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PRINCIPAL INVESTIGATOR: Peter Weyand

CONTRACTING ORGANIZATION: Rice University
Houston, TX 77005-1892

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14. ABSTRACT
The objective of the proposed effort is to develop a brief and accurate method for the simultaneous assessment of anaerobic and aerobic fitness that is practical for both field and laboratory use. We anticipate that a method requiring an assessment period of only a few minutes or less, and two brief, minimally fatiguing efforts is possible. Each subject will undergo established tests to assess their maximal aerobic power and anaerobic power, respectively. Subjects will also complete a series of all-out efforts to establish their performance capabilities for efforts of different durations. Our analysis will focus primarily on two questions. First, we will determine if the relationship between the metabolic power available and all-out performance capabilities is common or dependent upon the fitness level of the individual. Second, we will determine whether the relationship between metabolic power and performance varies with the type of physical activity in which soldiers are engaged. We hypothesize that a single relationship will generalize to: 1) different individuals regardless of fitness level, and 2) to different types of physical activity. The development of a simple, practical and accurate method for assessing metabolic fitness and performance capabilities will provide a number of benefits.

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INTRODUCTION:

The objective of the proposed effort is to develop a brief and accurate method for the simultaneous assessment of anaerobic and aerobic fitness that is practical for both field and laboratory use. We anticipate that a method requiring an assessment period of only a few minutes or less, and two brief, minimally fatiguing efforts is possible. Each subject will undergo established tests to assess their maximal aerobic power and anaerobic power, respectively. Subjects will also complete a series of all-out efforts to establish their performance capabilities for efforts of different durations. Our analysis will focus primarily on two questions. First, we will determine if the relationship between the metabolic power available and all-out performance capabilities is common or dependent upon the fitness level of the individual. Second, we will determine whether the relationship between metabolic power and performance varies with the type of physical activity in which soldiers are engaged. We hypothesize that a single relationship will generalize to: 1) different individuals regardless of fitness level, and 2) to different types of physical activity. The development of a simple, practical and accurate method for assessing metabolic fitness and performance capabilities will provide a number of benefits.

The specific tasks identified in the approved statement of work were:

1. To determine the relationship between all-out exercise performance and anaerobic and aerobic sources of metabolic power during modes of exercise involving a significant fraction of the body's muscle mass

2. To determine the briefest testing protocol that will accurately quantify the anaerobic and aerobic fitness of soldiers or an equivalent population.

3. To determine whether the progressive recruitment of additional muscle motor units during fatiguing exercise is a factor that forces the cessation of the exercise or a decrement in performance.

BODY:

Official approval for testing of human subjects was granted by the HSRRB until 1/13/2005. The results reported below have been obtained between 2/2/2005 and 10/30/2005.

KEY RESEARCH ACCOMPLISHMENTS:

We hypothesized that all-out performance in any mode of exercise engaging a large fraction of the boy's muscle mass could be accurately predicted by our anaerobic reserve model (1,2,3). The model, originally developed for running, postulates that all-out efforts all in a common exponential manner for the maximum burst sprint performance to the maximum intensity that can be supported aerobically as the duration of the effort becomes more prolonged. The hypothesis has the following quantitative form:

$$Perf\ (t) = Perf_{aer} + (Perf_{mech\ max} - Perf_{aer}) \cdot e^{(-k \cdot t)} \quad (1)$$

where Perf is expressed as an intensity (i.e., running speed, cycling power, etc) and thus Perf(t) is the power output maintained for a trial of duration t, $Perf_{mech\ max}$ is the maximum power output for a trial of 3 seconds, $Perf_{aer}$ is the maximum mechanical power output that can be supported by aerobic metabolism, the quantity $PO_{mech\ max} - PO_{aer}$ is the anaerobic reserve, e is the base of the natural logarithm, and k is the exponent that describes the decrements in performance occurring with increments in the duration of all-out cycling efforts. We hypothesized that a single value of the exponent k will describe duration-dependent decrements in performance of any individual regardless of their mechanical and aerobic maxima and for any type of exercise.

