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MUSCLE GLYCOGEN, FIBER TYPE, AEROBIC FITNESS, AND ANAEROBIC CAPACITY OF WEST COAST U.S. NAVY SEA-AIR-LAND PERSONNEL (SEALS)

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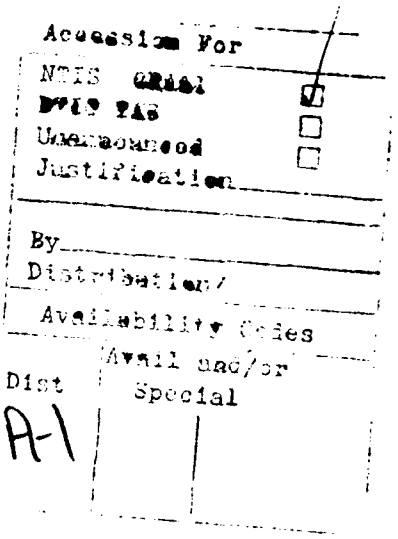

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ABSTRACT

Thirty-eight U.S. Navy Sea-Air-Land personnel (SEALs) participated in aerobic fitness and maximal anaerobic capacity tests on a cycle ergometer. Lactic acid concentration was measured in blood samples collected during the aerobic fitness test. Thirty-six subjects had biopsies taken from the *vastus lateralis* muscle after recording prior dietary intake and physical activity. The biopsy results showed that SEALs had a mean (± SD) of 55% (± 12) fast twitch muscle fiber type. The muscle samples had a mean glycogen concentration of 404 (± 124) $mmol \cdot kg^{-1}$. Dietary carbohydrate intake over the two days preceding the biopsy was significantly ($p < 0.01$) correlated with extant muscle glycogen concentration. The results of the biopsy indicate that SEALs have an unremarkable fiber type composition (55% ± 12% fast twitch) and a muscle glycogen concentration (404 ± 128 $mmol \cdot kg^{-1}$) that may put them at risk of insidious glycogen depletion over successive deployment days. Muscle glycogen concentration was significantly ($p < 0.01$) correlated with prior two-day dietary carbohydrate intake normalized for body weight ($n = 21$; $r = 0.63$). The blood lactate concentration during submaximal exercise suggests that SEALs' aerobic fitness was somewhat lower than expected for elite military personnel, approximately equal to that of male college physical education students. The anaerobic capacity tests indicate that SEALs demonstrate only moderate anaerobic fitness. Overall, the results of this study suggest that SEALs would benefit from: a) increasing carbohydrate intake to enhance pre-mission muscle glycogen concentrations (e.g., through dietary carbohydrate supplementation); and b) engaging in combined aerobic and anaerobic training programs that use established scientific principles governing the implementation of mode specificity, frequency, intensity, and duration of exercise.

INTRODUCTION

Several reports have documented the body composition, physical performance, and associated physiological characteristics of personnel in conventional military units (for review, see Vogel, 1985). The mission requirements of elite combat personnel pose demands for exceptional aerobic fitness and muscular power. Typically, physical fitness tests that include aerobic and strength fitness measures are used to evaluate candidates for entry into such units (e.g., BUPERS Manual 1410-380 for U.S. Navy Sea-Air-Land personnel [SEALs], AR 614-200 Ch. 6 Sect. 4 for U.S. Army Special Forces). Coupled with the regular, rigorous physical training that such units undergo, it is not surprising that Special Forces personnel do exhibit high fitness levels (e.g., Muza, et al., 1987; Beckett, et al., 1989; Jacobs, et al., 1989).

Although it is accepted in scientific circles that skeletal muscle fiber characteristics (e.g., fiber type and muscle glycogen concentration) are related to certain fitness components, the requirement for invasive procedures has hampered direct determination of these characteristics in SEALs. Anthropometric characteristics, standardized physical fitness test scores, and physical training patterns of SEALs have been reported previously (Beckett, et al., 1989; Prusaczyk, et al., 1990). This report extends the existing descriptive information about SEALs to include aerobic and anaerobic fitness using current technologies and techniques. In addition, percutaneous muscle biopsies obtained from the leg musculature were analyzed for the relative proportion of slow twitch and fast twitch muscle fibers and the concentration of muscle glycogen.

METHODS

Subjects.

The subjects were volunteers recruited from the instructors at the Naval Special Warfare Center (NAVSPECWARCEN); members of SEAL Teams One, Three, and Five; and SEAL Delivery Vehicle (SDV) Team One at Naval Special Warfare Group One, Naval Amphibious Base Coronado, California. After being informed of the

details of the study and the associated risks and discomforts, all subjects read and signed an informed consent form. The protocol for this study was approved by the Naval Health Research Center's Committee for the Protection of Human Subjects.

Thirty-eight SEALs volunteered to participate: 24 instructors at NAVSPECWARCEN; 12 members of SEAL Teams One, Three and Five; and 2 SDV operators. The mean (± SD) age, height, and weight for all subjects were 33 (± 5) years, 180 (± 5) cm, and 82.6 (± 7.9) kg, respectively.

Muscle Biopsies.

Thirty-six of the subjects volunteered for the biopsy procedures. After administering a local anaesthetic (lidocaine, 10 $mg \cdot ml^{-1}$, mixed with 1:100,000 epinephrine) to the skin and underlying fascia, a biopsy of the *vastus lateralis* muscle was performed using the percutaneous needle technique (Bergström, 1962). The tissue sample (~60 mg) was immediately divided into two pieces. One piece was frozen in liquid nitrogen (-190°C) for subsequent determination of glycogen concentration. The second piece was mounted in an embedding medium (OCT) and frozen in isopentane (-170°C) cooled with liquid nitrogen for subsequent histochemical staining. All samples were packed in dry ice, shipped to the Defence and Civil Institute of Environmental Medicine, Toronto, Canada, and stored at -80°C until analyzed.

Each muscle tissue sample used for the glycogen assay was freeze-dried. Three pieces of each sample were then dissected free of dried blood, connective tissue, and fat. Each piece was hydrolyzed in hydrochloric acid (1 N), and glycogen assayed as glucose residues using an enzymatic fluorometric method (Karlsson, 1971). Muscle glycogen concentration was expressed as the mean concentration of the three pieces assayed. The coefficient of variation for glycogen determination among pieces from the same sample was 5.2%.

The OCT-embedded tissue samples were cut into 10 μm sections using an AO Histostat® microtome at -20°C. The proportion of fast twitch (FT) and slow twitch (ST) fibers was determined from histochemical stains for myofibrillar ATPase activity (Brooke and Kaiser, 1970; Doriguzzi, et al., 1983).

At the time the biopsy was taken, subjects completed a form documenting their physical training and nutritional intake histories for the 36-48 hours preceding the biopsy.

Aerobic Fitness Test.

