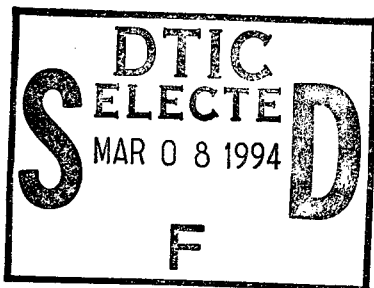


NAVAL HEALTH RESEARCH CENTER

ADAPTATIONS TO THREE WEEKS OF AEROBIC/ANAEROBIC TRAINING IN WEST COAST U.S. NAVY SEA-AIR-LAND PERSONNEL (SEALS)



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SUMMARY

Problem.

The physical demands of U.S. Navy Special Warfare missions require that Sea-Air-Land personnel (SEALs) maintain high aerobic and anaerobic fitness. SEAL missions can involve prolonged periods of low-intensity work, fueled predominantly by aerobic metabolism, interspersed with short, high-intensity activity fueled predominantly by anaerobic metabolism. With the extensive commitment to operational training, physical training time can be limited, but must be appropriate to meet the diverse job requirements.

Objective.

The objective of this study was to test the hypothesis that engaging in short-term training at a single, appropriately chosen exercise intensity would elicit simultaneous improvement of aerobic and anaerobic exercise capacity. Training programs were developed to efficiently enhance both aerobic and anaerobic fitness by training at a single average exercise intensity.

Approach.

Thirty-eight SEALs matched on aerobic and anaerobic fitness, were assigned to one of three cycling training groups: 1) Continuous (CNT) training at 70% of peak oxygen consumption ($\dot{V}O_{2peak}$) for 30 min three times per week, 2) Intermittent (INT) training for 10 sequential 3 min bouts with 2 min at 50% and 1 min at 110% $\dot{V}O_{2peak}$ (averaging 70% $\dot{V}O_{2peak}$ over the 30 min), and 3) Supramaximal (SMX) training with 3 to 5 maximal effort sprints distributed over 30 min of low-intensity exercise (105 W). Prior to and following three weeks of training, subjects

performed progressive, load incremented cycle tests to assess indicators of aerobic fitness, and a short, maximal effort (~2.5 min) test to assess anaerobic fitness. Changes in time to exhaustion (TE), $\dot{V}O_{2peak}$, submaximal blood lactate (LA) concentrations, and maximal oxygen deficit were used to evaluate and compare the training programs.

Results.

At three weeks, 20 subjects (53%) remained having a sufficient training volume to be included in the analyses. Following training, there were no significant changes in $\dot{V}O_{2peak}$, but TE was increased ($p \leq 0.05$) from 18.1 to 19.3 min for all subjects, with no differences among groups. LA concentrations at two submaximal exercise intensities were decreased ($p \leq 0.05$) after training, dropping from 3.3 to 2.1 mmol \cdot l $^{-1}$ at 180 W (n=20) and from 6.2 to 4.3 mmol \cdot L $^{-1}$ at 240 W (n=18). Maximal oxygen deficit was increased ($p \leq 0.05$) from 38 to 46 mL oxygen equivalent \cdot kg $^{-1}$ body weight for INT and SMX, but did not change for CNT.

Conclusions.

This study demonstrated that training at a single, appropriately chosen exercise intensity and program can elicit simultaneous improvement of aerobic and anaerobic exercise capacity, and thus use available training time more efficiently. The results also suggest that both aerobic and anaerobic training adaptations can occur more rapidly than traditionally believed.

INTRODUCTION

The physical demands of Navy Special Warfare (NSW) missions require that Sea-Air-Land personnel (SEALs) maintain high levels of aerobic and anaerobic fitness. NSW missions can involve prolonged periods of low-intensity work, during which the active musculature is fueled by aerobic metabolism, interrupted by short intervals of high-intensity bouts fueled by anaerobic metabolism. Therefore, SEALs are required to maintain both aerobic and anaerobic fitness to be fully mission capable.

Training time is limited for NSW personnel. SEALs, for example, must devote most of their time to developing and maintaining diverse operational skills and abilities (e.g., parachuting, fast roping, ship/oil rig boarding, land navigation, explosive demolition, weapons systems, communications, etc.). These activities reduce the amount of time available to devote solely to physical conditioning.