As proposed we have used cycle ergometry as an alternate mode of exercise to test our anaerobic reserve model. In the 6 months since our last report we have tested 7 male subjects of varying levels of fitness and performance capabilities. Metabolic and mechanical data during all-out cycling efforts of different durations appear in Figure 1.

Both the metabolic and mechanical responses are similar to those we have previously reported for running. However, two mode-specific differences are noteworthy. First, the maximum burst sprint intensities during cycling exceed the maximum intensity that can be supported aerobically by four-fold. The equivalent difference during running is only two-fold. Thus, appreciably greater sprinting intensities are possible during cycling vs. running. Second, we have found in accordance with our model that the same exponent describes the performance decrements observed as the durations of all-out effort increase (see Figure 2) if intensities are expressed relative to the difference between the respective burst sprint and aerobic maximums (i.e. the anaerobic reserve). However, contrary to our expectation the exponent describing these decrements is not the same for

different modes of exercise. The best fit value for k_{cycle} is two times greater than that previously identified for k_{run}.

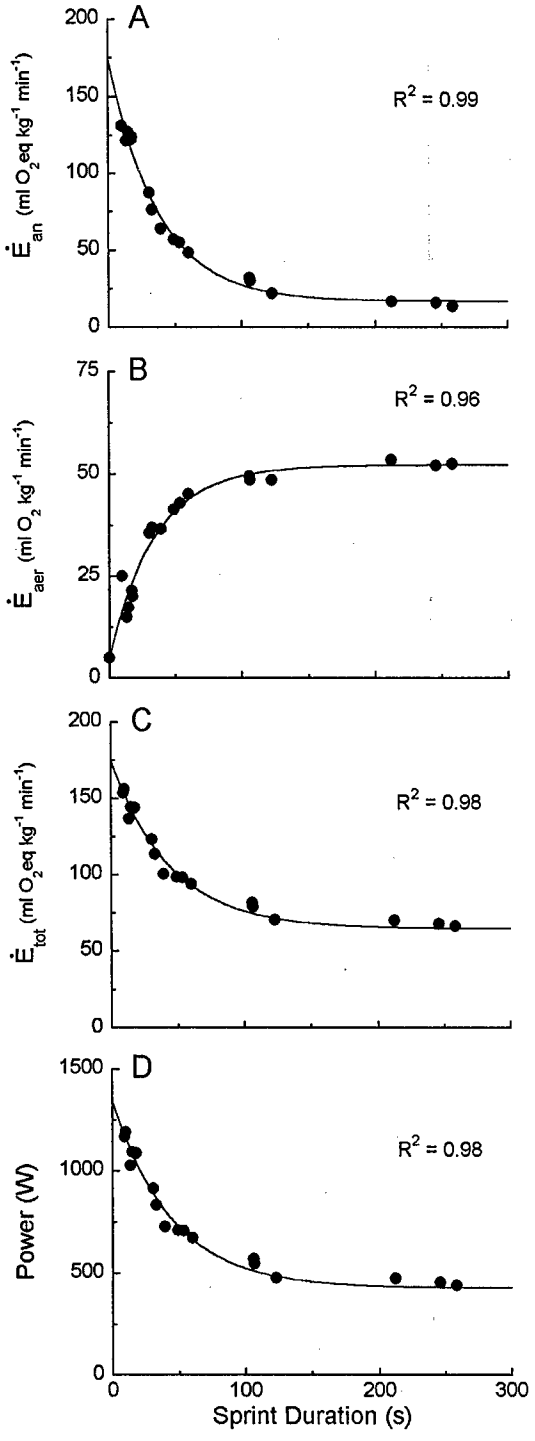

Figure 1. Rates of anaerobic (A), aerobic (B), and total metabolic power output(C), during all-out cycling efforts of different durations for a representative subject (male of 71.2 kg). The mechanical power output supported appears in panel D.