Aerobic endurance performance was evaluated based on the blood lactate response to a progressive load-incremented cycle exercise test. Exercise was performed on a mechanically braked bicycle ergometer (Monark) at a pedalling rate of 60 $rev \cdot min^{-1}$. Power output began at 60 W and was increased in a step-wise fashion by 60 W at the end of each fourth minute. The test continued until the subject could not maintain 60 $rev \cdot min^{-1}$. To arterialize the capillary blood sampled during exercise, an ointment (Finalgon®) which causes local vasodilation and hyperemia, was applied to one ear lobe. Following a 10-minute wait to insure hyperemia, the ear lobe was cleaned of remaining ointment and a small incision (≈ 5 mm) was made on the inferior edge of the ear lobe. Patency of the incision was maintained during exercise by covering the ear lobe with an isopropyl alcohol-soaked gauze pad. Once prior to exercise (resting) and at the end of each power output stage (i.e., every fourth minute), 20 μL of blood were collected in a capillary tube from the incision, expelled into 0.4 $mmol \cdot L^{-1}$ perchloric acid, and stored at -80°C until assayed for lactate concentration (Maughan, 1982). Respiratory gas exchange (Sensormedics® Horizon 4400 Metabolic cart), heart rate (Polar heartwatch), and subjective ratings of perceived exertion (Noble, et al., 1983) were determined during the final 30 seconds of each power output.

Anaerobic Fitness Test.

Following the aerobic fitness test, the subjects were allowed to recover for 90 minutes. The ability to transduce energy to the thigh musculature via anaerobic energy metabolism was evaluated by determining the maximal oxygen deficit accumulated during a short (~ 2 min) cycle exercise test. The subjects exercised at a power output calculated to elicit 120% of the peak oxygen uptake determined during the aerobic fitness test. Based on the results of the aerobic fitness test, individual linear regression equations of oxygen uptake versus power output were calculated; thus, the oxygen demand (i.e., the aerobic component) of the anaerobic fitness test was known for each individual. During this test, the subjects pedalled the ergometer at a frequency of 75 rev·min^{-1}. Oxygen uptake ($\dot{V}O_2$) was monitored during the test (Sensormedics® Horizon 4400 Metabolic cart). The difference between the $\dot{V}O_2$ elicited and the calculated oxygen demand of exercise was considered to be the maximal oxygen deficit (Medbø, et al., 1988). Following this test, subjects recovered by pedalling at 37 W for five minutes.

RESULTS AND DISCUSSION

MUSCLE BIOPSY RESULTS

Muscle Fiber Type Composition. The mean (± SD) fiber type composition (percent FT) of SEALs in this study was 55% (± 12%), ranging from 27% to 87%. The fiber type composition appears to be normally distributed (Figure 1). Other studies of elite combat units have reported *vastus lateralis* muscle fiber type compositions of 60% (± 11%) FT in 30 Canadian Forces (CF) infantry commandos (Jacobs, et al., 1989), and 48% (± 11%) FT in 21 Swedish coastal commandos.[1] The proportion of FT fibers in this sample is slightly greater than that reported for civilian populations (see Saltin and Gollnick, 1983).

Insert Figure 1 about here

[1] Jacobs, unpublished data.

The relevance of muscle fiber type composition to physical performance is based upon the metabolic and contractile property differences between ST and FT fibers (see Saltin and Gollnick, 1983, for detailed review). In general, a muscle composed of a large percentage of ST fibers has fatigue-resistant contractile characteristics, and a metabolic profile conducive to aerobic energy transduction. In contrast, a muscle high in FT fibers reaches peak tension almost twice as fast as one with predominantly ST fibers, and the FT fiber metabolic profile favors energy transduction via anaerobic glycolysis and glycogenolysis. Thus, muscles with a large proportion of ST fibers are advantageous for prolonged, endurance-type activities; on the other hand, musculature high in FT fibers is advantageous for explosive power generation. In terms of performance prediction, prior knowledge of muscle fiber type is of limited value because fiber type proportions are primarily genetically determined (Komi, et al., 1977); however, fiber type composition may be a good indicator of a muscle's ability to adapt to a specific type of physical training.

Muscle Glycogen. Mean muscle glycogen concentration was 404 (± 124) $mmol \cdot kg^{-1}_{dry\ weight}$, and ranged from 170 to 679 $mmol \cdot kg^{-1}_{dry\ weight}$ (Figure 2). The broad range was likely due in part to the lack of control over diet and physical activity prior to the biopsy. Figure 3 shows that the SEALs' mean muscle glycogen concentration is lower than, but similar to, values previously reported for well-fed and well-rested infantry commandos in Sweden (570 $mmol \cdot kg^{-1}$; Jacobs, et al., 1983a) and Canada (412 $mmol \cdot kg^{-1}$; Jacobs, et al., 1989).

Insert Figures 2 & 3 about here

The resting muscle glycogen concentration of untrained, sedentary individuals has been reported to range from 348 to 435 $mmol \cdot kg^{-1}$ (Bergström and Hultman, 1967; Hultman, 1967). Aerobically-trained individuals consuming a diet of approximately 45% to 50% carbohydrates have been reported to have muscle glycogen concentrations ranging from 565 to 587 $mmol \cdot kg^{-1}$. Furthermore, it is possible for endurance athletes to achieve supercompensated muscle glycogen

concentrations of 740 to 910 mmol·kg^{-1} after resting several days and consuming a high carbohydrate diet (see Conlee, 1987).

Resting muscle glycogen concentrations are affected by both short-term and long-term exercise and dietary intake histories (Costill, et al., 1981). Physical training histories obtained prior to the biopsies in this study revealed that the subjects engaged in a wide variety of exercise modes, intensities, frequencies, and durations. Exercise modes reported by the SEALs included running, cycling, soccer, volleyball, Versiclimber®, calisthenics, and weightlifting. These activities are consistent with the training habits of a larger sample (n = 102) of West Coast SEALs (Prusaczyk, et al., 1990). In the present study, the majority of subjects (58%) were engaged in a daily program of lower body endurance exercise that was classified as "light" in volume (i.e., three to four miles running, or five to ten miles cycling, per day). Only 8% were engaged in daily heavy-volume training (eight to fifteen miles running). Most of the subjects also engaged in regular upper body resistance training.

Records of dietary intake and physical training activities during the previous 36 hours were collected on a subsample (n=21) of subjects. Their mean daily diet was estimated to contain 84 ± 56 g protein (20% of total calories), 55 ± 35 g fat (29% of total calories) and 224 ± 126 g carbohydrate (51% of total calories). This is consistent with findings from a study of the dietary habits of west coast SEALs,[2] which estimated a daily intake of 240 g of carbohydrate (42% total calories). This modest intake of carbohydrate is substantially below the 8-10 g·kg^{-1} body wt. (i.e., 640-800 g for the average 80 kg SEAL) recommended for athletes to facilitate rapid repletion of muscle glycogen stores (Costill, et al., 1981).