The physical training practices of shore based SEALs vary substantially with training phase, deployment status, and location (Prusaczyk, Goforth, and Nelson, 1990). Historically, physical training programs for SEALs have been designed and directed by veteran SEAL Team members. Such programs emphasize exercises routinely used in the training course at Basic Underwater Demolition/SEAL school (BUD/S). Consequently, current programs are based more on tradition than scientific principles or the physical demands of operational tasks (Stuster, Goforth, Prusaczyk, and Meyer, 1994). Furthermore, these programs are not well suited for use aboard submarines, a primary SEAL deployment platform. Identifying training methods and devices to rapidly improve a broad range of fitness components in a concurrent strength and endurance training program would be beneficial to SEALs. However, physiological adaptations

to concurrent training, such as increased cardiac output and lactate threshold, may vary in rate of adaptation or economy of training time required compared to more traditional training methods.

Earlier attempts to achieve concurrent improvements in strength and endurance fitness typically involved two separate training programs (e.g., Hickson, 1980; Hunter, Demment, and Miller, 1987; McCarthy, Griffith, Prusaczyk, Goforth, and Vailas, 1992). In some studies both programs were performed on the same day (Nelson, Arnall, Loy, Silvester, and Conlee, 1990), while in other studies they were performed on alternating days (e.g., Sale, Jacobs, MacDougall, and Garner, 1990; Sale, MacDougall, Jacobs, and Garner 1990). Significant strength and endurance training effects have been reported in subjects engaged in concurrent training. It is not clear whether the rate of adaptation to training is impaired by concurrent training (Dudley and Djamil, 1985; Hickson, 1980; Nelson et al., 1990). Yet even in those studies that reported significant impairments in adapting to concurrent training, the impairments were related to methodology (Dudley and Djamil, 1985) or resulted from overtraining due to the volume and intensity of training required to elicit both strength and endurance effects (Dudley and Fleck, 1987; Hickson, 1980). Our interpretation, therefore, is that the main limiting factor to inducing simultaneous adaptations to strength and endurance training is not physiological, but rather the time required to engage in training and recover between training sessions. Accepting that premise, more research should be devoted to strategies exploiting the available training time as did Bell, Petersen, Quinney, and Wenger (1988); Bell, Petersen, Wessel, Bagnall, and Quinney (1991); and Sale, Jacobs et al. (1990).

The studies demonstrating that concurrent adaptations to contrasting physical fitness variables are achievable (Asfour, Ayoub, and Mitol, 1984; Nelson et al., 1990), do not address the question of efficiency. "Efficiency" is the extent of adaptation expressed relative to the amount of time spent in a training session and to the duration of the entire training program. Training time was simply increased in these studies to accommodate both strength and aerobic fitness. Available training time limits the extent to which the desired physiological adaptations can be elicited. Of those factors affecting the rate and extent of adaptations to physical training (i.e., genetic predisposition, frequency, duration and intensity of training), intensity is most readily manipulated to accommodate available training time. There is a large body of literature about training designed specifically to improve either aerobic or anaerobic fitness (for reviews see Green and Dawson, 1993; Shephard and Åstrand, 1992). In contrast, there are few published studies which have systematically evaluated the effects of different training intensities designed to develop both fitness components. The ability to fuel prolonged low-intensity exertion by aerobic metabolism differs from the ability of anaerobic metabolism to fuel intensities of exertion so high that they lead to fatigue in less than 3 minutes. However, both fitness components are relevant to NSW operational requirements.

This investigation compared the physiological and performance adaptations to differing training programs using approximately the same average exercise intensity. Training regimens were chosen to enhance either aerobic, anaerobic, or both fitness components in an efficient manner by training at a single average exercise intensity. The rate and extent of adaptation during concurrent training was expected to be less than that achieved if only one of the two fitness components were to be enhanced.

The specific objective of this study was to design and test a 30-min exercise program that would elicit and maintain simultaneous adaptations in both anaerobic and aerobic fitness.

METHODS

Subjects

The subjects were volunteers recruited from SEAL Teams One, Three, and Five, SEAL Delivery Vehicle Team One, and the Naval Special Warfare Center, all located at the Naval Amphibious Base, Coronado, California. After being informed of the details of the study and the associated risks and discomforts, each subject gave written consent to participate. The protocol for this study was approved by the Naval Health Research Center's Committee for the Protection of Human Subjects.

During the recruitment briefing, the subjects were told that a primary condition of participation was their willingness to maintain constant the frequency, intensity, and volume of their routine physical training, apart from additional training prescribed, for the duration of the study. They were also told that they would have to perform a prescribed training protocol three to four times weekly, "on their own time." To facilitate compliance, cycle ergometers and training logs were always available at Naval Special Warfare Center for the duration of the study.

Thirty-eight SEALs volunteered to participate in the proposed 12-week program, but only twenty-four of the original volunteers were still training at the end of three weeks. Of these 24, only 20 subjects met our "training compliance" criterion, which was that at least seven training sessions had been completed by the end of three weeks. All statistical analyses and data presentation are based on the results from these 20 subjects.