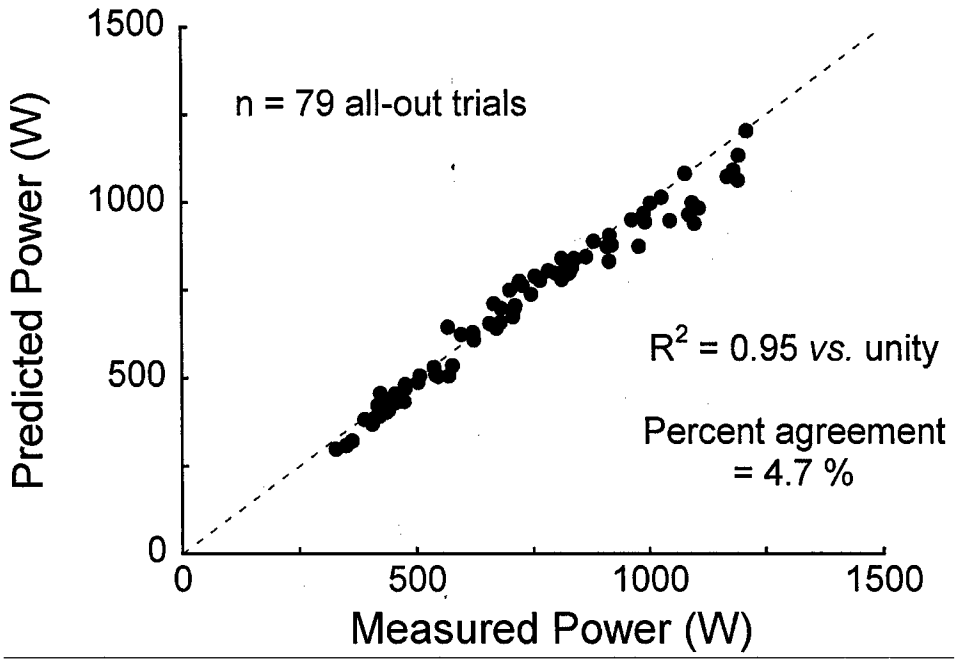

Figure 2. Actual vs. measured sprint performances of 7 subjects. Predicted power outputs were generated from our anaerobic reserve model (eq. 1) using the measured peak power, the maximum power supported by aerobic metabolism and an expeontial constant k = 0.026.

