

EXERCISE TESTING LABORATORY #2

ESTIMATION OF MAXIMAL OXYGEN UPTAKE (VO_2MAX) AND AEROBIC FITNESS

Introduction

Aerobic tests measure aerobic power, a term that is often used synonymously with cardiovascular endurance. Aerobic power is of primary importance in performing exercise that continues beyond 3 min. Thus, most aerobic tests do not require short explosive bouts of exercise, but usually require submaximal bouts of exercise varying in duration. For example, some tests may conclude in 3 min, whereas some may take upwards of 30 min.

The importance of aerobic fitness is accentuated by the reported association of low cardiovascular (aerobic) endurance fitness and increased coronary heart disease risk factors. The importance of cardiovascular endurance for the maintenance of health is its inclusion as one of the 5 factors of physical fitness.

The best indicator of aerobic fitness is the assessment of maximal oxygen uptake (VO_2max). Maximal oxygen uptake is the maximum amount of oxygen a person's body can utilize. The more aerobically fit an individual is, the greater the amount of oxygen their body can utilize. The most accurate means to measure VO_2max is through the use of a graded exercise test in a laboratory. During this test, the subject exercises, usually walking/running or cycling, and the intensity is gradually increased until the subject can no longer continue. During the exercise test, the subject wears a mouthpiece and noseclip and the expired gases are continuously collected and analyzed by a metabolic measurement cart to determine oxygen uptake. A demonstration of the laboratory determination of VO_2max will be provided in a subsequent laboratory.

Because of the expensive equipment needed to measure VO_2max in the laboratory, many field tests have been developed to estimate VO_2max . Most of the tests are submaximal and require inexpensive equipment that is readily available in many settings. Some tests, such as the 1.0 mile run, the 1.5 mile/12 minute run, and the Rockport Walk Test require only a stopwatch and/or a measurement of HR to estimate VO_2max and/or aerobic fitness level. The benefits of these tests are that they are inexpensive to administer, they may be administered in large groups, and they are appropriate for individuals of a wide fitness and age range.

The maximum HR varies substantially among different people of the same age, however. One standard deviation is ± 12 bpm, which means that two-thirds of the population varies an average of plus or minus 12 heart beats from the average. Thus, submaximal exercise tests that use an extrapolation to maximum HR may result in substantial error in estimating VO_2max .

There are many different types of submaximal exercise tests. These tests can utilize a treadmill, cycle ergometer, or bench step. The YMCA Bike Test and the Astrand Cycling Test are two other submaximal exercise tests that are often used to estimate VO_2max . These tests require that the subject exercise at varying intensities with HR being measured at each intensity. Because of the linear relationship between HR, oxygen uptake, and exercise intensity, VO_2max may be estimated from such tests. Again, these tests are easy to administer and do not require expensive equipment beyond that of a cycle ergometer such as the Monarch Bike.

The use of submaximal exercise tests to estimate VO_2max makes three assumptions:

1. That a linear relationship exists between HR, oxygen uptake, and exercise workload.
2. That the maximum HR at a given age is uniform.

3. That the mechanical efficiency (oxygen uptake at a given workload) is the same for everyone

These assumptions are not entirely accurate, however, and can result in an error in estimating VO_{2max} of 10 to 20%. In many submaximal exercise tests, HR at submaximal workloads are plotted, then extrapolated to an estimated maximum HR level, and then further extrapolated to an average oxygen consumption. These extrapolations can result in substantial error. The maximum HR is the fastest HR that can be measured when one is brought to total exhaustion during a graded exercise test. A formula has been developed to represent the average maximum HR in humans:

$$\text{Max HR} = 220 - \text{Age}$$

The purpose of this laboratory is to familiarize you with the different protocols involved in the estimation of VO_{2max} . We will concentrate on the submaximal treadmill protocols and the YMCA and Astrand Cycling Test.