[2] Goforth, H.W., unpublished data

It is of some interest that eight SEALs (22%) exhibited resting muscle glycogen concentrations of less than 320 $mmol \cdot kg^{-1}_{dry\ weight}$., which is slightly below that reported for untrained, sedentary individuals (348-435 $mmol \cdot kg^{-1}$) (Bergström and Hultman, 1967; Hultman, 1967). During the pre-biopsy period (36 hours), these eight SEALs had engaged in moderate-to-heavy exercise and consumed a diet estimated to contain less than 126 g of carbohydrate.

In contrast, six SEALs (19%) had resting muscle glycogen levels between 500 and 650 $mmol \cdot kg^{-1}_{dry\ weight}$, which approximates the values reported for trained individuals consuming a diet containing 45-50% carbohydrate (Sherman, 1987). In comparison to the eight SEALs above, the diet of these subjects contained much larger amounts of carbohydrate (i.e., 378 ± 158 g or 54% of total calories). Among the subset of SEALs with dietary intake data, the muscle glycogen concentration was significantly correlated ($r = +0.62$; $p < 0.01$) with prior 24-hour dietary carbohydrate intake normalized (i.e., $kg^{-1}_{body\ weight}$) for body weight (Figure 4).

Insert Figure 4 about here

If the muscle glycogen concentrations seen in this study represent the range typically found in the SEAL population, then a substantial number of SEALs could be relatively glycogen-depleted at any point in time. Further, if these individuals were required, on short notice, to participate in activities demanding high rates of energy expenditure for prolonged periods, they would reach glycogen depletion states (muscle glycogen concentrations associated with physical performance impairments) earlier than SEALs with higher initial glycogen concentrations. Physical performance impairments associated with this type of glycogen depletion have been demonstrated in both laboratory and field settings (Bergström, et al., 1967; Hermansen et al., 1967; Karlsson and Saltin, 1971). Glycogen depletion could negatively affect the success of missions requiring time-dependent coordination of unit movements. Achieving a greater degree of nutritional homogeneity and physical/mission training activities to maintain high

levels of resting muscle glycogen concentrations and of physical fitness, may be beneficial to SEAL performance and aid in mission accomplishment (see Jacobs, 1987).

SEAL missions also can require an individual to engage in high-intensity exertion on several consecutive days. It has been well documented that, given such a scenario, muscle glycogen levels can become progressively lower with each succeeding day (Costill, et al., 1971). Therefore, performance impairments associated with glycogen depletion could occur progressively earlier into each mission segment on successive days of the operation. It is also likely that self-paced work intensity would be reduced due to the decreased availability of glycogen in the exercised muscles (Saltin, 1972; Askew, et al., 1987). This problem could be further exacerbated by the possibility that, during a prolonged mission, carbohydrate intake, and nutrient intake in general, could be limited.

Glycogen depletion and its associated physical performance impairments may occur even earlier than expected during missions involving prolonged cold stress, a situation occurring commonly during SEAL training and operations. Recently, some studies (Martineau and Jacobs, 1988; Martineau and Jacobs, 1989), but not all (Young, et al., 1989), have found that intramuscular glycogen utilization due to shivering is greater during exercise with cold stress than when metabolic rates are elevated similarly during physical exercise without cold stress. Glycogen depletion in large skeletal muscle groups also appears to be detrimental to regulation of core body temperature during cold stress (Martineau and Jacobs, 1989). Once an individual is cold enough to shiver, even light work in a cold environment results in greater glycogen utilization than work performed without cold stress (Jacobs, et al., 1985).

AEROBIC AND ANAEROBIC FITNESS TEST RESULTS

Aerobic Fitness Indicators. For descriptive purposes, group mean values of aerobic fitness indicators (metabolic and perceptual) monitored during the aerobic fitness tests are presented in Table 1, and graphically in Figures 5 through 8. These values represent a relatively steady-state condition, because an individual's data were included in the analysis only if he was able to complete a full four minutes of exercise at a specific power output.

Insert Table 1 about here

Insert Figures 5 through 8 about here

The kinetics of blood lactate accumulation during exercise are an accurate predictor of endurance exercise capacity (see Jacobs, 1986 for a review). Physiological strain during exercise can be accurately equated among subjects by comparing lactate concentrations at a specific absolute exercise intensity. Conversely, aerobic fitness can be evaluated by calculating the exercise intensity required to produce a specific blood lactate concentration (i.e., the higher the power output required, the more aerobically fit the subject). Several previous studies have used a lactate concentration of 4 $mmol \cdot L^{-1}$ as the reference point to evaluate aerobic fitness (e.g., Jacobs, et al., 1983b; 1985).

In the present study, the mean lactate concentration at each power output was used to calculate a regression equation best describing the relationship between lactate concentration and power output. Figure 9 shows the curve of best-fit using an exponential equation. From this curve, the power output associated with a 4 $mmol \cdot L^{-1}$ blood lactate concentration was calculated. In Figure 10, this calculated lactate concentration is compared with published values for other population samples tested using similar procedures. The results suggest that the SEALs participating in this study had an aerobic fitness level comparable to that of male physical education students. In light of how well lactate concentration is related to endurance exercise performance (Jacobs, 1986), it was concluded that the aerobic fitness of the SEALs in this study was

only average, and well below that which would be expected of elite combat personnel who have engaged in appropriate aerobic fitness training.

Insert Figures 9 & 10 about here

Anaerobic Capacity Tests. The mean maximal oxygen deficit was 41 (± 12) $mL \cdot kg^{-1}_{body\ weight}$, ranging from 22 to 68 $mL \cdot kg^{-1}_{body\ weight}$. Figure 11 shows the mean maximal oxygen deficit for SEALs in this study compared to mean values recently reported for other samples. The use of maximal oxygen deficit to evaluate anaerobic capacity is relatively new, and most investigators have employed treadmill running as the exercise mode. Treadmill exercise typically results in a 30% higher peak oxygen deficit than does cycling, primarily because of the larger muscle mass recruited (Medbø and Tabata, 1989). Thus, to facilitate comparisons, Figure 11 includes both actual SEAL cycle exercise values and a "corrected" value (30% higher). The corrected mean maximal oxygen deficit for SEALs is similar to that reported for healthy, but relatively untrained, male college students. With a few exceptions in which individuals displayed values typical of sprint-trained athletes, these SEALs' performance reflected only a moderate level of anaerobic fitness.

Insert Figure 11 about here

CONCLUSIONS AND RECOMMENDATIONS

This report documents the muscle fiber type composition and glycogen concentration in the *vastus lateralis* (quadriceps) muscle of a sample of West Coast SEALs. It also presents selected physiological responses of SEALs to laboratory tests of aerobic and anaerobic physical fitness components.

The results of the study suggest that the ability of these SEALs to perform prolonged endurance exercise, as well as the generation of maximal muscular power for short periods, is not consistent with that expected of an elite combat unit.

