N93-26077

UTILIZATION OF THE GRADED UNIVERSAL TESTING SYSTEM TO INCREASE THE EFFICIENCY FOR ASSESSING AEROBIC AND ANAEROBIC CAPACITY

Final Report

NASA/ASEE Summer Faculty Fellowship Program--1992

Johnson Space Center

Prepared By: Sandra L. Rodgers, Ph.D.

Academic Rank: Associate Professor

University & Department: Louisiana Tech University
Dept. of Health and Physical Education
Ruston, LA 71272

NASA/JSC

Directorate: Space and Life Sciences

Division: Medical Life Sciences

Branch: Space Biomedical Research Institute

JSC Colleague: Steven F. Siconolfi, PhD.

Date Submitted: August 27, 1992

Contract Number: NGT-44-005-803

ABSTRACT

The in-flight exercise test performed by cosmonauts as part of the Russian Exercise Countermeasure Program is limited to 5 minutes due to communication restrictions. During a recent graded exercise test on a US Shuttle flight, the test was terminated early due to an upcoming loss of signal (LOS) with the ground. This exercise test was a traditional test where the subject's exercise capacity dictates the length of the test. For example, one crewmember may take 15 minutes to complete the test, while another may take 18 minutes. The traditional exercise test limits the flight schedulers to large blocks of space flight time in order to provide medical and research personnel information on the fitness capacity (maximal oxygen uptake: VO2max) of crewmembers during flight. A graded exercise test that would take a finite amount of time and a set preparation and recovery time would ease this problem by allowing flight schedulers to plan exercise tests in advance of LOS. The Graded Universal Testing System (GUTS) was designed to meet this goal.

Fitness testing of astronauts before and after flight provides pertinent data on many variables. The Detailed Supplemental Objective (DSO608) protocol (6) is one of the graded exercise tests (GXT) currently used in astronaut testing before and after flight. Test times for this protocol have lasted from 11 to 18 minutes. Anaerobic capacity is an important variable that is currently not being evaluated before and after flight. Recent reports (1,2,5) from the literature have suggested that the oxygen deficit at supramaximal exercise is a measure of anaerobic capacity. We postulated that the oxygen deficit at maximal exercise would be an indication of anaerobic capacity. If this postulate can be accepted, then the efficiency of acquiring data from a graded exercise test would increase at least twofold. To examine this hypothesis anaerobic capacity was measured using a modified treadmill test (3,4) designed to exhaust the anaerobic systems in approximately 45 to 75 seconds. Lactate concentration in the blood was analyzed after all tests, since lactate is the end-product of anaerobic energy production. Therefore, the peak lactate response is an additional indication of anaerobic capacity.

A preliminary comparison of the GUTS and the DSO608 suggests that the GUTS protocol would increase the efficiency of VO2max testing of astronauts before and after flight. Results for anaerobic capacity have not been tabulated.

INTRODUCTION

The in-flight exercise test performed by cosmonauts as part of the Russian Exercise Countermeasure Program is limited to 5 minutes due to communication restrictions. During a recent graded exercise test on a US Shuttle flight, the test was terminated early due to an upcoming loss of signal (LOS) with the ground. This exercise test was a traditional test where the subject's exercise capacity dictates the length of the test. For example, one crewmember may take 15 minutes to complete the test, while another may take 18 minutes. The traditional exercise test limits the flight schedulers to large blocks of space flight time in order to provide medical and research personnel information on the fitness capacity (maximal oxygen uptake: VO2max) of crewmembers during flight. A graded exercise test that would take a finite amount of time and a set preparation and recovery time would ease this problem by allowing flight schedulers to plan exercise tests in advance of LOS. The Graded Universal Testing System (GUTS) was designed to meet this goal.

Fitness testing of astronauts before and after flight provides pertinent data on many variables. The Detailed Supplemental Objective (DSO608) protocol is one of the graded exercise tests (GXT) currently used in astronaut testing before and after flight (6). Test times for this protocol have lasted from 11 to 18 minutes. Anaerobic capacity is an important variable that is currently not being evaluated before and after flight. Recent reports (1,2,5) from the literature have suggested that the oxygen deficit at supramaximal exercise is a measure of anaerobic capacity. We postulated that the oxygen deficit at maximal exercise would be an indication of anaerobic capacity. If this postulate can be accepted, then the efficiency of acquiring data from a graded exercise test would increase at least twofold. To examine this hypothesis anaerobic capacity was measured using a modified treadmill test (3,4) designed to exhaust the anaerobic systems in approximately 45 to 75 seconds. Lactate concentration in the blood was analyzed after all tests, since lactate is the end-product of anaerobic energy production. Therefore, the peak lactate response is an additional indication of anaerobic capacity.

