IN-52
68724
p 11

NASA Technical Paper 3175

January 1992

Fuel Utilization During Exercise After 7 Days of Bed Rest

Linda H. Barrows,
Bernard A. Harris,
Alan D. Moore,
and Steven F. Siconolfi

NASA

NASA
Technical
Paper
3175

1992

Fuel Utilization During Exercise After 7 Days of Bed Rest

Linda H. Barrows
KRUG Life Sciences
Houston, Texas

Bernard A. Harris
Lyndon B. Johnson Space Center
Houston, Texas

Alan D. Moore
KRUG Life Sciences
Houston, Texas

Steven F. Siconolfi
Lyndon B. Johnson Space Center
Houston, Texas

NASA

National Aeronautics and
Space Administration

Office of Management

Scientific and Technical
Information Program

INTRODUCTION

Fuel utilization during exercise is affected by an individual's state of physical conditioning. Coyle [1] has shown reduced oxidative (aerobic) enzyme levels and increased glycolytic (anaerobic) enzyme levels after detraining. The decrease in oxidative enzyme activity seen with detraining suggests a lowered ability to use fat as a fuel source during exercise, while increased glycolytic enzyme levels would indicate a greater reliance on carbohydrate for energy metabolism.

Bed rest is a model used to simulate exposure to a microgravity environment. The deconditioning incurred after prolonged periods of bed rest is of equal or greater magnitude than that seen with classic detraining. Prolonged bed rest has been shown to decrease several performance variables, including maximal and submaximal oxygen uptakes [2, 3, 4, 5, 6], and skeletal muscle performance [7, 8, 9]. The decrease in these factors may be associated with altered energy metabolism.

Respiratory quotient (RQ), or the respiratory exchange ratio, has been used to indicate substrate utilization (percent of calories from fat and carbohydrate, ignoring protein contribution) during exercise. Post-bed rest elevations in RQ have been reported during submaximal [4, 10, 11] and maximal exercise [5]. These elevated RQ values post-bed rest may be indicative of a greater reliance on carbohydrate for energy during exercise and earlier onset of increased anaerobic metabolism.

Several studies support the hypothesis of greater reliance on anaerobic energy pathways during graded exercise after imposed deconditioning. Increased concentrations of blood lactate and decreased levels of total circulating free fatty acids were found during submaximal bicycle ergometry following ten days of -6° head-down tilt bed rest [10]. Coyle [1] reported a 40% decrease in mitochondrial enzyme activity levels and a change in total lactate dehydrogenase activity after 56 days of detraining in seven endurance athletes. These studies suggest that, with prolonged disuse, there is a decrease in aerobic metabolism and an increase in carbohydrate utilization during exercise.

Evidence of a reduced aerobic capacity, as shown by bed rest, has significant implication for the physical performance of crewmembers during space flight. Crewmembers are often required to perform demanding tasks during space flight, such as extravehicular activity (EVA), under less than optimal conditions for maintaining performance. In addition, pilot proficiency during entry and landing, and performance of nominal and/or emergency egress pose real concerns for Extended Duration Orbiter (EDO) space flight (missions exceeding 13 days) and emphasize the need to minimize decrements in aerobic capacity. The following study was designed to evaluate changes in fat and carbohydrate metabolism, indicators of energy pathways used for ATP synthesis, during exercise performed after seven days of simulated microgravity.

METHODS

Subjects were recruited through the Health Screening Facility at the NASA Johnson Space Center and required to pass a screening examination similar to an Air Force Class III physical prior to commencing the study. Eight male subjects [(mean ± SD) age, 34.4 ± 4.1 yr; height, 177.8 ± 8.5 cm; weight, 83.7 ± 12.6 kg; body fat, 15.9 ± 7.3%] were selected for this study based on having similar morphological characteristics to those of the current male astronaut corps. All subjects were nonsmokers, not taking any prescription medications at the time of the study, and reported no orthopedic limitations. Subjects gave written informed consent to participate in this study.