The capacity for individual adaptation to physical training is, in large part, one of genetic predisposition, and cannot be controlled. However, factors critical in the physiological adaptation to training *can* be controlled. Among these are the mode, frequency, intensity, and duration of physical training. It appears that insufficient attention has been paid among SEALs to one or more of these controllable factors. Further, given the existing state of aerobic and anaerobic fitness among these SEALs, inadequate attention has been paid to pre-mission/training nutrition. The relatively low muscle glycogen concentrations found in this sample suggest the potential for glycogen-depletion-related performance decrements early into strenuous and/or prolonged military operations. Enhancement of muscle glycogen stores could be achieved by increasing the SEALs' dietary carbohydrate intake, perhaps by advocating the consumption of glucose polymer beverages.

In order for SEALs to complete mission-critical tasks optimally, it is essential that they be optimally trained for the aerobic and anaerobic requirements of those tasks. To maximize the benefits gained from physical training programs designed for the development and maintenance of peak fitness, it is also critical that nutrition programs be implemented that emphasize the relationship to physical performance. Achievement of these goals requires the continuing education of SEAL commands, SEAL instructors, SEAL platoon leaders, and the individual SEAL operator in the scientific fundamentals of physical training and performance nutrition.

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Table 1. Physiological, metabolic, and perceptual responses to the incremental aerobic fitness test. Values are mean ± SEM.

Power Output (W)	Subjects (n)	Oxygen Uptake ($mL \cdot min^{-1}$)	Heart Rate ($beats \cdot min^{-1}$)	RPE* (Borg Scale)	Lactate ($mmol \cdot L^{-1}$)
60	38	1189 ± 43	96 ± 2	1.0 ± 0.1	1.2 ± 0.1
120	38	1789 ± 25	118 ± 3	2.4 ± 0.1	1.7 ± 0.1
180	38	2477 ± 27	140 ± 2	3.8 ± 0.2	3.1 ± 0.2
240	35	3211 ± 34	162 ± 2	5.8 ± 0.3	5.6 ± 0.4
300	11	4114 ± 82	170 ± 4	8.5 ± 0.5	7.7 ± 0.7

* RPE = Ratings of Perceived Exertion

FIGURE LEGENDS

1. Frequency distribution of fiber type compositions in *vastus lateralis* muscle of SEALs.

2. Mean muscle glycogen concentrations in the *vastus lateralis* muscle of SEALs. Mean ± SEM is displayed.

3. Mean muscle glycogen concentration of SEALs compared with other rested, well-fed, elite combat units.

4. Relationship between muscle glycogen concentration and dietary carbohydrate intake.

5. Oxygen uptake at the end of four minutes of exercise at various power outputs. Values are means ± SEM.

6. Heart rate at the end of four minutes of exercise at various power outputs. Values are means ± SEM.

7. Ratings of perceived exertion after four minutes of exercise at various power outputs. Values are means ± SEM.

8. Blood lactate concentration at the end of four minutes of exercise at various power outputs. Values are means ± SEM.

9. Exponential regression of mean lactate concentration vs. power output of SEALs. This regression was used to estimate the power output eliciting a 4 $mmol \cdot L^{-1}$ lactate concentration ($y = 0.704 + 10^{0.2213x}$; $R^2 = 0.99$).

10. Power output at 4 $mmol \cdot L^{-1}$ blood lactate concentration for various groups during cycle exercise.

11. Maximal oxygen deficit in various groups of male subjects.

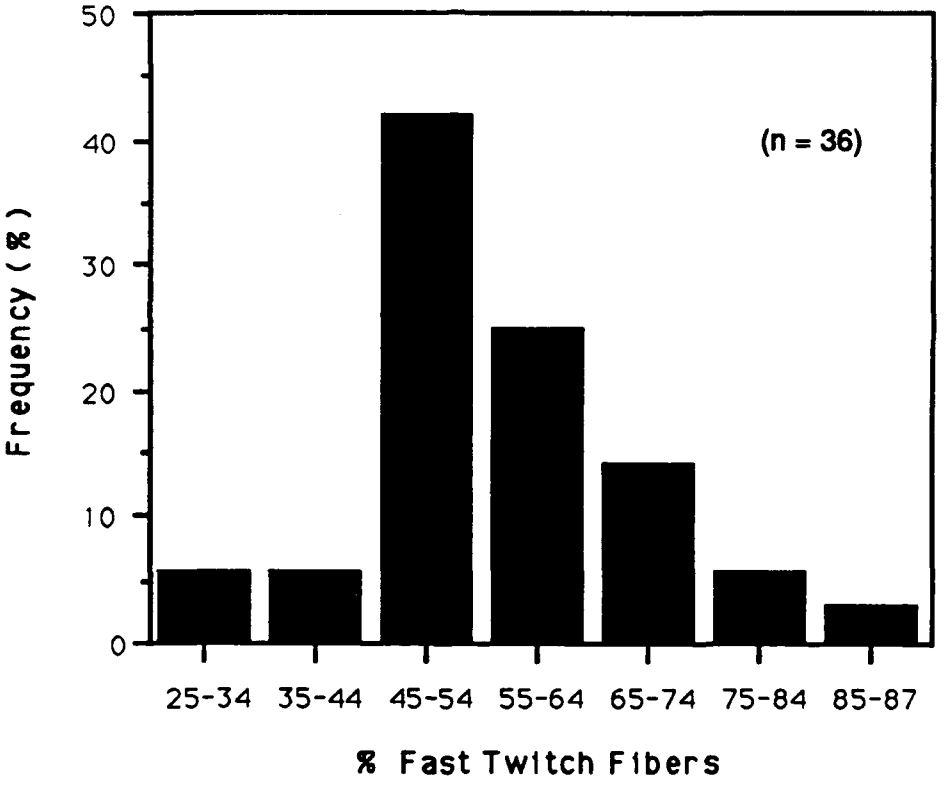

Figure 1. Frequency distribution of fiber type compositions in *vastus lateralis* muscle of SEALs

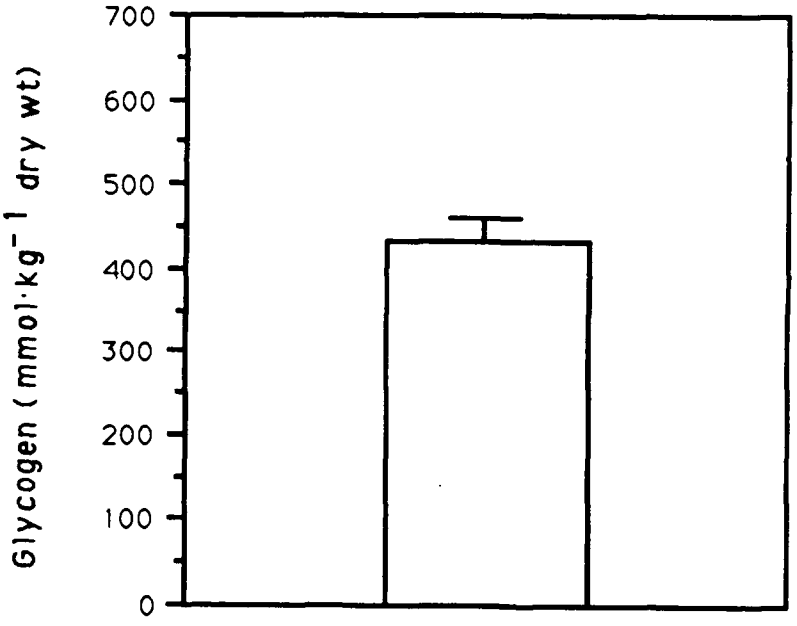

Figure 2. Mean muscle glycogen concentrations in the *vastus lateralis* muscle of SEALs. Mean ± SEM is displayed.

