Chart' under Obtain Help, Extra Data or Charts for a report of the exercise time. Again, be certain to clean the model out (Start Over') between runs by reinitializing.

IV. Complete the HUMAN "checkup" and hand it in **(<= Not required for short lab)**

On a separate, attached sheet, you will find a "checkup" form to fill out. This form has space for

a) Starting and final "resting condition" values (Part A, section II, "baseline values" above) and

b) Exercise at low or moderate levels (Part B, section III above) including exercise cessation time for moderate level exercise.

☞ Hand these forms if/as specified at the beginning of the lab

The purpose of the "checkup" is to verify that you can indeed perform all the operations you need in order to gather the data for the lab . These forms are needed by the end of the day so that by that time, you (and the instructor) will know if there is any difficulty. We can then take 'corrective' action early on.

V. Exercise at severe levels

I. Gathering Data

Start over by initializing again, reset Tables as before, and run the simulation for severe exercise (EXER = 3.0; remember to set XERMIN high). Record data as before. HOWEVER, this time after determining the time to exercise cessation, rerun a newly initialized model *for only that amount of time* (at the severe exercise level). This will allow you to use the Obtain Help, Extra Data, or Charts option to view the Charts of the various physiological systems *at the point*(= at the exact time) of exercise cessation. From the 'Choose one' pulldown menu, pick the systems you are interested in viewing. Look at as many system charts as you find informative.

Some of things you should be asking (as you view the charts) include:

1) what is happening to acid-base balance during anaerobic work (check lactate, PCO2, etc.)

1) how efficiently are the lungs exchanging gases (how are the blood arterial and venous PO2 & PCO2 values, pH, anaerobic indicators such as lactate, etc.)

2) how do the vascular system reflex centers respond to the muscle's increased need for blood flow (e.g. what fraction of CO is being sent to the muscles, how are regional flows shifted, etc.)?

Part B INCREASING ENDURANCE **(<==done independently)**

Which part of the cardiopulmonary system is the limiting factor in supplying oxygen to the exercising muscles (that is, why does the model run up an O2DEBT)? Is it due to an insufficient respiratory O_2 intake rate or to an insufficient circulatory O_2 transport rate? Which of these two legs of the O_2 transport system gives in first and fails to meet the needs of the aerobic muscles?

To answer this question, try to increase the subject's tolerance (time to 10 L debt) during moderate exercise (EXER=2.0) in two ways. First, have him/her breathe 100% oxygen while exercising. This removes as much as possible any respiratory restraint. Then, restoring the inhaled O2 to its normal value, instead increase the model's basic heart strength (i.e. simulate a cardiac muscle training effect). This 'conditions' the CV system & tends to remove the circulatory restraint. Whichever of these maneuvers works best (gives the longer increase in exercise time) indicates that that particular system was the most limiting one originally.

To breathe 100% O2, set the fractional concentration of O2 in the atmosphere (**FO2AT**) to 1.0 (this may be varied between 0.0 <-> 1.0; it is, of course, normally 0.21). Remember to initialize ('Start over') and reset the View Output column headers, substituting **O2V** for EXER (you already know how EXER will behave, when it will turn off, etc.) before you start. Record data as before.

To increase basic heart strength (normally = 1.0) you must set the values of right heart strength (**RHSB**) *and* left heart strength (**LHSB**) to higher (yet equal) values. A recommended value is 1.25. (What would happen if you raise the strength of only one side of the heart?) Use the same tables as in the 100% O2 section above.

Note: One way to set up an experiment that requires changing 3 variables is to first change two (e.g. EXER & XERMIN) then run for 0 min. with 0 min. between printouts, then change the third and finally run the experiment itself.