An estimate of the regular training performed by the SEALs in this study was obtained by interviewing 14 of the 20 subjects. Subjects reported the intensity, volume, and mode of exercise during the previous three days, thus the sample period encompassed 42 training days.

Training Programs

The original 38 subjects were divided into three groups matched for their initial peak oxygen consumption ($\dot{V}O_{2peak}$, expressed as $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and maximum oxygen deficit (expressed as $\text{mL}\cdot\text{kg}^{-1}$). Each group performed either continuous (CNT), intermittent (INT), or supramaximal (SMX) training.

CNT subjects trained continuously for 30 min at an intensity of 70% $\dot{V}O_{2peak}$. Such training is a well-established method of improving aerobic fitness (for review see Wenger and Bell, 1986; American College of Sports Medicine, 1990).

SMX subjects performed 30-s sprints on the cycle pedaling at maximal frequency against a resistance of $75 \text{ g}\cdot\text{kg}^{-1}$ body weight. Subjects were asked to perform three sprints/session during the first week, four sprints/session during the second week, and five sprints/session during the third training week, spacing the sprints evenly throughout the session, and to pedal at a light intensity ($\sim 105 \text{ W}$) between sprints. Such training has been shown to improve physiological and performance indicators associated with anaerobic fitness (Jacobs, Esbjörnsson, Sylven, Holm, and Jansson, 1987; Esbjörnsson, Sylven, Holm, and Jansson, 1993).

INT subjects performed 10 sequential 3-min bouts of exercise per 30-min training session; each bout was two min at 50% of $\dot{V}O_{2peak}$ followed by one min at 110% of $\dot{V}O_{2peak}$. Thus, the average training intensity over each training session was 70% $\dot{V}O_{2peak}$. It was

hypothesized that this training would elicit improvements in both aerobic and anaerobic fitness, similar to those achieved separately by the CNT and SMX groups.

All training was done on mechanically-braked cycle ergometers individually identified so that subjects would always train on the same ergometer. Each subject's training log contained his training requirements (including resistance setting on the cycle). After each exercise session, subjects recorded the training accomplished in the log. An investigator was present during the first week of training to instruct and monitor all subjects during the initial training sessions.

After attrition and program compliance were considered, the 20 subjects remaining in training were distributed among the three groups as follows: eight subjects were in the CNT group, six subjects were in the INT group, and six subjects were in the SMX training group.

Muscle Fiber Type

Biopsies were obtained from the subjects' *vastus lateralis* muscle prior to commencing training. The tissue samples were histochemically stained to calculate the percentage of fast twitch and slow twitch fibers. A detailed description of this methodology was published by Jacobs, Prusaczyk, and Goforth (1992).

Test Battery

Subjects performed a test battery during the week before commencing training, and again within five days of completing the three weeks of training. The tests were selected as reasonable and valid measures of aerobic and anaerobic fitness components.

Aerobic endurance fitness was evaluated based on $\dot{V}O_{2peak}$, time to exhaustion, and blood lactate response during a progressive, load incremented exercise test on a mechanically braked bicycle ergometer (Monark® Model 868). Peak $\dot{V}O_2$ was determined by a multistage test

beginning at 60 W for 4 min, and increasing in a stepwise fashion by 60 W every 4 min until the subject voluntarily terminated or failed to maintain 60 rev•min⁻¹. Respiratory gas exchange (Sensormedics® Horizon 4400 Metabolic cart) was monitored continuously, and heart rate (Polar Vantage XL™ heartwatch) was determined during the final 30 s of each power output stage.

Blood lactate concentrations were determined from arterialized capillary blood samples obtained from the earlobe prior to exercise (resting) and at the end of each power output stage. The earlobe was treated with an ointment (Finalgon®) that causes local vasodilation and hyperemia. Following a 10 min wait to ensure hyperemia, the earlobe was cleaned and sterilized (isopropyl alcohol), and a small incision (\approx 5 mm) was made along the inferior edge of the earlobe. Patency of the incision was maintained during exercise by covering the earlobe with an isopropyl alcohol soaked gauze pad. Twenty μ L of blood was collected from the incision in an untreated capillary tube. The sample was immediately expelled and deproteinized in 0.4 mmol•L⁻¹ perchloric acid, and was stored at -80°C until assayed for lactate concentration (Maughan, 1982).