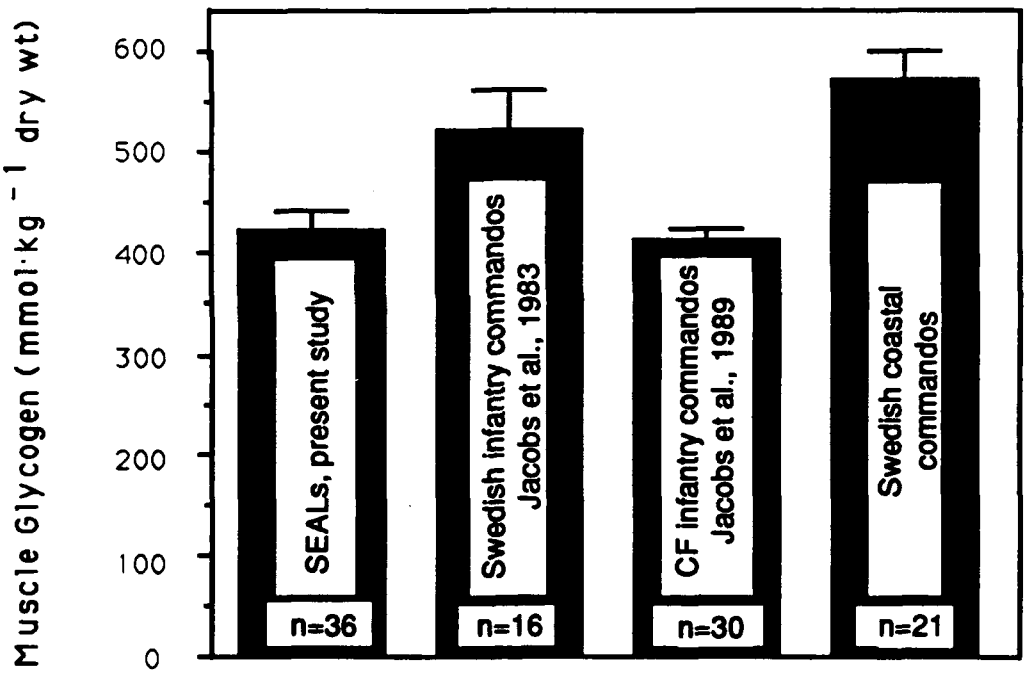

Figure 3. Mean muscle glycogen concentration of SEALs compared with other rested, well-fed, elite combat units.

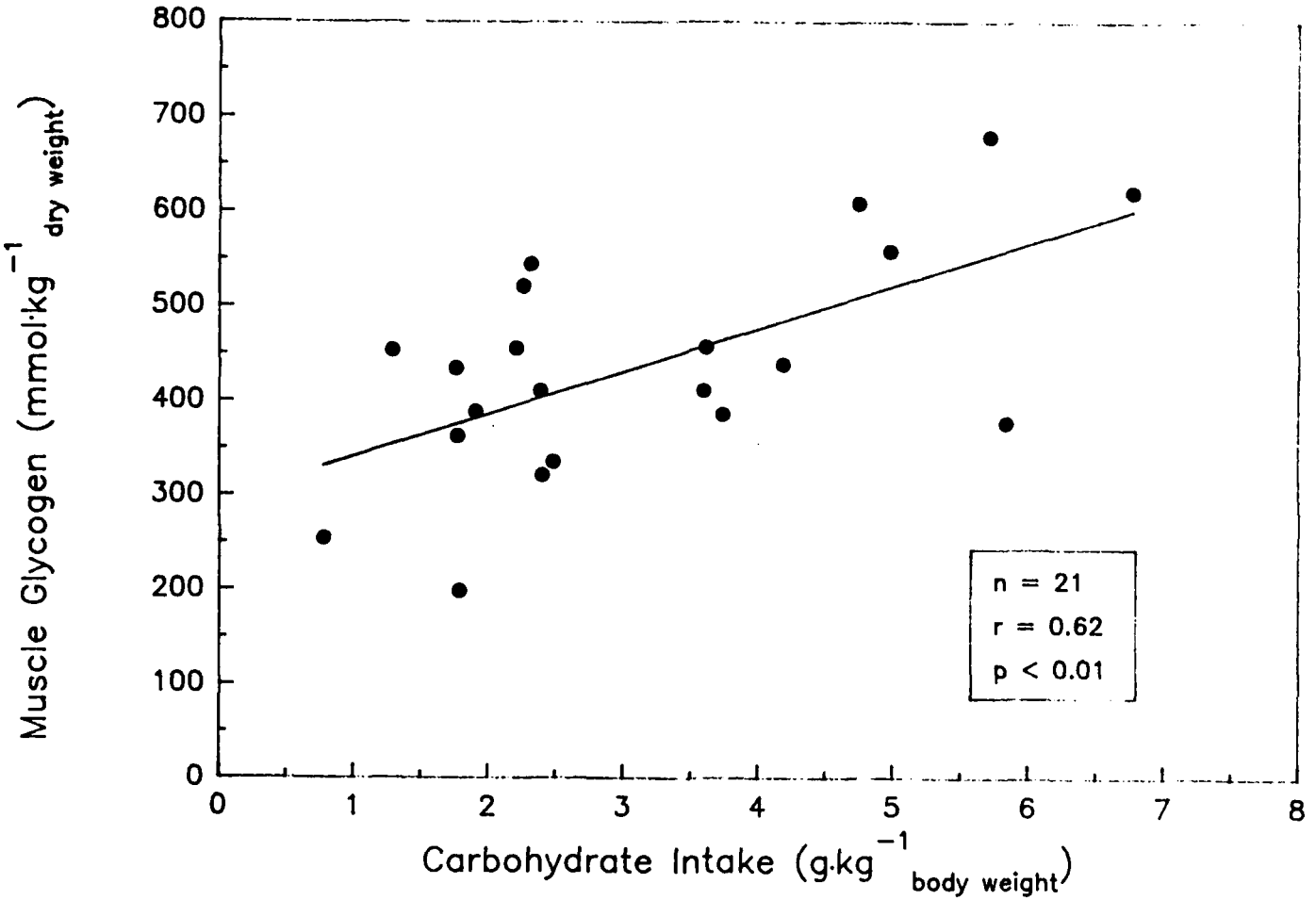

Figure 4. Relationship between muscle glycogen concentration and dietary carbohydrate intake in SEALs.

