LAB: MEASURING LOCAL AND WHOLE-BODY OXYGEN DYNAMICS DURING AN INCREMENTAL EXERCISE TEST WITH MOXY

I. PURPOSE

A. Measure cardiorespiratory functions during a maximal exercise testing protocol
B. Learn techniques for determining a true VO_{2max} using a Modified Astrand protocol
C. Gain exposure to the Rating of Perceived Exertion Scale (RPE)
D. Gain exposure to Moxy Monitor and measure Muscle Oxygen Saturation (SmO_2)

II. EQUIPMENT NEEDED

- Calibrated platform beam scale
- Stadiometer
- Metabolic Cart
- Hans Rudolph valve and mask
- Moxy Monitor with Light Shield and Stickers
- Treadmill
- HR Monitor and Watch
- Stopwatch
- RPE Scale
- Prewrap

III. RATIONALE—UNDERSTANDING VO_{2max} and SmO_2

Typical aerobic fitness tests measure cardiorespiratory function and whole-body oxygen consumption. The use of oxygen to fuel exercise has been widely studied and is a main focus of this laboratory. As individuals perform exercise, the rate at which they consume oxygen increases in response to the higher energetic demand of oxygen within the muscle to perform contractions. When the individual gradually increases exercise intensity, there is an increased demand of oxygen to continue to perform. As one approaches the maximal exercise intensity that the muscles can sustain, they will also reach a maximal oxygen consumption (VO_{2max}) as their body is unable to continue to fuel the activity aerobically - resulting in fatigue and exercise cessation. When testing VO_{2max} at least two of the criteria listed below must be observed for the test to be a true maximum test, although there are still debates on which criteria should be required:

- Plateau of the VO_2 value with increasing workloads (i.e., an increase of less than 2 ml/kg/min [or 5%] with an increase in exercise intensity)
- Respiratory exchange ratio (RER) of 1.10 or higher
- Peak blood lactate concentration greater than 8 mmol/l
- Exhaustion of the subject
- Heart rate within 10 beats/min of age-predicted maximal heart rate
- Borg RPE of >17, OMNI RPE >8

Rating of Perceived exertion (RPE) is a common subjective variable used in fitness testing. Two of the most common scales are the Borg 6-20 scale and the OMNI 0-10 scale. This scale provides insight into how the subject is feeling throughout varying stages of fitness testing. This measure is included within this laboratory to highlight overall exertion level of the subject during the test.

Muscle oxygenation (SmO_2) is measured via Near-Infrared Spectroscopy (NIRS). The device used in this lab is a Moxy Monitor, a commercially available validated NIRS device that may be seen in research laboratories or even used by an athlete to train. The primary outcome variable measured by a Moxy Monitor is SmO_2 which informs athletes, coaches, and researchers on the localized oxygenation status of the underlying tissues using a Moxy Monitor. NIRS devices shine light through the skin and measure the amount of oxygen in the underlying muscular tissues. The monitor measures SmO_2 from 0-100% which can provide valuable insights on the dynamics of oxygenation throughout activity. Typically, as a subject engages in more intense activity, the SmO_2 will drop indicating the oxygen that is being delivered is being used for energy production and if this intensity is sustained, muscular fatigue is approaching due to the lack of abundance of oxygen needed to continue exercising aerobically at that intensity.

IV. PROTOCOL

Subjects will perform a modified Astrand treadmill test, with durations of the test varying based on fitness level and performance. The test is progressive and continuous to test the body's response to increasing exercising demands. This type of test is considered a gold-standard for determining aerobic fitness level and cardiorespiratory function.

Pre-exercise:

1. Calibrate metabolic cart
2. Obtain and record subject demographic information
    a. Predicted HR_{max} = 208 - (0.7 x age)
3. Explain testing protocol to subject
4. Orient subject to RPE scale
5. Fit subject with valve and monitors
6. Organize testing roles

Moxy Monitor Placement:

1. As demonstrated by the instructor, sit your subject on the edge of a chair and have them extend their knee to flex the quad muscles.
2. Place the Moxy sensors on the vastus lateralis muscle of the dominant leg.
    a. To find the vastus lateralis, ask your subject to sit on the edge of a chair and extend their knee to flex the quad muscles.
    b. Locate the vastus lateralis muscle on the outside of the thigh and place the Moxy sensor on the muscle belly between the patella and the greater trochanter of the femur. Ensure that the curvature of the Moxy Monitor is aligned with the curvature of the leg so the Moxy Monitor sits flush with the skin.
3. Holding the Moxy in place, turn it on by pressing and holding the power button until a red light flashes on the front of the device.
4. Connect it to the iPad (Moxy Portal App) to ensure its populating the data properly before taping it in place.
5. Affix the Moxy to the leg using the large pore tape over the light shield with the Moxy in it.
6. Please avoid using lotion on the skin and avoid placing the sensors over tattoos, as those can interfere with the light signal and the security of the tape.