Following the aerobic fitness test, subjects were allowed to recover for 90 min before anaerobic fitness was evaluated. The capacity to transduce energy to the thigh musculature via anaerobic metabolism was evaluated by determining the maximal oxygen deficit accumulated during a short (\approx 2 min) maximal-effort cycle exercise test. Details of the methodology, reproducibility, validity, and sensitivity to training can be found elsewhere (Medbø and Bergers, 1990; Medbø and Tabata, 1989; 1993; Medbø, Tabata, Bahr, Vaage, and Sejersted, 1988). Based on the results of the aerobic fitness test, individual linear regression equations of $\dot{V}O_2$ versus power output were calculated and the work load that would elicit 120% of $\dot{V}O_{2peak}$ was

determined. Subjects pedaled the ergometer at $75 \text{ rev} \cdot \text{min}^{-1}$ at the power output calculated to elicit $120\% \dot{V}O_2$ until they could no longer maintain the prescribed pedal rate. During this test, each subject's $\dot{V}O_2$ was monitored continuously (Sensormedics® Horizon 4400 Metabolic cart). Following the test, subjects recovered by pedaling at 37 W for 5 min. The oxygen demand (i.e., the requirement if all energy was provided aerobically) of the anaerobic test was determined for each individual. Maximal oxygen deficit was calculated as the difference between the $\dot{V}O_2$ elicited during the test and the calculated oxygen demand of the test (Medbø et al., 1988).

Statistical Analyses

Intergroup comparisons of pretraining data were made using a one-way analysis of variance (ANOVA). A two-factor (group x trial) ANOVA with repeated measures was performed to compare the group responses to the training program. Statistical significance was declared at the $p \leq 0.05$ level. Data were analyzed with SuperANOVA® (Abacus Concepts, Inc., Berkeley, CA).

RESULTS AND DISCUSSION

Subject Attrition

Based on knowledge of subject attrition typically found in training studies, we assumed that our subject sample size would be reduced by 10-20%. Although the training program was to be 12 weeks long, only 63% of the subjects were still training after three weeks, and only 53% met training compliance requirements (Table 1). This high subject attrition limited the statistical power of the tests to examine the experimental hypothesis. Table 2 lists the frequency of factors contributing to the unexpectedly large subject attrition.

Table 1. The effect of attrition and compliance on the sample size (n) of the Continuous (CNT), Intermittent (INT), and Supramaximal (SMX) groups.

Group	All Subjects	CNT	INT	SMX
Original <i>n</i>	38	12	13	13
Still training after 3 weeks	24	8	10	6
≥7 training sessions per 3 weeks	20	8	6	6

Table 2. Causes of subject attrition in the Continuous (CNT), Intermittent (INT), and Supramaximal (SMX) groups. Data are numbers of subjects.

Group	Total Dropouts	Lost Interest	Deployed, Illness, or Injury	< 7 Training Bouts
CNT	4*	1	2	0
INT	7	1	2	4
SMX	7	5	2	0
Total	18	7	6	4

* One subject was eliminated from the analyses for substantially increasing his training outside the study.

Subjects' Pretraining Status

Prior to participating in this study, the surveyed subjects spent an average of 72 min per day in physical training. Approximately 20 min was devoted to aerobic exercise (e.g., cycling, swimming, running, Versiclimber®) and 50 min for muscle strength development (e.g., upper body, resistance training, calisthenics, rock climbing, etc.). These SEALs performed some form of exercise on 83% (35 of 42) of the available training days they reported. These data are quite

similar to those reported for a larger sample (n=102) of West Coast SEALs (Prusaczyk et al., 1990).

There is a well established inverse relationship between status prior to commencing training and the rate and magnitude of adaptation caused by training. Therefore, the data were analyzed with a one factor ANOVA to determine whether there were pretraining differences among groups in the variables of interest. There were no significant differences among groups for the pretraining physical characteristics or for any of the measured physiological test variables (Table 3).

Table 3. Mean (\pm SD) pretraining physical and physiological characteristics of the subjects in the Continuous (CNT), Intermittent (INT), and Supramaximal (SMX) groups.

	All Subjects	CNT	INT	SMX
<i>n</i> for analysis	20	8	6	6
Age (y)	32 (5)	33 (5)	32 (6)	32 (5)
Height (cm)	178 (5)	179 (6)	178 (5)	179 (4)
Weight (kg)	79.9 (7.0)	78.2 (5.5)	79.7 (7.0)	82.5 (9.0)
$\dot{V}O_{2peak}$ (mL \cdot kg $^{-1}$)	48 (5)	49 (5)	49 (5)	47 (6)
Max O ₂ Deficit (mL \cdot kg $^{-1}$)	38 (10)	38 (n=7) (8)	37 (n=5) (15)	41 (7)
Fast Twitch (% muscle fibers)	57 (11)	58 (11)	53 (9)	61 (12)
180 W	3.4 (0.9)	3.9 (0.6)	3.4 (1.1)	3.0 (1.1)
Blood Lactate (mmol \cdot L $^{-1}$)	6.3 (1.6)	6.4 (1.4)	6.9 (2.1)	5.8 (1.5)
240 W				

The pretraining mean values for the aerobic and anaerobic fitness indicators for the subjects in this study were similar to the values for the "average" SEAL. A more detailed discussion of the subjects' physical fitness status prior to training, and a comparison to other subject samples, has been reported previously (Jacobs, et al., 1992).