☞ The Lab Writeup (short version)

☞ Factors Determining Endurance Time (Part B above - INCREASING ENDURANCE)

required 1) Which maneuver, the 100% O2 or the heart conditioning, increased endurance time more? Which system is then normally the limiting one? Select data from this section and graph it (one plot only) in a way that supports your conclusion. [If you wish to enter *web*-HUMAN data into Excel and have forgotten how to do so, click on Help and find the Graphing *web*-HUMAN Data in Excel link.]

extra credit 2) Ultimately, O2 flow to the muscles must be adequate in order to support aerobic exercise and prevent anaerobiasis & lactate buildup. Think about how to *calculate*** O2 flow or O2 flow to the muscles (ml/min. of O2). You have enough data in your tables to do it [hint: review the lectures on O2 flow, cardiac output & the Fick method]. Under which condition is O2 flow to the muscles highest?

** Not to be derived from Patient Charts.

Lab Writeup Checklist: (Short write-up)

Your writeup should include the following:

1) A data graph and supporting *very* brief analysis (1 page MAXIMUM-10 point type) showing which system, cardiac or respiratory, is the limiting one in endurance exercise.

2) This write-up is due at the beginning of lab next week (or at the end of this lab period if announced).

3) The O2 Flow analysis above is for extra credit and optional.

Comparative Vertebrate Physiology - 2005 NAME ____________________

HUMAN "checkup" - Exercise

(for short write-up fill in only section III. & IV.)

I. Resting Condition (Part A)

Day/Time ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

II. Moderate Intensity Exercise (Part A)

Day/Time ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

________ ________ ________ ________ ________ ________ ________

III. Time to exercise cessation ________

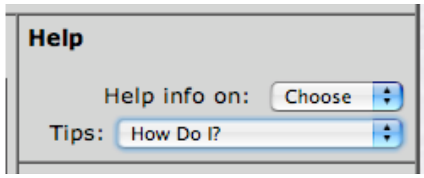
IV. Values at exercise cessation taken in Part B (increasing endurance)

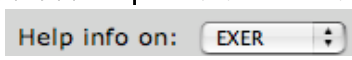
Variable	Value	Units
O2A =	____________	____________
O2V =	____________	____________
MUSFLO=	____________	____________

Quick summary- Using web-HUMAN's (new) on-line Help features

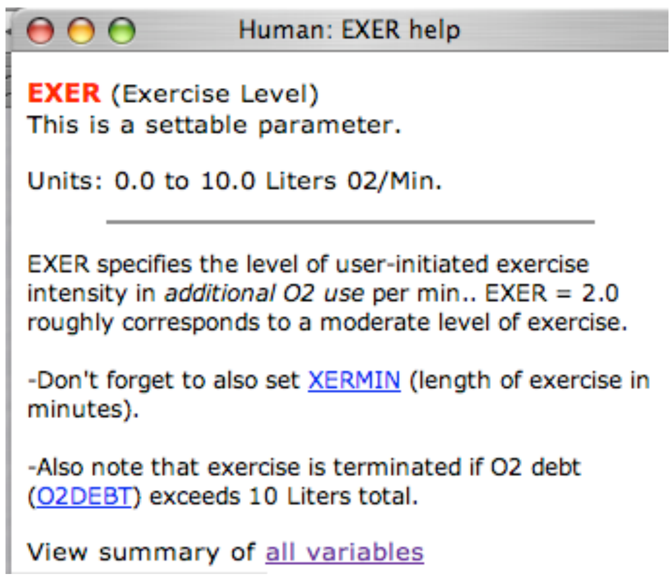
Note well: Make certain your popup blocker is OFF before using the functions below

1) Find the **Help** section on the screen right. Notice that it allows you to a) look up information on a variable (Help Info on: <Choose>) and 2) look up how to run a procedure (Tips: <How Do I?>)



2) To check a variable, select Help Info on: <Choose> with your mouse & roll down to the variable of interest. e.g. 

A window pops open with information on that variable & links to related variables (see below).



3) To learn how to run a procedure (e.g. exercise, infusion, etc.), mouse down to your procedure under Tips: <How Do I?> and a window will open detailing how to run the procedure.