Using a Submaximal Treadmill Protocol to Estimate VO_{2max}

In general, the principle of using a submaximal treadmill protocol to estimate VO_{2max} is the same as is highlighted in the introduction. There are a variety of protocols you can use. We will concentrate on the Modified-Bruce, the Bruce, and the Balke protocols. Regardless of which protocol you use, the test should continue until the subject achieves a HR of approximately 85% of the age-predicted maximal HR. The specific procedures are stated below:

Using the Balke Protocol

Stage	Time (min)	Speed (mph)	Grade (%)	METS
I	0-2	3.0	0	3.2
II	2-4	3.0	2.5	4.3
III	4-6	3.0	5	5.4
IV	6-8	3.0	7.5	6.4
V	8-10	3.0	10	7.4
VI	10-12	3.0	12.5	8.5
VII	12-14	3.0	15	9.5
VIII	14-16	3.0	17.5	10.5
IX	16-18	3.0	20	11.6
X	18-20	3.0	22.5	12.6
XI	20-22	3.0	25	13.6

1. Begin the protocol and collect HR, BP, and RPE during the last 30 seconds of each state and record the data.
2. Terminate the test when the HR reaches 85% of the age-predicted maximal HR.
3. To calculate, estimated VO_{2max} :
 - a. Make a graph plotting METS on the x-axis and HR on the y-axis.
 - b. A line is then drawn through the HR points from 7.5% grade to the final workrate.
 - c. The line is then extended to the person's estimated maximal HR.
 - d. A vertical line is dropped from the point where the plotted line meets the person's estimated maximal HR to the x-axis to estimate the maximum METS that the subject would have achieved.
 - e. Lastly, to calculate estimated VO_{2max} (ml/kg/min), multiply the estimated maximal METS by 3.5.

Using the Bruce Protocol

Stage	Time (min)	Speed (mph)	Grade (%)	METS
I	0-3	1.7	10	4.6
II	3-6	2.5	12	7.1
III	6-9	3.4	14	10.2
IV	9-12	4.2	16	13.5
V	12-15	5	18	17.3
VI	15-18	5.5	20	20.4
VII	18-21	6	22	23.8

To estimate $VO_2\text{max}$ (ml/kg/min), use the same procedures listed for the Balke Protocol, except, instead of beginning at the 7.5% grade point, begin extending the plotted line where it becomes linear.

Using the Modified Bruce Protocol

Stage	Time (min)	Speed (mph)	Grade (%)	METS
0	0-3	1.7	0	2.3
½	3-6	1.7	5	3.5
I	6-9	1.7	10	4.6
II	9-12	2.5	12	7.1
III	12-15	3.4	14	10.2
IV	15-18	4.2	16	13.5
V	18-21	5	18	17.3
VI	21-24	5.5	20	20.4
VII	24-27	6	22	23.8

To estimate $VO_2\text{max}$ (ml/kg/min), use the same procedures listed for the Balke Protocol, except, instead of beginning at the 7.5% grade point, begin extending the plotted line where it becomes linear.

Example

Name: _____ Age: 37 Estimated HRmax: 183 85% HRmax: 155

Test type: Balke Standard

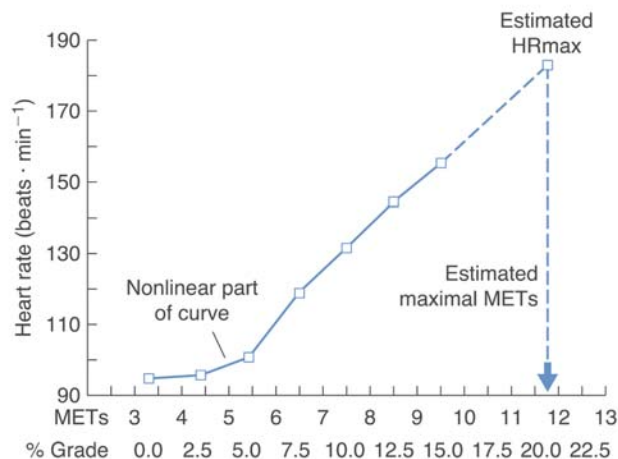
Ht: _____

Wt: _____

Sex: Male

Speed: 3 mph

% grade	Time (min)	Heart rate
0	1	
	2	94
2.5	3	
	4	95
5	5	
	6	100
7.5	7	
	8	118
10	9	
	10	131
12.5	11	
	12	143
15	13	
	14	155