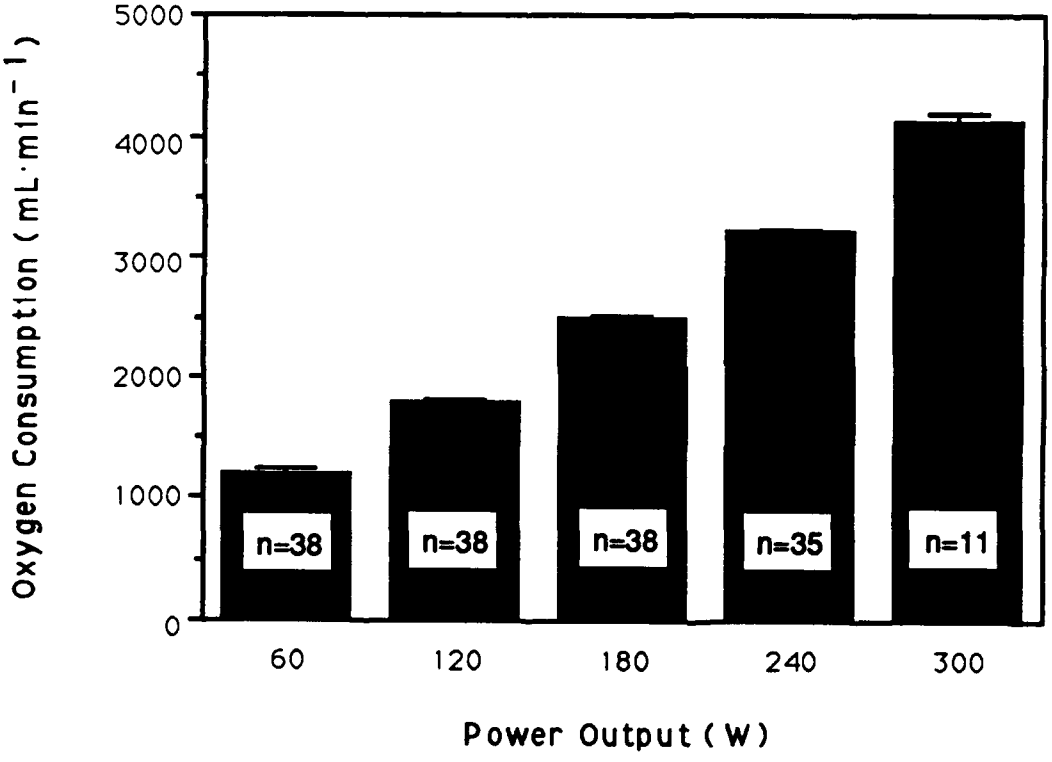

Figure 5. Oxygen uptake at the end of four minutes of exercise at various power outputs. Values are means ± SEM.

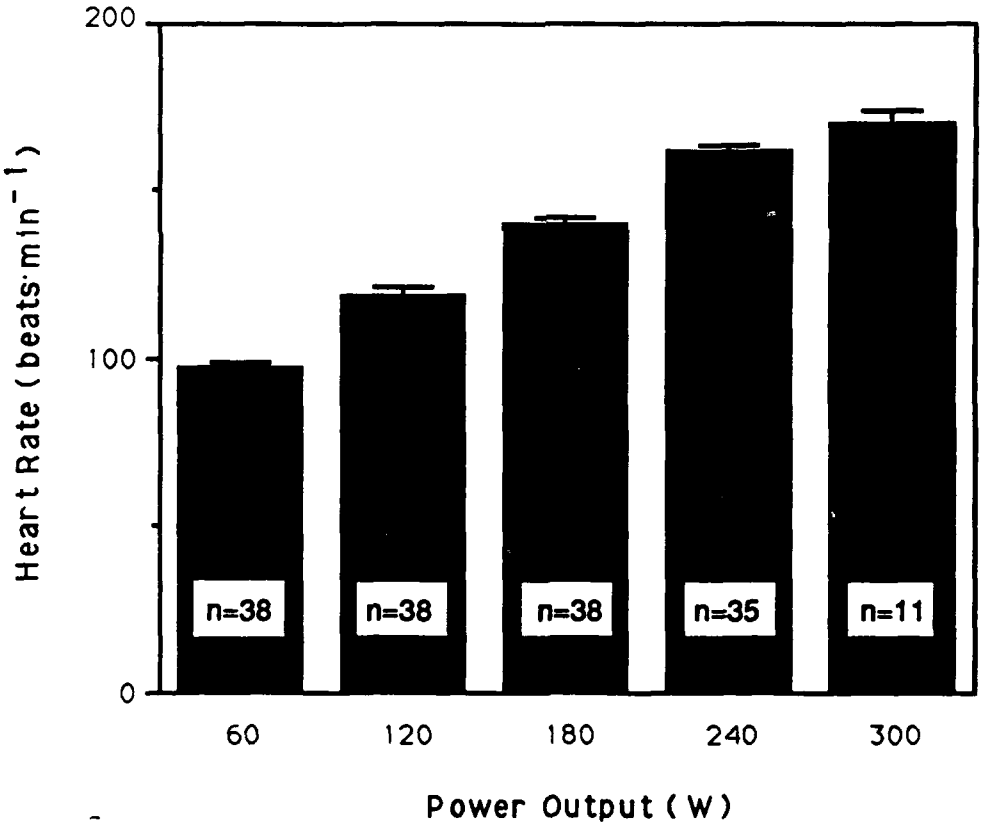

Figure 6. Heart rate at the end of four minutes of exercise at various power outputs. Values are means ± SEM