Consumption of a liquid diet (ENSURE and ENRICH, Ross Laboratories, Columbus, OH; mean kcal/kg/day = 28.9 ± 2.8) began three days prior to bed rest and was designed to maintain subjects' weight at ± 1% of their pre-bed rest body weight. Consumption of a liquid diet continued through the second day after bed rest. Bed rest consisted of seven days in the horizontal position (0° head-down tilt) during which subjects remained completely supine with arms as close to their sides as possible.

Two treadmill familiarization trials were completed prior to the start of data collection. Graded exercise testing was conducted on a continuous, motor-driven treadmill (Quinton Model 65, Quinton Instruments, Seattle, WA) in the Exercise Physiology Laboratory at the Johnson Space Center. Testing was carried out once two days pre-bed rest (GXTl) and again immediately post-bed rest (GXT2), within hours of assuming an upright position. A modified Cunningham treadmill protocol [12] was utilized to assess energy metabolism. This protocol increased treadmill speed every three minutes from 3.5 mph to 4.0, 4.5, 5.0, 6.0, and then 7.0 mph. Once a speed of 7.0 mph was attained, treadmill grade increased by 2.5% every minute thereafter until subjects attained a plateau in $\dot{V}O_2$ response (an increase of less than 100 mL/min with increasing workload) or indicated volitional fatigue.

A 12-lead electrocardiogram (Quinton 4000), asculatory blood pressure, and ratings of perceived exertion [13] were obtained during each stage of exercise. Expired gas was analyzed by a Marquette MGA 1100 Mass Spectrometer (Marquette Gas Analysis Inc., St. Louis, MO), with a SensorMedics VMM2 turbine flow meter (Alpha Technologies Inc., Laguna Hills, CA). Respiratory parameters were computed using breath-by-breath software (First Breath Inc., Ontario, Canada).

Percentage of calories derived from fat (%FAT) and carbohydrate (%CHO), and grams of fat (gFAT) and carbohydrate (gCHO) utilized in four submaximal stages of treadmill exercise, ranging from 4-6 mph, (4.7-10.1 Metabolic Equivalents, METS) were computed from $\dot{V}O_2$ and $\dot{V}CO_2$ values obtained during the last 30 seconds of each three-minute stage. Grams of fat and carbohydrate burned were computed utilizing the following equations in which units of $\dot{V}O_2$ and $\dot{V}CO_2$ are measured in L/min [14]:

Grams of FAT: $[\dot{V}O_2 - \dot{V}CO_2]/0.570$

Grams of CHO: $[4.2144 \cdot \dot{V}CO_2 - 3.007 \cdot \dot{V}O_2]$

A 2x4 repeated measures ANOVA with Newman-Kuels post hoc test was used to analyze carbohydrate and fat metabolism during submaximal exercise performed pre- and post-bed rest.

RESULTS

There were no significant ($p>0.05$) differences in mean weight or percent body fat (hydrostatic weighing) pre- and post-bed rest. There was, however, a significant ($p<0.05$) decrease in absolute aerobic capacity after seven days of bed rest, measured in GXT1 and GXT2 (Table I).

TABLE I. Post-bed rest subject characteristics (n = 8) compared to pre-bed rest (mean ± SD).

	Pre-Bed Rest	Post-Bed Rest
Weight (kg)	83.7 ± 12.6	81.6 ± 11.6
Body fat (%)	15.9 ± 7.3	16.1 ± 7.4
$\dot{V}O_2max$ (mL/min)	3638.8 ± 548	3454.9 ± 523*

*(p<0.05)

In both GXT1 and GXT2, there was a significant ($p<0.05$) increase in carbohydrate use as exercise intensity increased, while fat utilization significantly ($p<0.05$) decreased with increasing workloads. There were no significant ($p>0.05$) differences in %CHO, %FAT or gFAT in comparable submaximal stages of GXTl and GXT2 (Table II, Figures 1, 2, 4). There was, however, a significant ($p<0.05$) increase in gCHO from GXTl to GXT2 at stages of exercise corresponding to 8.1 and 10.1 METS (Table II, Figure 3).