Number of Training Bouts

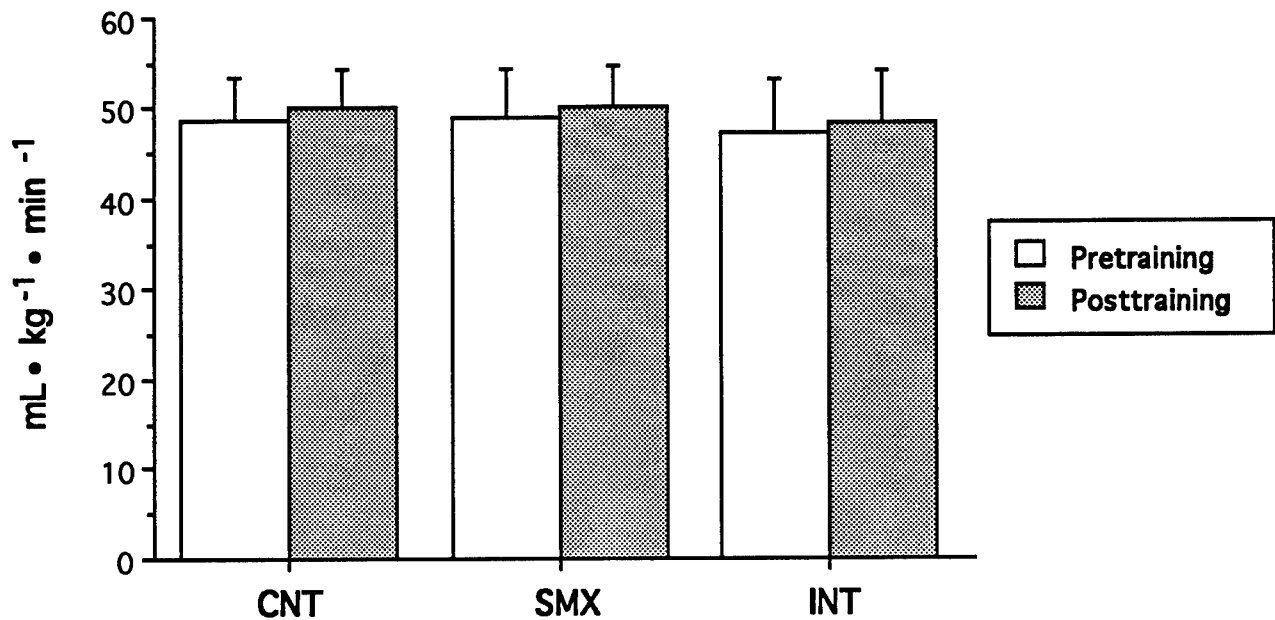
The mean \pm SD number of training sessions completed by each group was 10 ± 2 , 10 ± 2 , and 8 ± 1 , for CNT, INT, SMX, respectively, and 9 ± 2 for all subjects. There were no significant differences among groups in the number of training sessions completed during the three weeks of training.

Aerobic Fitness Indicators

There was significant improvement in indicators of aerobic fitness. Time to exhaustion during the aerobic exercise test was significantly increased ($F=15.19$; $df=1/16$; $p<0.01$) from a mean \pm SD of 18.1 ± 1.4 min to 19.4 ± 1.6 min; there were no differences among groups. While there was a trend toward a significant increase in $\dot{V}O_{2peak}$ (Figure 1), it failed to achieve statistical significance ($F=3.82$; $df=1/16$; $p=0.068$). During bicycle exercise, maximal aerobic power is probably underestimated in subjects who are not experienced cyclists, since leg muscular fatigue can limit the ability to fully exploit cardiovascular capacity.