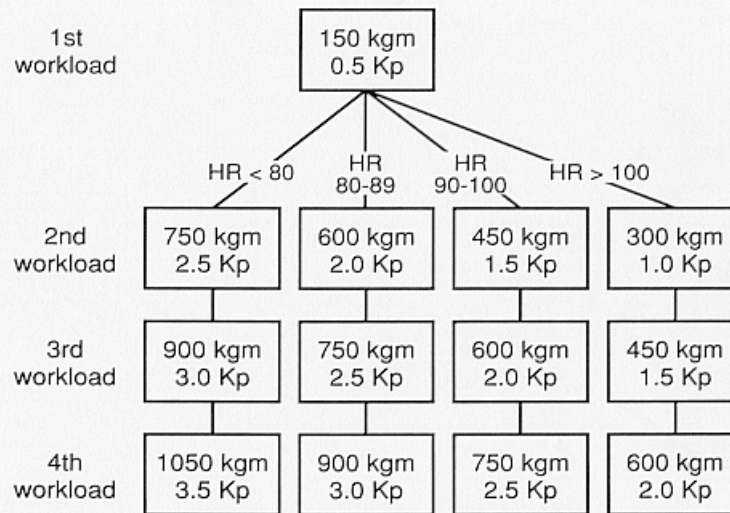
Protocols for the YMCA Submaximal Bicycle Test

- For the YMCA test, set the metronome at 100 beats per minute, for a rate of 50 rpm (one beat for each foot down). Let the person being tested get used to the cadence, warming up for about 3 to 5 minutes. Make sure to adjust the seat height to the correct level.
- Next, set the workload, using Figure 4.10. The initial workload is set at $150 \text{ kg} \cdot \text{m} \cdot \text{min}^{-1}$.

The person cycles at the first workload for 3 minutes with the heart rate being taken during the last 15-30 seconds of the second and third minute of the stage. HR can be taken using a Polar HR monitor or palpated for 10 seconds (and then multiplied by 6). If the two heart rates are not within 6 beats per minute, then the subject should continue cycling at the workload for an additional 1 minute at which time heart rate should be measured again. The objective is to get a steady state heart rate at this particular workload. Also, measure blood pressure and RPE at the end of each stage.

- Check Figure 4.10 to decide on the next workload setting. Workloads are adjusted on the basis of heart rate response. The same guidelines used to measure HR, BP, and RPE during the initial stage are used for each subsequent stage.
- Regularly check the workload setting on the cycle ergometer during each workload period. As the friction belt gets hot, the workload creeps upward, so continual readjustment during the early stages is necessary.
- Throughout the test, watch for exertional intolerance or other signs of undue fatigue or unusual response.
- The objective of the YMCA submaximal bicycle test is to obtain two heart rates between 110 bpm and the heart corresponding to 85% of the age-predicted maximal HR. There is a linear relationship between heart rate and workload between these two rates for most people. When the heart rate is less than 110, many external stimuli can affect the rate (talking, laughter, nervousness, etc.). However, once the heart rate climbs between 110 bpm and 85% of the age-predicted maximal HR, external stimuli should no longer affect the rate, and there is a linear relationship. If the heart rate climbs above 85% of the age-predicted maximal HR, the relationship becomes curvilinear. So the objective of this test is to obtain two heart rates between 110 bpm and 85% of the age-predicted maximal HR (steady state) at two consecutive workloads, to establish linearity between heart rate and workload for the person being tested.
- To establish the line, two points are needed. It is important that the heart rates taken be true steady state values. To ensure this, it is better to let participants cycle beyond 3 minutes, especially during the second workload (the heart rate takes longer to plateau when the workload is harder).
- Once the test is completed, the two steady-state heart rates should be plotted against the respective workload in Figure 4.12. A straight line is drawn through the two points and extended to that participant's predicted maximal heart rate ($220 - \text{age}$). The point at which the diagonal line intersects the horizontal predicted maximal heart rate line represents the maximal working capacity for that participant. A perpendicular line should be dropped from this point to the baseline where the maximal physical workload capacity can be read in $\text{kg} \cdot \text{m} \cdot \text{min}^{-1}$.
- The maximal physical workload capacity in $\text{kg} \cdot \text{m} \cdot \text{min}^{-1}$ can then be used to predict a person's maximum oxygen uptake. These values are listed at the bottom of the graph. Use the norms in Tables 42 and 44 for interpretation. Remember that these results are predictions or estimates, not direct measurements, and are thus open to error (but usually within 15 percent of the actual value).

Guide to Setting Workloads on Bicycle Ergometer



Directions:

1. Set the first workload at 150 kgm/min (0.5 Kp).
2. If the HR in the third min is
 - less than (<) 80, set the second load at 750 kgm (2.5 Kp);
 - 80 to 89, set the second load at 600 kgm (2.0 Kp);
 - 90 to 100, set the second load at 450 kgm (1.5 Kp);
 - greater than (>) 100, set the second load at 300 kgm (1.0 Kp).
3. Set the third and fourth (if required) loads according to the loads in the columns below the second loads.