The purpose of this study was to compare the relative abilities of the GUTS and DSO608 GXT protocols to assess VO2max. This study was also concerned with the feasibility of the DSO608 and GUTS protocols to obtain values of aerobic and anaerobic capacity and thereby increase the efficiency of acquiring data from a graded exercise test.

METHODS

Fifteen subjects participated in the study. All subjects underwent cardiovascular screening prior to testing utilizing the Bruce GXT protocol. A subject profile is presented in Table 1. Two GXT's were administered to measure maximal oxygen uptake (VO2max), and an anaerobic test was utilized to assess anaerobic capacity. Small blood samples were drawn to measure the lactate concentration before and after all tests. Blood lactate is an indicator of anaerobic responses.

The GUTS Protocol is a maximal treadmill test designed to assess VO2max in 12 minutes by setting speed and grade for each stage of the test based on the subject's estimated VO2max. The starting treadmill speed was based on 70% of the subject's age, sex, weight predicted VO2max. Subsequent increases are determined by the subject's heart rate response at the end of each stage. The test consists of six stages increasing in difficulty every three minutes through stage three and then every minute until the test ends at 12 minutes.

The DSO608 is the standard treadmill GXT (6) utilized to evaluate the VO2max of astronauts before and after flight. Speed increases from 3.5 miles per hour (mph) in stage one to 7 mph in stage four. Subsequent workload increases are accomplished by a grade change of 3% until the subject reports volitional fatigue.

An anaerobic test was administered in order to determine if selected measures obtained during aerobic GXT's reflect anaerobic capacity, and thereby eliminate the need for astronauts to perform an anaerobic test. The instrument was a modified (3) version of a test developed by Schnabel and Kindermann (4). Subjects were required to run at 8 mph, 20% grade until volitional exhaustion after a one minute warm-up run at 5 mph. To encourage subjects to push to reach true exhaustion, all subjects were placed in a modified parachute harness that would prevent them from falling on the treadmill.

Anaerobic capacity may be expressed as total work (kgm, kcal, or kj) performed during the treadmill run or as average power (6). The values are based on the product of the subject's body weight and total vertical distance covered during the test.

Total vertical distance (TVD) can be determined from test time utilizing one of the equations below:

Test time from 0 to 39 seconds:

$$TVD(m) = -5.304 \times 10^{-3} - (1.7391 \times 10^{-2} \times time) + (9.1581 \times 10^{-3} \times time^2)$$

Test time for 40+ seconds:

$$TVD(m) = 13.902 + (0.70079 \times (40\text{-}time))$$

Total work can be computed from the following:

$$Work\ (kgm) = Body\ Weight(kg) \times TVD(m)$$

$$Work\ (kcal) = Work(kgm) \times 2.3427 \times 10^{-3}\ \ (kgm/kcal)$$

$$Work\ (kJ) = Work(kcal) \times 4.186\ (kJ/kcal)$$

Average Power can be computed from:

$$Power(watts) = (Work(kgm) \times time(sec)/60)\ /\ 6.118$$

RESULTS/DISCUSSION

The DSO608 protocol is a GXT designed to assess VO2max by allowing the subject to exercise until exhaustion. The end of the test is determined by the subject and test times vary from 11 to 18 minutes. The GUTS test is designed to elicit VO2max in 12 minutes. Estimated and measured VO2max values were compared on both protocols to determine if a true VO2max was achieved or if the test measured VO2peak. On both tests the final two work rates were examined and the per cent change in work rate was compared to the per cent change in VO2. If the change in work rate was larger than the change in VO2 by 5% the VO2 was considered a maximum rather than a peak value.

Preliminary comparisons of the results would indicate that the GUTS protocol is a valid test for assessing VO2max (Figure 1). Validity is based on acceptable correlations, no physiologically significant differences and low standard error of estimates (SEE). The correlation for VO2max between the protocols was r= 0.85 with a SEE of 0.40 L/min or ~10% of the DSO608 mean value. The mean difference between the measures was 0.25 L/min or ~6%. This difference was statistically significant (p=0.0346) but is close to being

within measurement error (5%). The final external work rates for the two protocols were not significantly (p=0.4467) different. The final external work rate for the DSO608 protocol was 327 (±72) watts while the final work rate achieved with the GUTS protocol 321 (±64) watts.