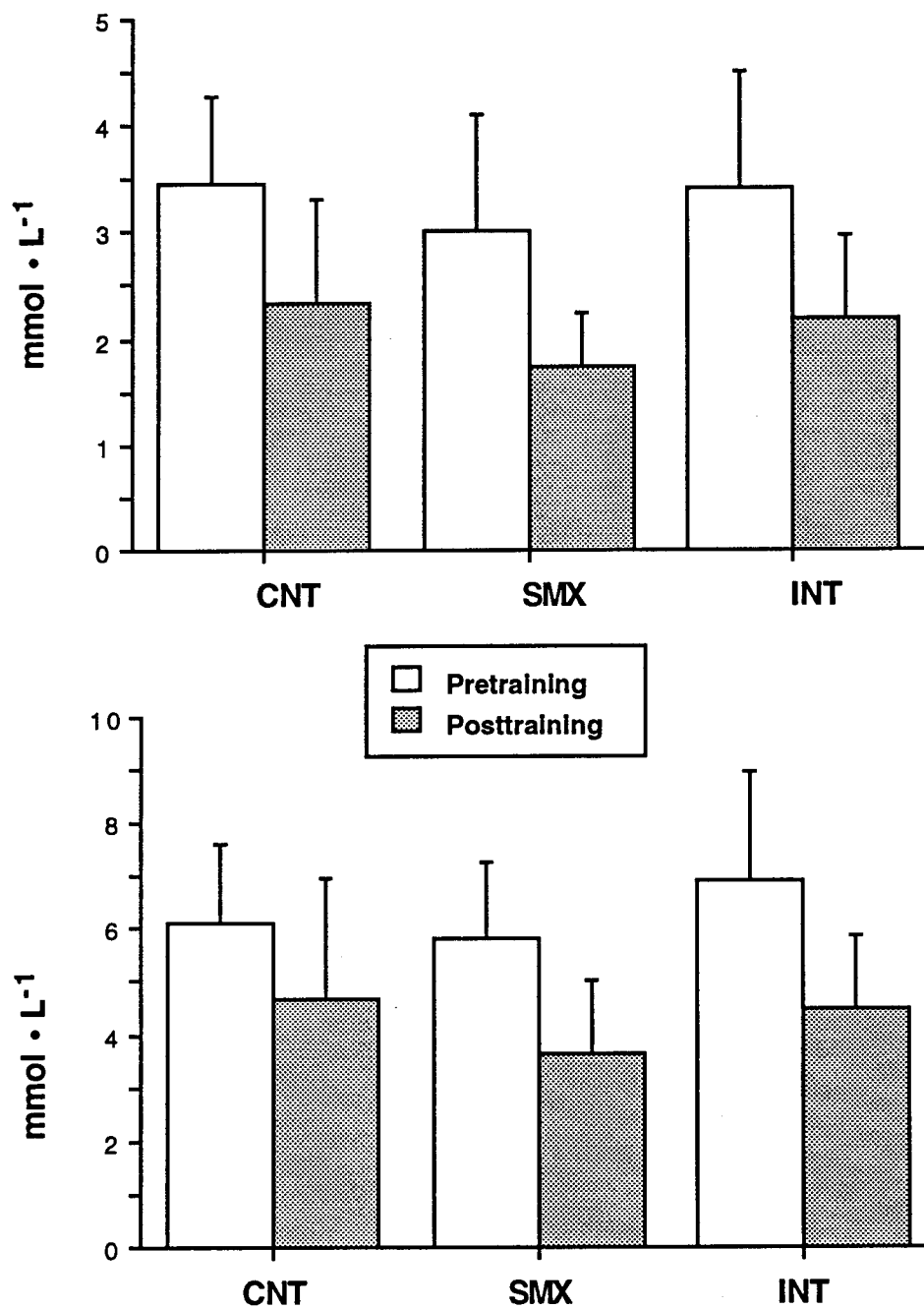
Under controlled conditions, a decrease in blood lactate at a given submaximal exercise intensity is an established, sensitive, and valid indicator of aerobic training adaptation and a more valid indicator of submaximal and endurance fitness than is maximal aerobic power (Jacobs 1986; Jacobs, Sjödén, and Schéle, 1983; Jacobs, Schéle, and Sjödén, 1985).

Figure 1. The effect of three weeks of training on mean \pm SD peak oxygen consumption during cycle exercise in the Continuous (CNT), Intermittent (INT), and Supramaximal (SMX) groups.



Since the highest intensity all subjects completed both before and after training was 180 W, the lactate concentration after 4 min of exercise at this intensity was selected as an indicator of changes in the capacity to perform prolonged endurance exercise. Lower lactate concentrations at a given exercise intensity indicate that peripheral adaptations within the active musculature are facilitating oxidative metabolism, which delays fatigue. In the present investigation, blood lactate concentration after exercise at a power output of 180 W was significantly ($F=30.25$; $df=1/14$; $p<0.01$) lower after training. The subjects who completed 4 min of exercise at 240 W on both testing occasions also demonstrated a significant ($F=20.51$; $df=1/14$; $p<0.01$) decrease of lactate concentrations after training. Thus, for both exercise intensities, training induced a significant decrease in blood lactate concentration; however, there were no differences among groups (Figure 2).