Figure 4.10 Guide to setting workloads for males on the YMCA's submaximal bicycle ergometer test. Source: Reprinted from Y's Way to Physical Fitness (3rd ed.) with permission of the YMCA of the U.S.A., 101 N. Wacker Drive, Chicago, IL 60606.

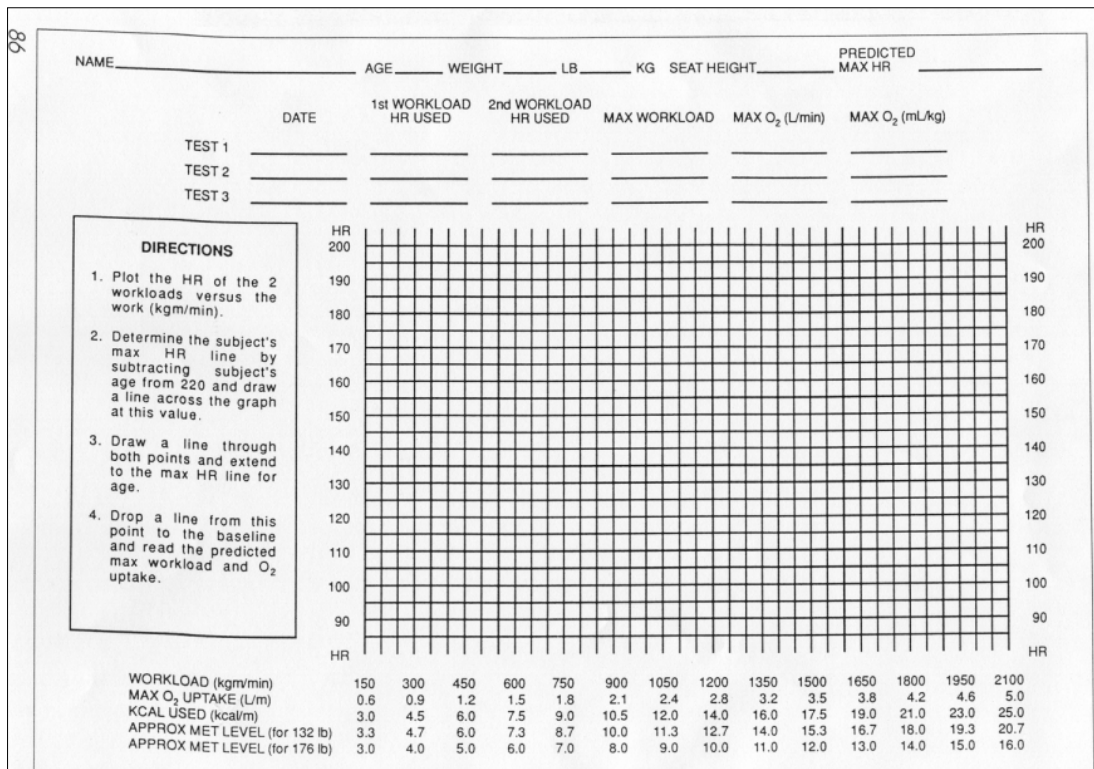


Figure 4.12 Graph for determining $\dot{V}O_{2max}$ from submaximal heart rates obtained during the YMCA's submaximal bicycle test. Source: Reprinted from Y's Way to Physical Fitness (3rd ed.), with permission of the YMCA of the U.S.A., 101 N. Wacker Drive, Chicago, IL 60606.

Protocols for the Astrand Cycling Test

- Start the metronome setting it at 100 beats per minute which is equal to 50 RPM.
- Ask the participant to begin cycling at the proper cadence using the metronome as an aid.
- Once the subject has achieved the proper cadence, increase the power level to the prescribed settings:
 - Males-unconditioned: 300 or 600 kg · m · min⁻¹ (50 or 100 Watts)
 - Males-conditioned: 600 or 900 kg · m · min⁻¹ (100 or 150 Watts)
 - Females-unconditioned: 300 or 450 kg · m · min⁻¹ (50 or 75 Watts)
 - Females-conditioned: 450 or 600 kg · m · min⁻¹ (75 or 100 Watts)
- Determine the HR at 3:00 (2:30-3:00). The target HR is between 125 and 170 bpm. If the HR is within this zone, continue cycling for an additional 3 minutes. Again, check the HR between 5:30 and 6:00 minutes.
- If the HR is not within this range, adjust the workload according to Table 3 or Figure 6. Column 3 (force; kg) gives the appropriate changes to the resistance of the bike based on the HR. Have the subject continue cycling at this new workload for an additional 3 minutes. Check the HR at 4:00 minutes and again at 6:00. If a steady state HR has not been achieved, the subject should continue exercising another minute until a steady-state HR is achieved.
- After the 6th minute of exercise (or when the test is over if additional time was necessary), decrease the resistance of the bike to 0.5 kp and allow the subject to cool down.
- Determine the predicted VO₂max using the nomogram provided (Figure 5-1) or Table 5.8 (Howley Book, p. 89). Use the final steady state HR and the final workload to estimate VO₂max using the nomogram or table.
- Multiply the VO₂max value by the correct age correction factor factor (p. 74 ACSM guidelines or p. 90 Howley book) to calculate the final VO₂max value.
- Table 6 provides norm values for the Astrand Cycling Test.