TABLE II. Summary of carbohydrate and fat utilization for GXTl and GXT2 (mean ± SD). (mph = 0.62 km/hr)

	Stage 2 (4.0 mph)	Stage 3 (4.5 mph)	Stage 4 (5.0 mph)	Stage 5 (6.0 mph)
%CHO				
GXT1	74.0 ± 35.1	79.3 ± 44.4	84.9 ± 21.7	91.9 ± 29.6
GXT2	68.9 ± 20.4	88.5 ± 23.1	100.1 ± 14.7	105.2 ± 18.3
%FAT				
GXT1	26.0 ± 35.1	20.7 ± 44.4	5.1 ± 21.7	8.1 ± 29.6
GXT2	31.2 ± 20.4	11.5 ± 23.1	-0.08 ± 14.7	-5.2 ± 18.3
gCHO				
GXT1	1.7 ± 0.96	2.4 ± 1.2	2.6 ± 0.73*	3.3 ± 0.89*
GXT2	1.6 ± 0.56	2.6 ± 0.72	3.1 ± 0.47	3.8 ± 0.7
gFAT				
GXT1	0.26 ± 0.34	0.14 ± 0.36	0.21 ± 0.29	0.07 ± 0.35
GXT2	0.34 ± 0.18	0.11 ± 0.21	0.03 ± 0.18	-0.1 ± 0.22