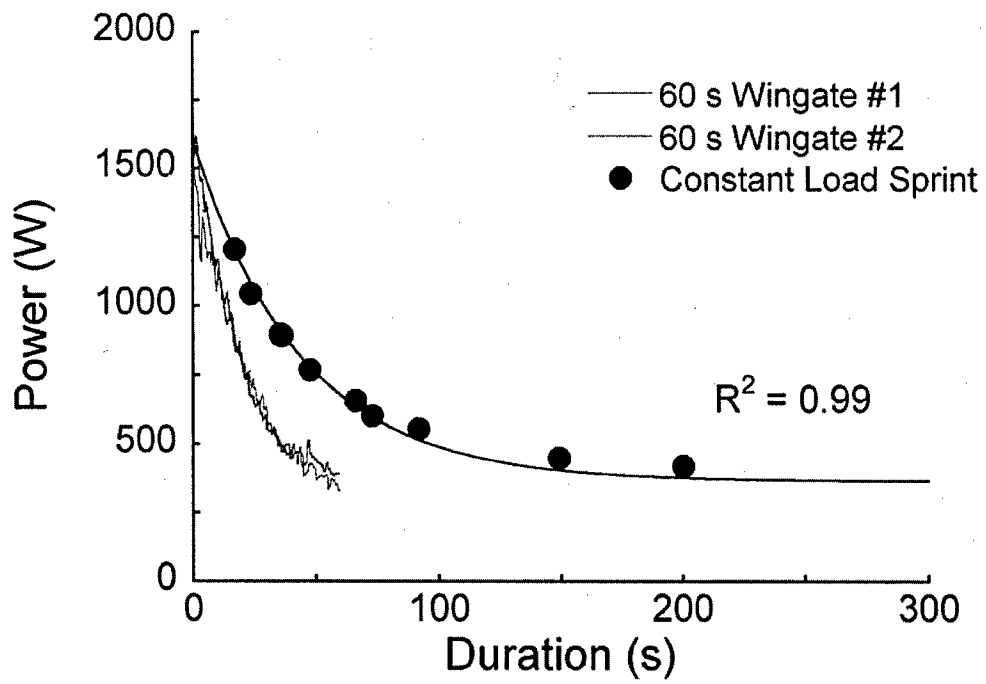

Figure 3. Decrements in power output in relation to duration for a single subject across trials of different durations (solid line, closed circles) and during two all-out per the standard all-out Wingate test of 60 s duration (blue and red colored lines, no symbols).

In accordance with specific task 2, our results thus far are consistent with the possibility that a single all-out test like such as the conventional Wingate test also conforms to the basic form of our anaerobic reserve model. We have thus far found that the four subjects tested underwent power decrements from the burst maximum to the aerobic maximum with a common time course (eq. 1, k = 0.056) that is more rapid than that quantified across bouts of different durations. These results raise the possibility that a single exercise test may be used to identify peak sprint power, maximum aerobic power and the entire power-duration curve for sprint cycling. However, additional work is necessary to fully evaluate this idea.

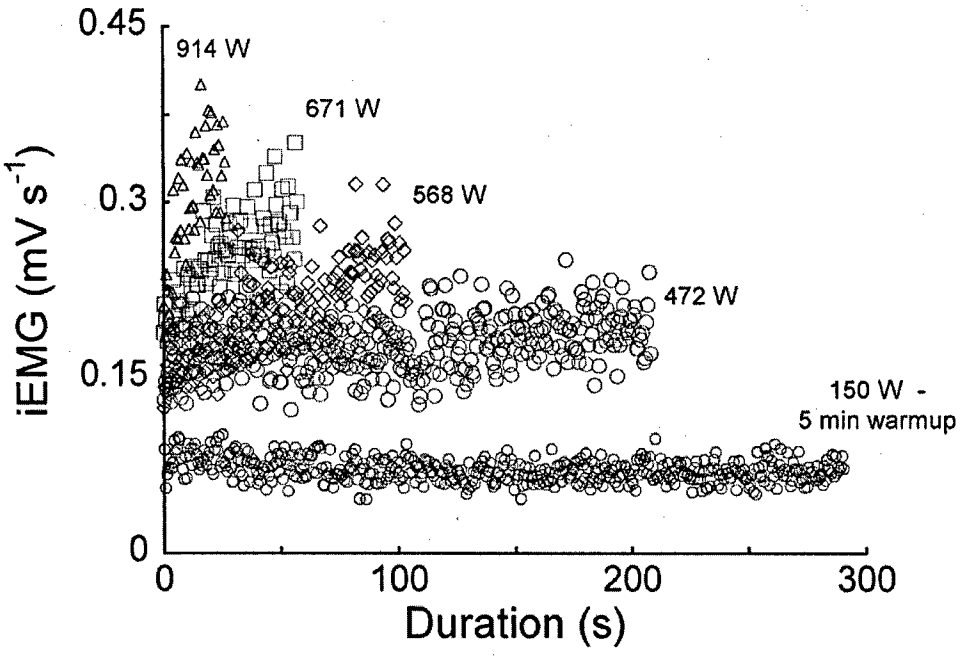

Figure 4. Surface electromyograms (iEMG) from the vastus lateralis muscles during all-out sprint cycling efforts at different intensities above the maximum intensity that could be supported by aerobic power and one submaximal cycling intensity. Surface iEMG activity increases throughout sprint cycling trials. Increases are more rapid at greater intensities.