A. Raise Power Level by:		Heart Rate	Force	
kg·m·min ⁻¹	W	b·min ⁻¹	kg	N
300–450	50–75	if HR is <110	1.0–1.5	10–15
150–300	25–50	if HR is 110–129	0.5–1.0	5–10
≤150	≤25	if HR is 130–139	≤0.5	≤5
B. Lower Power Level by:		Heart Rate	Force	
kg·m·min ⁻¹	W	b·min ⁻¹	kg	N
150–300	25–50	if HR is 160	0.5–1.0	10
≤150	≤25	if HR is 150–159	≤0.5	≤5

Note: ^aSubtract (if A) or add (if B) one-half beat per minute for each year above or below 30 years of age, respectively.

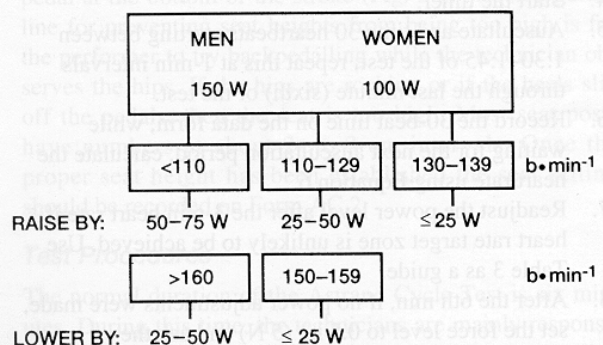


Figure 6 Schematic of power adjustments after the third minute (2:30–3:00) of the Astrand Cycle Test. Also adjust for age by subtracting or adding one-half b·min⁻¹ for each year above or below 30 years of age, respectively.