*GXT2 > GXT1, $p<0.05$

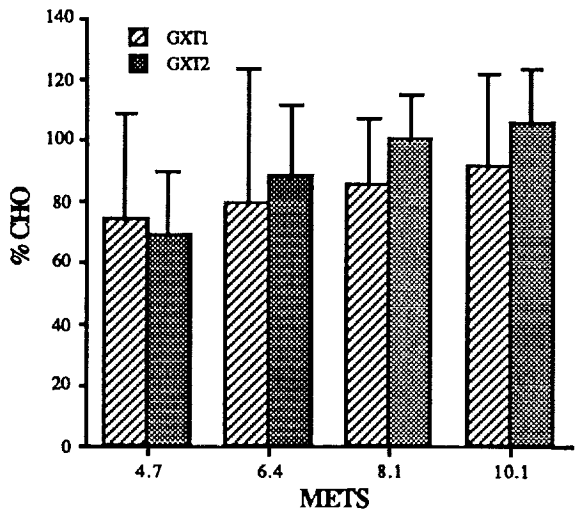

Figure 1 - %Calories from Carbohydrate

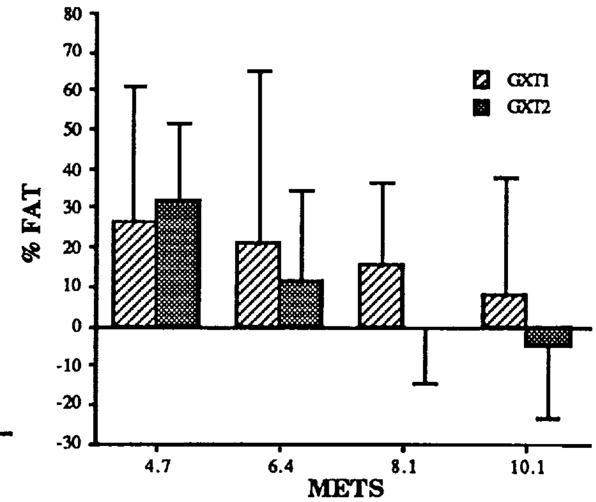

Figure 2 - %Calories from Fat

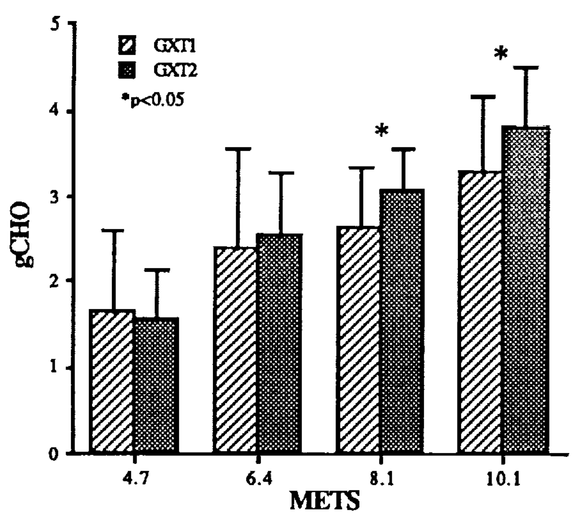

Figure 3 - Grams of Carbohydrate Burned

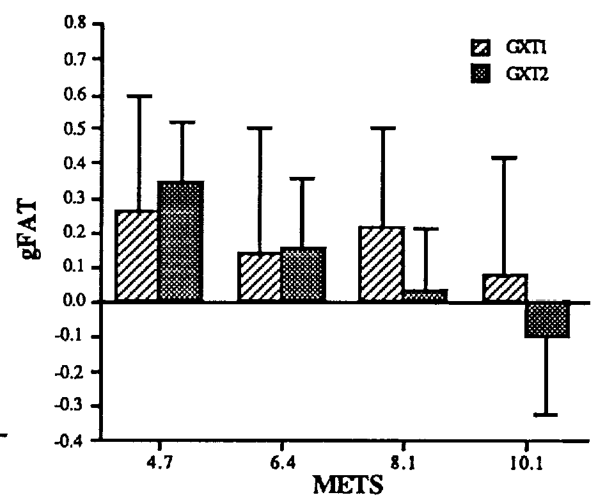

Figure 4 - Grams of Fat Burned

CONCLUSION

Results of this study suggest an increased rate of carbohydrate utilization during submaximal exercise after seven days of horizontal bed rest. This finding was more evident when carbohydrate utilization was expressed in grams rather than when expressed as a percentage of total calories burned during exercise. Therefore, fuel utilization during exercise, expressed as a percentage of total exercise caloric cost, may not be a sensitive measure of energy metabolism.

An increased rate of carbohydrate metabolism during exercise after bed rest suggests that the efficiency of aerobic energy metabolism decreased, similar to that seen with detraining, with a trend toward earlier onset of anaerobic metabolism. This earlier onset supports the findings of previous investigations in which higher submaximal RQs were seen during exercise after periods of bed rest, also indicative of anaerobic metabolism [4, 10, 11].

A shift in fuel utilization during extended duration spaceflight may prove deleterious to performance of mission tasks. A greater reliance on anaerobic energy metabolism could result in glucose depletion with prolonged activity, lactic acid accumulation, and forced, premature termination of a planned activity. Exercise countermeasures need to be designed to minimize space flight induced deconditioning and, therefore, maximize aerobic pathways for energy derivation.

REFERENCES

1. Coyle, E. F., Martin, W. H., Bloomfield, S. A., Lowry, O. H., and Holloszy, J. O. Effects of detraining on responses to submaximal exercise. *J. Appl. Physiol.* 59(3):853-859, 1985.

2. Nicogossian, A. E., Huntoon, C. L., and Pool, S. L. *Space Physiology and Medicine*, 2nd Ed. Philadelphia, PA, Lea & Febiger, 1989.

3. Greenleaf, J. E., Wade, C. E., and Leftheriotis, G. Orthostatic responses following 30-day bed rest deconditioning with isotonic and isokinetic exercise training. *Aviat. Space Environ. Med.* 60:537-542, 1989.

4. Convertino, V. A., Goldwater, D. J., and Sandler, H. Bed rest-induced peak $\dot{V}O_2$ reduction associated with age, gender, and aerobic capacity. *Aviat. Space Environ. Med.* 57:17-22, 1986.

