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LABORATORY #5

MAXIMAL OXYGEN CONSUMPTION & ADJUSTMENTS to PROGRESSIVE EXERCISE

I. Purpose:

To summarize the physiological events occurring during treadmill or bicycle exercise of progressively increasing intensity.

II. Theory:

There is little doubt concerning the primary metabolic processes which contribute to high intensity short duration exercise (phosphagen depletion and/or anaerobic glycolysis) or in longer duration performance (oxidation). The transition period from low intensity aerobic exercise to high intensity anaerobic exercise has generated much discussion in recent years. A determination of the adjustments, particularly those which are respiratory related, and an identification of the phases which occur during transition can assist in understanding the ongoing metabolic processes involved.

There appears to be three phases which can be clearly identified in the progression from low to high intensity exercise. This lab will measure parameters of gas exchange (VO_2, VCO_2, FEO_2, $FECO_2$, RQ, V_E) and heart rate response, while making reference to typical changes in blood lactate. The actual measurement of blood lactate levels would be useful but are beyond the scope of this laboratory procedure.

Phase I (Refer to Figure 1 for a representation of typical values and changes one may expect)

With increasing levels of relatively low intensity exercise, a greater amount of oxygen is being extracted by the tissues resulting in a gradually decreasing fraction of oxygen (FEO_2) in the expired air. There is also linear increases in oxygen uptake (VO_2), minute ventilation (V_E), and heart rate (HR). As greater amounts of CO_2 are produced, expired fraction ($FECO_2$) and volume of CO_2 produced (VCO_2) also increase. Since blood lactates (La) during this period remain near resting levels, there is little doubt that this first phase primarily involves aerobic metabolism.

Phase II:

As the exercise intensity increases and reaches a point between 40% and 60% VO_{2MAX}, VO_2 and HR continue to rise linearly and there is an initial rise in La to twice resting values (about 2 mmol/liter). In an attempt to compensate for the impending metabolic acidosis, due to higher levels of La and CO_2, the respiratory center is stimulated to increase V_E; the combined effect of a higher V_E and a higher level of CO_2 in the blood produces a higher VCO_2. Since the La rises to a value lower than approximately 4 mmol/liter during this second phase, this respiratory compensation appears reasonably effective. Since the body does not consume more oxygen than is needed to replace the ATP utilized, the extra increase in V_E results in a lower extraction of oxygen per volume of per volume of air ventilated and there is a corresponding rise in F_EO_2. Therefore, the onset of Phase II is characterized by a nonlinear increase in V_E and VCO_2, and an increase in F_EO_2 without a corresponding decrease in F_ECO_2, plus a rise in blood La from approximately 2 mmol/liter. This onset of blood La accumulation corresponds to the anaerobic threshold described by Wasserman, Whipp, Royal & Beaver (1973).

Onset of Blood Lactate Accumulation (OBLA)

During steady-rate exercise, sufficient oxygen is supplied to and used by the working muscles. Under these conditions, lactic acid production does not exceed lactic acid uptake and no increase is noted in blood lactate. The exercise level or level of oxygen consumption that blood lactate begins to show a sytematic increase above a resting or some slightly higher base-line level is termed the lactate threshold, or point of onset of blood lactate accumulation (OBLA) (McArdle, Katch & Katch, 1991). This normally occurs between 55-65% of the maximal oxygen uptake in healthy, untrained subjects and is often over 80% in more highly trained endurance athletes (Wasserman et al., 1973).

Phase III:

With further increases in intensity to about 65-90% VO_{2MAX}, the linear rise in VO_2 and the HR continues until near-maximal work loads at which time they begin to plateau. At the onset of this phase, blood La is around 4 mmol/liter and then increases more rapidly until the subject attains their VO_{2MAX}. There is also a further increase in V_E and a continuous rise in VCO_2 in an attempt to compensate for the marked rise in La. At this point, however, the hyperventilation cannot compensate adequately and there is a drop-off in F_ECO_2, while FEO_2 continues to rise. The onset of Phase III is thus characterized by a sharp rise in blood La from a level of about 4 mmol/liter, a decrease in F_ECO_2, a marked hyperventilation. This onset, with its "break-away" ventilation, appears to correspond to the anaerobic threshold noted by MacDougall (1978) and Green, Daub, Painter, Houston & Thomson (1979).

In the past, both the onset of Phase II and Phase III have been referred to by different authors as the anaerobic threshold. Skinner and McLellan have suggested that since the initial rise in lactate and the non-linear increases in VE and VCO_2, which characterize the onset of Phase II, are related to the recruitment of slow twitch fibers and to an imbalance between the rate of pyruvate production and pyruvate oxidation and are related less to anaerobiosis that this be designated the aerobic threshold. Similarly since the sharp rise in lactate and the "break-away" V_E seen at the onset of Phase III are related more to anaerobiosis and the increasing recruitment of fast twitch fibers with their predisposition to hypoxia, Skinner and McLellan suggest that this point be termed the anaerobic threshold. For the purposes of this lab we have adopted these definitions.

III. Equipment Needed:

A. Gas analysis and volume measurement equipment

B. Bicycle ergometer or treadmill

C. Electrocardiograph or heart rate monitor

IV. Procedures:

A. Subject should be trained (healthy) and accustomed to high intensity exercise.

B. Subject will be outfitted for oxygen uptake and heart rate measurement and will begin walking on the treadmill at the stipulated speed (Bruce Treadmill Protocol). Each stage will last for three (3) minutes.

C. All values for completing the recording form will be collected every twenty (20) seconds. Heart rate and Rating of Perceived Exertion (RPE) will be measured every minute.

D. This process should continue until the subject reaches maximal effort. During the final stage, collect the values during the last minute of exercise if the subject cannot continue until the end of the stage.

V. Questions:

1. Construct a series of graphs with time on the horizontal axis and VO2, VCO_2, V_E, F_ECO_2, F_EO_2, HR and RPE and identify on all graphs with a vertical line where your data identify the aerobic and ventilator/anaerobic thresholds.

2. Can you identify the aerobic and ventilatory/anaerobic thresholds? Are your results in agreement with the examples provided? Explain why the values were or were not in agreement.

3. What is your subject's VO_{2MAX} ? What was the relative intensity (%VO_{2MAX}) and heart rate (% Hr_{max}) at which the aerobic threshold occurred? At which relative intensity did the ventilatory threshold occur? How do your obtained values compare to norms in the literature?

4. How accurate are these non-invasive measures, based on your data, in identifying both the aerobic and ventilatory/anaerobic threshold?

5. Based upon the above findings (#'s 1-4) describe to your patient/subject their findings in "layman" terms. Secondly, develop an age-appropriate exercise prescription to develop **cardiovascular fitness** that is scientifically-based from the literature.

DATA RECORDING FORM

Subject's Name________________ Weight __________

Age ______ Fitness ________________

Workload Or Time	VO_2 l/min	VCO_2 l/min	V_E l/min	F_ECO_2 %	F_EO_2 %	HR b/min	RPE	RQ

VI. References

Green, et al. (1979) Anaerobic threshold and muscle fiber type, area and oxidative enzyme activity during graded cycling. *Med Sci Sports & Ex 11*, 113-114.

MacDougall, J. (1979). The anaerobic threshold: Its significance for the endurance athlete. *Canadian J of App Sports Sci 2*: 137-40.

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Wasserman, K., Hansen, J.E., Sue, D.Y., & Whipp, B.J. (1987). *Principles of Exercise Testing and Interpretation.* Philadelphia: Lea & Febiger.+