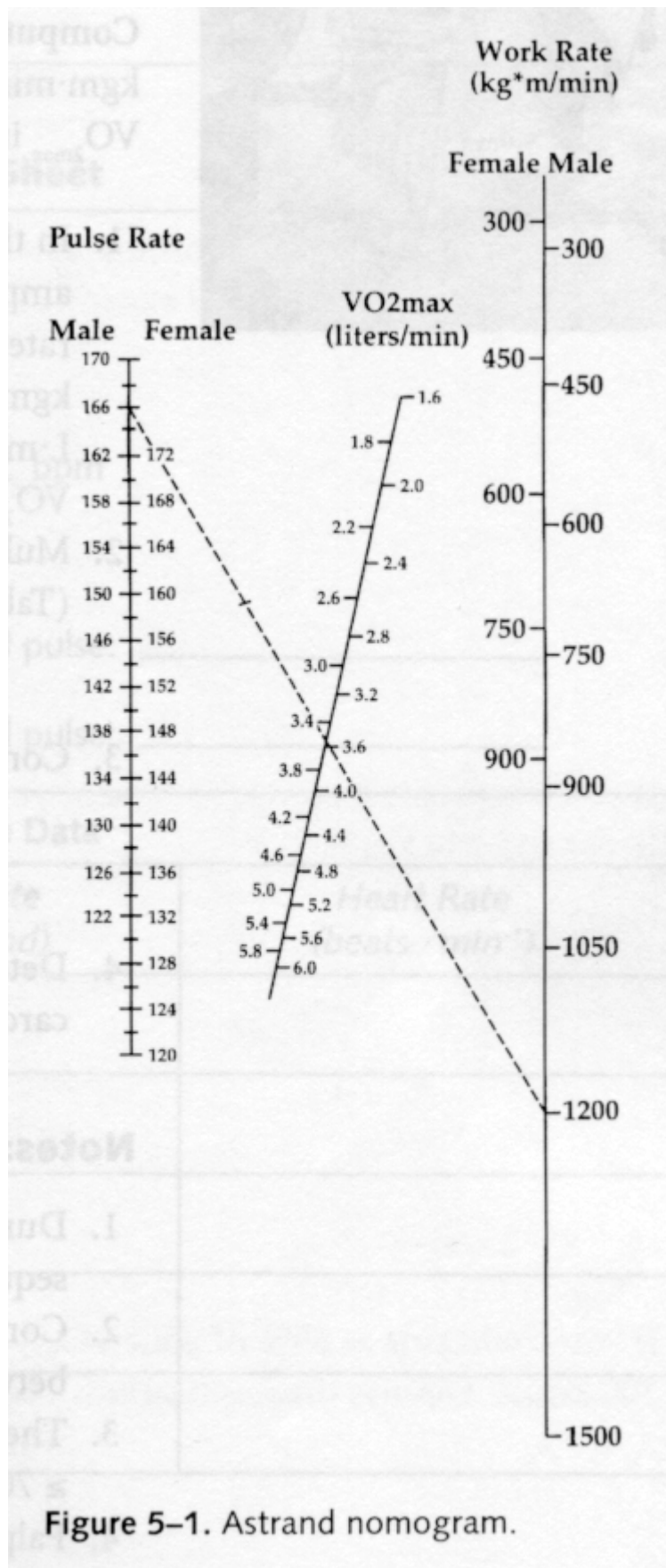


Figure 5-1. Astrand nomogram.

Table 6 Norms for Evaluating Astrand Cycle Test Performance

Age	Very High (VH)	Aerobic Fitness Categories				Fair (F)	Low (L)
		High (H)	Good (G)	Average (Ave)			
Maximal Oxygen Consumption (mL·kg ⁻¹ ·min ⁻¹)							
Men							
20-29	>61	53-61	43-52	34-42	25-33	<25	
30-39	>57	49-57	39-48	31-38	23-30	<23	
40-49	>53	45-53	36-44	27-35	20-26	<20	
50-59	>49	43-49	34-42	25-33	18-24	<18	
60-69	>45	41-45	31-40	23-30	16-22	<16	
Women							
20-29	>57	49-57	38-48	31-37	24-30	<24	
30-39	>53	45-53	34-44	28-33	20-27	<20	
40-49	>50	42-50	31-41	24-30	17-23	<17	
50-59	>42	38-42	28-37	21-27	15-20	<15	
60-69	>39	35-39	24-34	18-23	13-17	<13	

Source: Preventive Medicine Center, Palo Alto, CA; National Athletic Health Institute, Inglewood, CA.

Name: _____

EXERCISE TESTING LABORATORY #2

DATA COLLECTION

Protocols

1. Each student will complete both the YMCA Bike Test and the Astrand Cycling Test utilizing the protocols listed in the laboratory. Have all subjects complete the YMCA test before progressing to the Astrand test. This will allow for a proper cool-down and the returning of HR to resting level before completing the second test.
2. Record all data in the space provided.
3. Utilizing the extra sheets given, determine the estimated VO_2 max for both tests

Data

Subject Name: _____ Bodyweight: _____ kg Age: _____ Estimated max HR: _____

YMCA Bike Test

Workload 1: Workload: 150 kgm HR: _____

Workload 2 Workload: _____ HR: _____

Workload 3: Workload: _____ HR: _____

Workload 4: Workload: _____ HR: _____

Predicted maximal oxygen uptake: _____ LO_2 /min _____ mlO_2 /kg/min

Astrand Cycling Test

Data at 3:00 minutes: Workload: _____ HR: _____

Data at 6:00 minutes: Workload: _____ HR: _____

Predicted maximal oxygen uptake: _____ LO_2 /min _____ mlO_2 /kg/min

Note: To convert from LO_2 /min to mlO_2 /kg/min

1. *Multiply the LO_2 /min value by 1000 and then divide this value by bodyweight in Kg.*

Questions

1. Based on your values for each test and using the norm charts provided, classify your fitness level.
2. List and explain three sources of error that may contribute to errors in estimating VO_2max from the two tests. These errors may include technician errors and/or errors inherent to submaximal testing.
3. Compare your values for estimated VO_2max for the two tests. If different, how much did the two tests differ?
4. List and describe three benefits to submaximal testing compared to a true maximal laboratory test.