5. Convertino, V. A., Hung, J., Goldwater, D., & DeBusk, R. F. Cardiovascular responses to exercise in middle-aged men after 10 days of bed rest. *Circulation* 65(1):134-140, 1982.

6. Convertino, V. A., Sandler, H., Webb, P., and Annis, J. F. Induced venous pooling and cardiorespiratory responses to exercise after bed rest. *J. Appl. Physiol.: Respirat. Environ. Exercise Physiol.* 52(5):1343-1348, 1982.

7. Dudley, G. A., Gollnick, P. D., Convertino, V. A., and Buchanan, P. Changes of muscle function and size with bed rest. *The Physiologist* 32(1):565-566, 1989.

8. LeBlanc, A., Gogia, P., Schneider, V., Krebs, J., Schonfeld, E., and Evans, H. Calf muscle area and strength changes after five weeks of horizontal bed rest. *Am. J. Sports Med.* 16(6):624-629, 1988.

9. Greenleaf, J. E., Van Beaumont, W., Convertino, V. A., and Starr, J. C. Handgrip and general muscular strength and endurance during prolonged bed rest with isometric and isotonic leg exercise training. *Aviat. Space Environ. Med.* 54(8):696-700, 1983.

10. Williams, D. A. and Convertino, V. A. Circulating lactate and FFA during exercise: Effect of reduction in plasma volume following

exposure to simulated microgravity. *Aviat. Space Environ. Med.* 59:1042-1046, 1988.

11. Convertino, V. A., Goldwater, D. J., and Sandler, H. $\dot{V}O_2$ kinetics of constant-load exercise following bed rest-induced deconditioning. *J. Appl. Physiol.: Respirat. Environ. Exercise Physiol.* 57(5):1545-1550, 1984.

12. Cunningham, L. N. Physiologic characteristics and team performance of female high school runners. *Pediatric Exercise Science* 1:73-79, 1989.

13. Borg, G. A. A category scale with ratio properties for intermodal and interindividual comparisons. In: *Proceedings of the 22nd International Congress of Psychology.* Leipzig: Deutscher Verlag, 1980.

14. Karpovich, P. V. and Sinning, W. E. (eds.) *Physiology of Muscular Activity*, 7th Ed. Philadelphia: W. B. Saunders Company, 1971.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	January 1992	Technical Paper

4. TITLE AND SUBTITLE
Fuel Utilization During Exercise After 7 Days of Bed Rest

5. FUNDING NUMBERS

6. AUTHOR(S)
Linda H. Barrows, Bernard A. Harris, Alan D. Moore, and Steven F. Siconolfi

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Medical Sciences Division
Space Biomedical Research Institute
National Aeronautics and Space Administration
Johnson Space Center
Houston, Texas 77058

8. PERFORMING ORGANIZATION REPORT NUMBER
S-658

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, D.C. 20546-001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
NASA TP-3175

11. SUPPLEMENTARY NOTES
L. H. Barrows and A. D. Moore (KRUG Life Sciences, Houston, Texas)
B. A. Harris and S. F. Siconolfi (NASA Johnson Space Center, Houston, Texas)

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unclassified/Unlimited
Subject Category 52

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
Energy yield from carbohydrate, fat and protein during physical activity is partially dependent on an individual's fitness level. Prolonged exposure to microgravity causes musculoskeletal and cardiovascular deconditioning; these adaptations may alter fuel utilization during space flight. Carbohydrate and fat metabolism during exercise were analyzed in this study before and after 7 days of horizontal bed rest.

14. SUBJECT TERMS
Energy yield, fitness level, cardiovascular deconditioning, fuel utilization, and carbohydrate and fat metabolism

15. NUMBER OF PAGES
08

16. PRICE CODE
A02

17. SECURITY CLASSIFICATION OF REPORT	18 SECURITY CLASSIFICATION OF THIS PAGE	19 SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Uhclassified	Unclassified	Unclassified	Unlimited