Two individuals were unable to complete the GUTS protocol due to very high work rates (higher than that achieved on DSO608). An analysis of the data without these individuals improved the correlation to an r of 0.89 with a mean difference of 0.07 L/min. This suggests that the basic approach of the GUTS protocol is valid for 80-90% of the subjects tested. An improvement in the protocol may be accomplished by utilizing other submaximal data in the setting of the external work rates.

The relative abilities of the DSO608 and GUTS protocols to achieve true maximal work were examined. A physiological maximum (for VO2) was reached 80% of the time for DSO608 and 40% of the time for GUTS. Only 47% of the people reaching max on DSO608 reached max on GUTS.

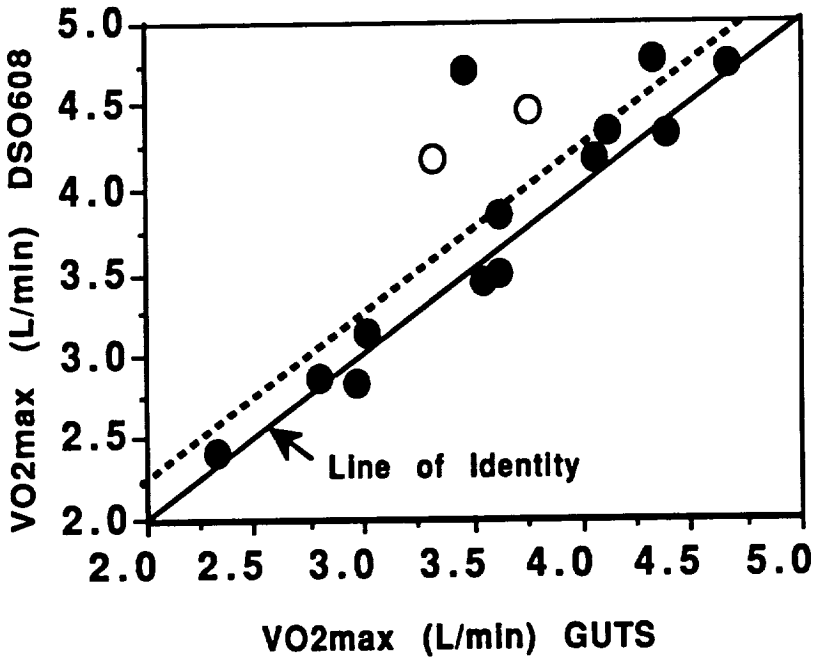

Figure 1: Comparing VO2max between the DSO608 and GUTS protocol. The solid line is the line of identity or a "perfect" match between the protocols. The dotted line is the regression line of GUTS on DSO608. The two open circles represent the two subjects who did not complete the GUTS protocol.

Table 1
Subject Characteristics

Age (yrs)	32.2±5.8
Height (cm)	164.5±27.5
Weight (kg)	73.7±15.1
Gender (M/F)	12/3

REFERENCES

1. Medbø, J. I., Mohn, A. C., Tabata, I., Bahr, R., Vaage, O., & Sejersted, O. M. *Anaerobic Capacity Determined by Maximal Accumulated O2 Deficit.* Journal of Applied Physiology, vol. 64, 1988, pp. 50-60.

2. Medbø, J. I., and Tabata, I. *Relative Importance of Aerobic and Anaerobic Energy Release During Short-lasting Exhausting Bicycle Exercise.* Journal of Applied Physiology, vol. 67(5), 1989, pp. 1881-1886.

3. Rodgers, S., Griffin, C., & Siconolfi, S. *Assessing Anaerobic Capacity on a Treadmill.* (Submitted Abstract to the Aerospace Medicine Association Annual Scientific Meeting for 1993).

4. Schnabel, A. and Kindermann, W: *Assessment of Anaerobic Capacity in Runners.* European Journal of Applied Physiology and Occupational Physiology, vol 52, 1983, pp 42-46.

5. Scott, C.B., Roby, F. B., Lohman, T. G., & Bunt, J.C. *The Maximally Accumulated Oxygen Deficit as an Indicator of Anaerobic Capacity.* Medicine and Science in Sports and Exercise.,vol. 23(5), 1991, pp. 618-624.

6. Siconolfi, S.F., Moore, Jr., A.D. Lane, H. W. *DSO608 The Effects of Microgravity on Aerobic and Anaerobic Energy Expenditure: The Role of Body Composition.* Flight Projects Office, NASA, Johnson Space Center, Houston, TX 77058.