Modified Astrand Test:

1. Subject should warm up for 3 minutes (walk or light jog)
2. Initial workload is 5-8 mph, 0% grade for 3 minutes; the subject should select a speed by the end of this initial stage
3. Subsequent workloads are 2 minutes, increasing the grade 2.5% with each stage while maintaining constant speed
4. Record HR and RPE during their respective times throughout the test
5. Encourage the subject to continue until exhaustion
    a. Once this point is reached, straddle the belt and hang onto the treadmill while swaying side to side until TM speed and grade are reduced

Recovery:

1. Once the TM speed and grade are reduced, perform a light walk until the subject is comfortable
2. Remove valve and monitors
3. Save testing results

Group Roles:

- *Testing Lead:* Professor or TA will perform this role with the metabolic cart and Moxy monitor.
- *Timer/TM Operator:* VP of the test. Initiates the test and reminds all team members when to collect data. Responsible for changing the speed/grade on the TM.
- *RPE Recorder:* Orient the subject to the RPE scale and records RPE throughout the test.
- *HR Recorder:* Records the HR variable throughout the test.
- *Subject:* Performs all aspects of the test. When wearing the mask, they must not speak or laugh during the test.
- *Supervisors:* Responsible for making sure the subject stays on the treadmill.

Lab: VO_{2max} Testing
Data Recording Form

Subject #1 Age (y): ______ Sex: _____________ Height (cm): ______ Wt (kg): ______

Age Predicted HR_{max}: __________ HR_{max}:______________ VO_{2max}: _____________

RPE_{max}: ________________ Fatigue Time:_____________

Data Extraction:

- Use the data handout to extract the value from the last reading in each stage
- This completed chart will serve as your Appendix material

Stage	Grade (%)	Speed (mph)	V_E (L/min)	RER	VO_2 (ml/kg/min)	RPE	HR (bpm)	SmO_2 (%)
1	0							
2	2.5							
3	5							
4	7.5							
5	10							
6	12.5							
7	15							

Subject #2 Age (y): ______ Sex: _____________ Height (cm): ______ Wt (kg): ______

Age Predicted HR_{max}: __________ HR_{max}:______________ VO_{2max}: _____________

RPE_{max}: ________________ Fatigue Time:_____________

Data Extraction:

- Use the data handout to extract the value from the last reading in each stage
- This completed chart will serve as your Appendix material

Stage	Grade (%)	Speed (mph)	V_E (L/min)	RER	VO_2 (ml/kg/min)	RPE	HR (bpm)	SmO_2 (%)
1	0							
2	2.5							
3	5							
4	7.5							
5	10							
6	12.5							
7	15							

Subject #3 Age (y): ______ Sex: _____________ Height (cm): ______ Wt (kg): ______

Age Predicted $HR_{max:}$ __________ HR_{max}:______________ VO_{2max}: _____________

RPE_{max}: ________________ Fatigue Time:_____________

Data Extraction:

- Use the data handout to extract the value from the last reading in each stage
- This completed chart will serve as your Appendix material

Stage	Grade (%)	Speed (mph)	V_E (L/min)	RER	VO_2 (ml/kg/min)	RPE	HR (bpm)	SmO_2 (%)
1	0							
2	2.5							
3	5							
4	7.5							
5	10							
6	12.5							
7	15							

Timer Helper Sheet		
Stage	Time	Role
1	0:45	
	1:45	
	2:45	HR, RPE
	2:55	TM %
2	3:45	
	4:45	HR, RPE
	4:55	TM %
3	5:45	
	6:45	HR, RPE
	6:55	TM %
4	7:45	
	8:45	HR, RPE
	8:55	TM %
5	9:45	
	10:45	HR, RPE
	10:55	TM %
6	11:45	
	12:45	HR, RPE
	12:55	TM %
7	13:45	
	14:45	HR, RPE
	14:55	TM %

Table:

1. Max values for each measured variable between subjects and total time lasted during test
2. Min value for SmO_2

Graphs: (All variables are across stages not time)

1. V_E
2. RER
3. VO_2
4. RPE
5. HR
6. SmO_2

Graphing Notes:

a. Put all subjects on the same graph
b. Use text box and shape on the line to identify max value and label max value
c. SmO_2 identify the minimum value instead of max value

Discussion Questions:

1. Describe how all variables changed throughout the exercise stages.
2. Did all subjects have a “true” maximal test? Why?
3. Compare and contrast the VO_{2max} values. Who performed better on the test, why do you think?
4. Looking at SmO_2 what subject was the most efficient in their effort?
5. Is the V_E threshold noticeable? What occurs during this “threshold”?
6. What was the maximal RER, what does that tell you about substrate usage?
7. Did the subjects achieve their age-predicted HR_{max}? Do you think the equation is accurate?

ACKNOWLEDGEMENTS

This lab was created, tested and implemented at the University of Pittsburgh School of Education by April Chambers, Ph.D. and Zachary Wilson, Ph.D. with input from Moxy Monitor Staff Physiologist Philip M. Batterson, Ph.D.