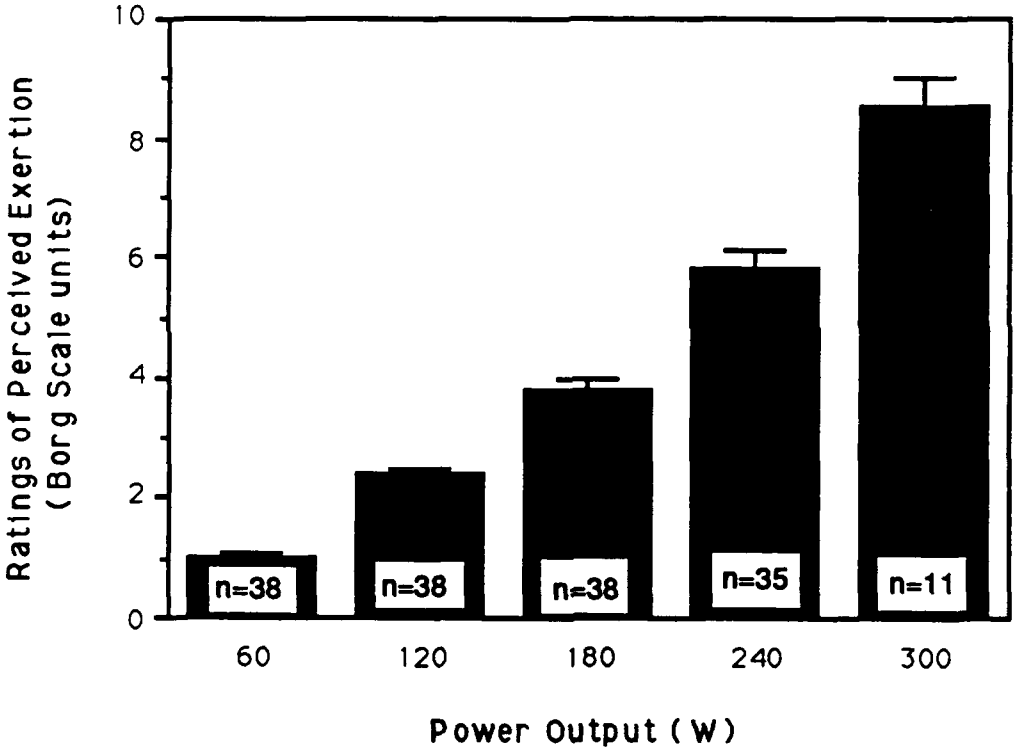

Figure 7. Ratings of perceived exertion after four minutes of exercise at various power outputs. Values are means ± SEM.

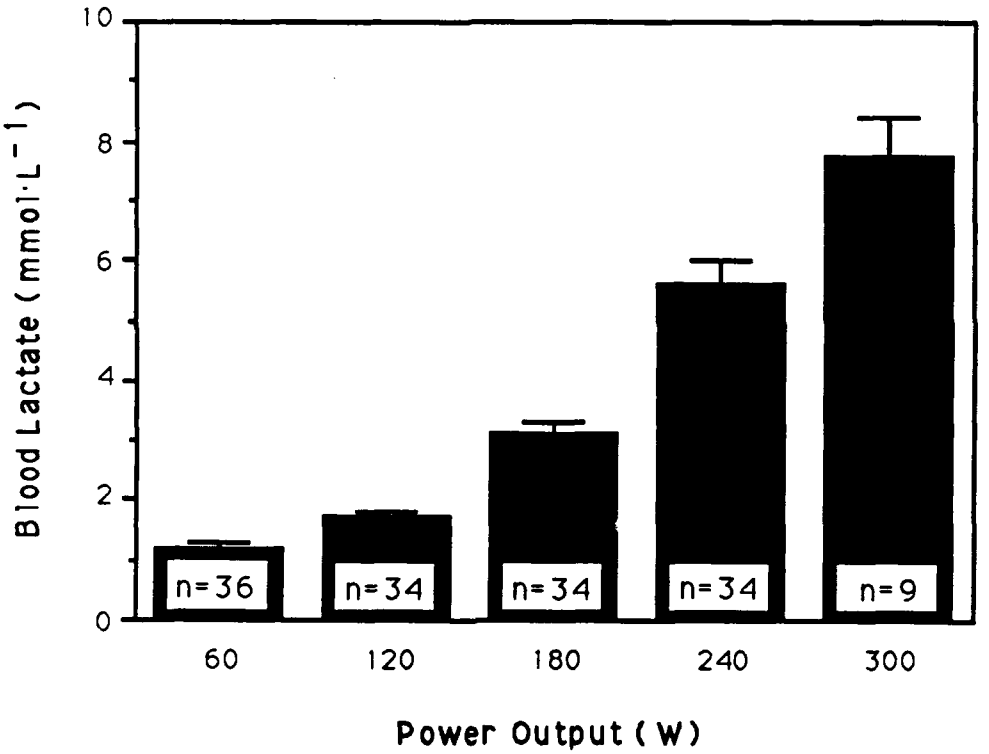

Figure 8. Blood lactate concentration at the end of four minutes of exercise at various power outputs. Values are means ± SEM.

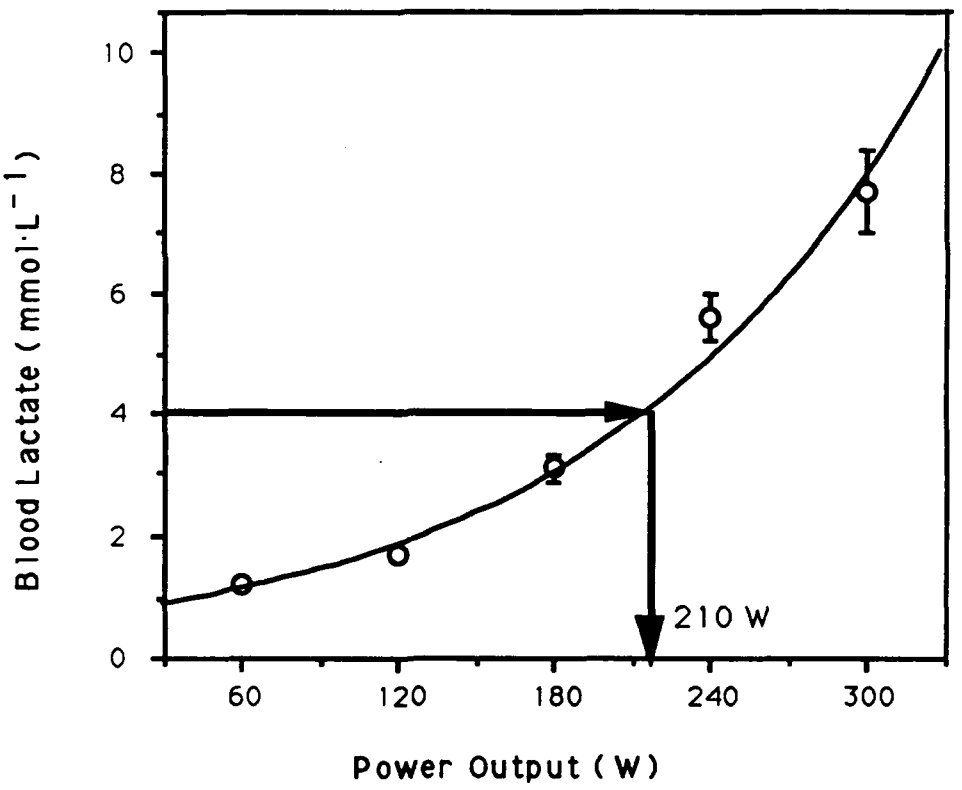

Figure 9. Exponential regression of mean lactate concentration vs. power output of SEALs. This regression was used to estimate the power output eliciting a 4 mmol·L^{-1} lactate concentration.