Figure 2. The effect of three weeks of training on mean \pm SD blood lactate concentration after cycle exercise at 180 W (top) and at 240 W (bottom) in the Continuous (CNT), Intermittent (INT), and Supramaximal (SMX) groups. Values are mean \pm SD.



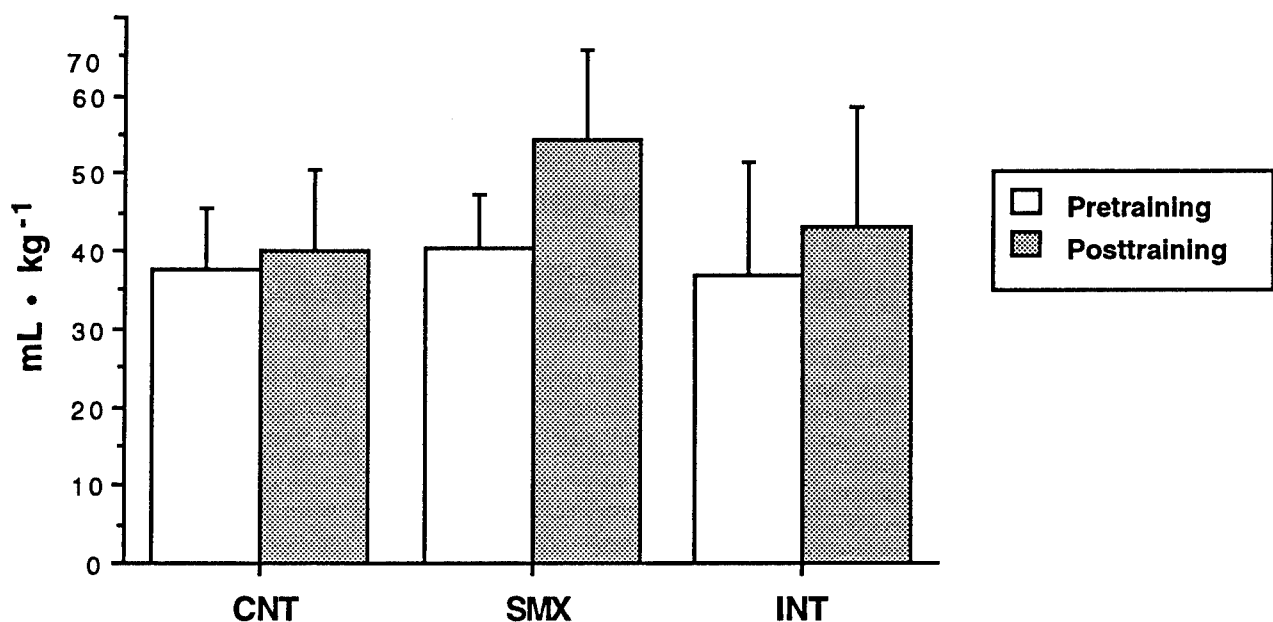
The mean lactate concentration for all subjects after four min of exercise at 180 W (n=20) decreased from 3.3 to 2.1 mmol•L⁻¹; and at 240 W (n=17) from 6.2 to 4.3 mmol•L⁻¹.

Maximal Oxygen Deficit

Mean (\pm SD) exhaustion time was 2.7 \pm 0.9 min during this test, a time which is within the range (2-3 min) required for a valid estimate of maximal oxygen deficit (Medbø et al., 1988; Medbø and Tabata, 1993).

The two factor ANOVA showed that maximal oxygen deficit was significantly ($F=9.50$; $df=1/16$; $p<0.01$) increased, but there was no significant difference among the groups. The mean values before and after training were 38 and 46 mL of oxygen equivalents•kg⁻¹ body weight, respectively. The greatest improvement in mean anaerobic capacity was in the SMX group (Figure 3), with both SMX and INT showing significant improvement with training.

Figure 3. The effect of three weeks of training on mean \pm SD maximal oxygen deficit during cycle exercise in the Continuous (CNT), Intermittent (INT), and Supramaximal (SMX) groups. Values are mean + SD.



To evaluate the change in maximal oxygen deficit, a one-way repeated measures ANOVA was performed on each group separately. Five of the SMX subjects increased and one decreased maximal oxygen deficit after the training ($p < 0.06$). Four of the CNT subjects increased and three decreased maximal oxygen deficit; the overall change was not significant ($p < 0.6$). Each of the six INT subjects increased their maximal oxygen deficit ($p < 0.02$).