In accordance with specific task 3 which was to determine whether the progressive recruitment of additional muscle motor units during fatiguing exercise is a factor that forces the cessation of the exercise or a decrement in performance we have recorded surface EMG activity from the quadriceps muscles during

all-out sprint cycle efforts of different durations. Data from the vastus lateralis muscle of one subject appear in Figure 4. In accordance with our hypothesis that an upper limit to the recruitable volume available may limit sprint cycle performances, we find that the iEMG activity of vastus lateralis and other muscles increase throughout these fatiguing trials. In contrast, during submaximal steady-state cycling, EMG activity also remains constant across time.

Rates of increase in the surface EMG signals for the same subject appear in Figure 5. Although we correctly hypothesized that surface iEMG activity would increase throughout these trials and that increases would be more rapid at greater sprinting intensities, we expected values at the failure point of the different sprints would be the same. Our results to date indicate this is not the case. End iEMG values for longer sprints are systematically lower. At present, we do not have an explanation for this finding.

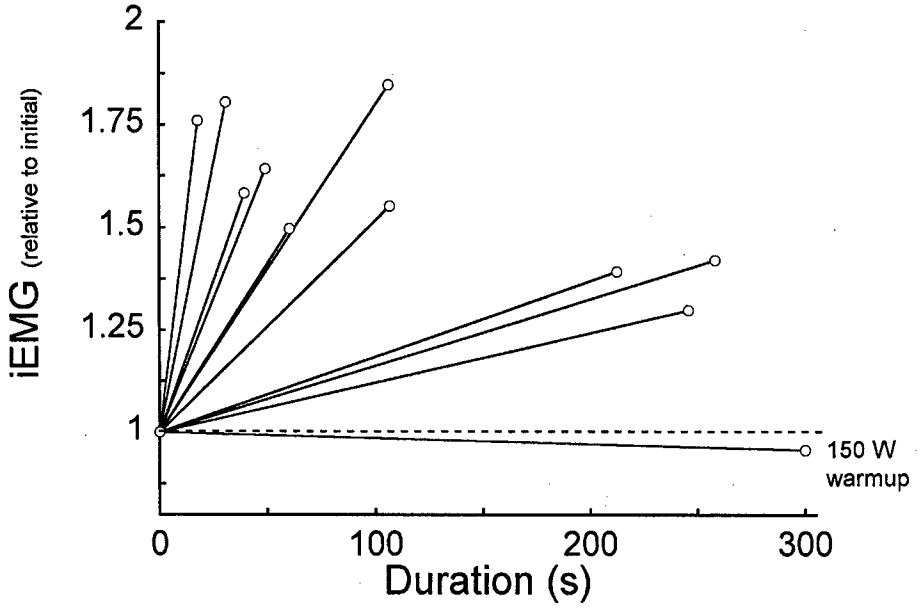

Figure 5. Surface iEMG activity of the vastus lateralis in relation to duration for all-out trials performed at different sprint intensities and fro different durations. All values are standardized to the value (1.0) measured at the outset of the trial.

KEY RESEARCH ACCOMPLISHMENTS:

In the previous report we noted that we had set up our custom force treadmill, software, and filtering techniques for the treadmill force signals. Similar technical work has been accomplished with our cycle ergometer. We have also identified

and streamlined the procedures for collecting EMG signals during cycling and treadmill locomotion.

REPORTABLE OUTCOMES:

Thus far all reportable outcomes are in the form of the original data collected and presented above. Because we were only approved to begin experimentation in January of 2005, manuscripts and presentations have not yet been possible.

CONCLUSIONS:

Preliminary conclusions are as follows:

1. Our anaerobic reserve model does provide a general quantitative description of performance capabilities for all-out exercise efforts of different types that engage a significant fraction of the body's musculature. The relationship is independent of both the mode of exercise and the fitness level of the individual.
2. The above relationship is sufficiently accurate and general that a brief testing protocol of either one or two tests should allow metabolic maximums for anaerobic and aerobic power as well as performance capabilities to be determined.
3. The progressive recruitment of additional motor units during fatiguing exercise is a manifestation of fatigue and does contribute to eventual inability to continue to perform.

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APPENDICES:

None