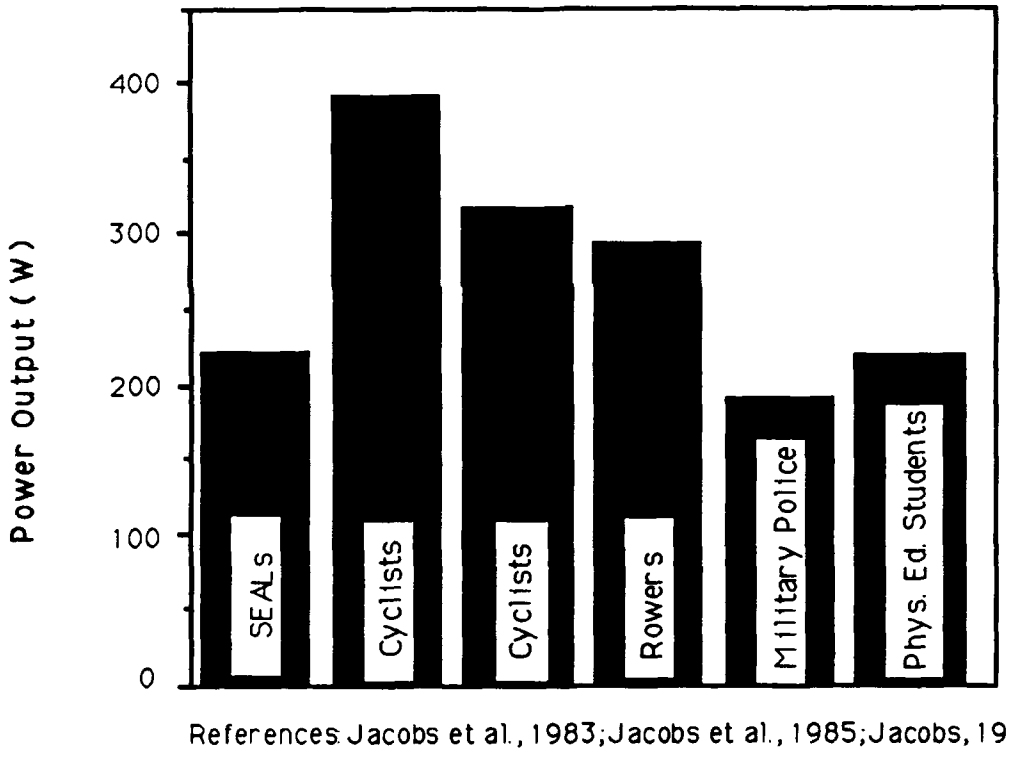

Figure 10. Power output at 4 mmol·L^{-1} blood lactate concentration for various groups during cycle exercise.

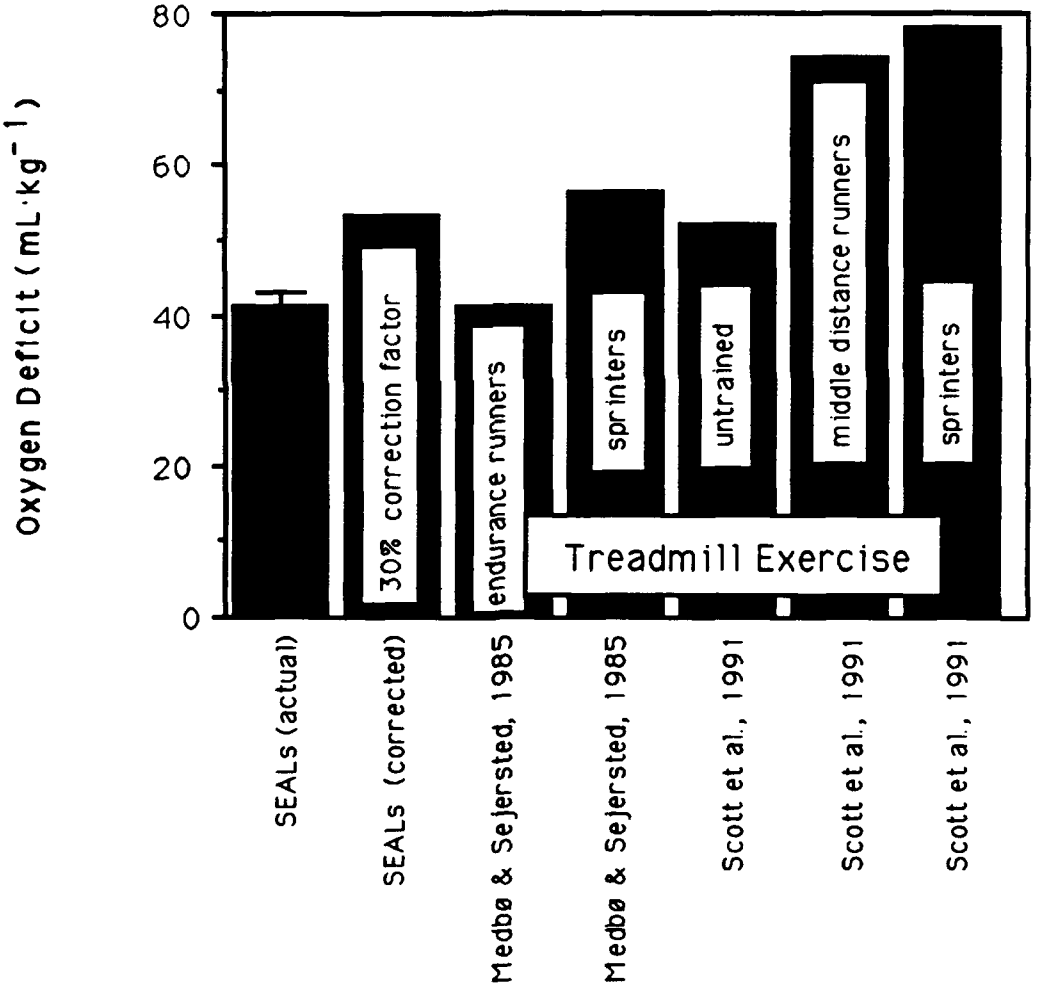

Figure 11. Maximal oxygen deficit in various groups of male subjects.

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13. ABSTRACT *(Maximum 200 words)* Thirty-eight Navy SEALs performed aerobic fitness and maximal anaerobic capacity tests on a cycle ergometer. Lactic acid concentration was measured in blood samples taken during the aerobic fitness test. After recording prior dietary intake and physical activity, thirty-six subjects had biopsies taken from the vastus lateralis muscle. Biopsy results showed that SEALs averaged 55% fast twitch muscle fiber type. The muscle samples had a mean glycogen concentration of 404 $mmol \cdot kg^{-1}$. Biopsy results show that SEALs have an unremarkable fiber type composition and a muscle glycogen concentration that may put them at risk of insidious glycogen depletion over successive deployment days. Muscle glycogen concentration was significantly correlated with 2-day dietary carbohydrate (CHO) intake normalized for body weight. Blood lactate concentration during submaximal exercise suggests that SEALs' aerobic fitness was somewhat low; anaerobic capacity tests show that SEALs would benefit from: (a) increasing CHO intake to enhance pre-mission muscle glycogen; and (b) engaging in combined aerobic/anaerobic training using established principles of mode specificity, frequency, intensity, and duration of exercise.

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