This protocol is a valid method of measuring the capacity to transduce energy to the working muscles via anaerobic metabolism (Green and Dawson, 1993; Medbø et al., 1988; Bangsbo et al., 1990; Medbø et al., 1993). The test values have also been demonstrated to be sensitive to the effects of training (Medbø and Bergers, 1990). The values obtained are related to the muscle mass used during the exercise test. Therefore, it is not surprising that the absolute values reported here are less than those reported for treadmill exercise or rowing (Bangsbo, Michalisk, and Petersen, 1993; Green and Dawson, 1993; Medbø and Tabata, 1989); however, the findings are similar to those reported for healthy, 25 year old male university students (Medbø and Tabata, 1993).

Implications of Results

In recent years it has been demonstrated that aerobic training adaptations can be induced more rapidly than previously believed. This is true even in subjects already moderately well-trained. Such adaptations can occur after less than two weeks of training (Green, Jones, Ball-Burnett, and Fraser, 1991; Green, Jones, Ball-Burnett, Smith, Livesey, and Farrance, 1991; Green, Helyar, Ball-Burnett, and Fraser, 1992). The present investigation confirms these findings and further suggests that significant improvements in anaerobic fitness can also be induced within three weeks of training.

The results of this investigation suggest that the INT training program effectively improved aerobic fitness similar to the level achieved by a classical endurance training program (i.e., CNT). The INT training program also improved anaerobic fitness to a level similar to that achieved by a classical anaerobic fitness training program (i.e., SMX). Thus, the hypothesis was supported in that an intermittent training program of 30 min of exercise two to five times a week can improve aerobic and anaerobic fitness concurrently.

Interestingly, the SMX protocol improved aerobic as well as anaerobic fitness. Muscle enzymatic adaptations consistent with an aerobic training effect have been reported for similar SMX training programs (Jacobs et al., 1987; Esbjörnsson et al., 1993). It has been shown that approximately 20% of the energy demand for 30 s of similar SMX exercise is provided by aerobic metabolism, and may increase to 85% during the last few seconds (Kavanagh and Jacobs, 1988). Repeated exposure to such SMX exercise can produce adaptations that reduce blood lactate during submaximal exercise and increase peak oxygen uptake. From the subjects' reports, it was found that SMX training was more uncomfortable than INT. Therefore, long-term compliance to SMX training is likely to be lower than to INT.

The high subject attrition rate limits our ability to extrapolate these results to the general SEAL population. Those subjects who were not genetically predisposed to rapid adaptations may have been more likely to attrite. Similar studies with more subjects are needed to confirm the present findings.

CONCLUSIONS AND RECOMMENDATIONS

The results support the hypothesis that three weeks of short interval, high-intensity training can improve both aerobic and anaerobic exercise capacity. With the selection of appropriate training intensities and programs, training time can be used more efficiently to simultaneously improve aerobic and anaerobic fitness.

It is recommended that further research be conducted with the following objectives:

- a. confirm the present findings with a larger number of subjects under more controlled conditions;
- b. confirm the relevance of the tests used in this study to the physically demanding operational tasks of SEALs;
- c. examine whether similar results can be obtained using other training modes and equipment that are accessible to SEALs in various operational training and deployment settings.

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13. ABSTRACT (Maximum 200 words) SEALs must optimize physical training "efficiency" i.e., adaptation per unit training time. This study was designed to determine if a single training program could simultaneously elicit aerobic and anaerobic adaptations. SEALs were assigned to groups matched for initial aerobic and anaerobic fitness. Each group trained on cycle ergometers for 30 min 3 times per week as follows: continuous (CNT; n=8) at 70% $\dot{V}O_{2peak}$; intermittent (INT; n=6) at an average of 70% $\dot{V}O_{2peak}$ [10 x (2 min @ 50% $\dot{V}O_{2peak}$ + 1 min @ 110% $\dot{V}O_{2peak}$)]; supramaximal (SMX; n=6) [3-5 x 30 sec maximal effort sprints spaced over 30 min]. Before and after 3 weeks of training, measurement of time to exhaustion (TE), $\dot{V}O_{2peak}$, and blood lactate concentration (LA) during submaximal exercise were used to assess aerobic fitness, and maximal O_2 deficit to evaluate anaerobic capacity. After training, $\dot{V}O_{2peak}$ did not change significantly for any group. Mean TE increased ($p < 0.05$) for all groups, averaging 18.1 to 19.3 min. LA at 180 W decreased ($p < 0.05$) for all groups, with pre to post changes of 3.3 to 2.1 mmol·L ⁻¹ . Maximal O_2 deficit increased ($p < 0.05$) for INT and SMX averaging 38 to 46 mL O_2 ·kg ⁻¹ , but did not increase ($p > 0.05$) for CNT. There were no other significant differences across training groups for any training adaptations. The results indicate that INT or SMX training can induce rapid improvements in both aerobic and anaerobic fitness using a single 30-min bout.				
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