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RELATIONSHIP OF ANAEROBIC POWER CAPACITY TO PERFORMANCE DURING A 5-DAY SUSTAINED COMBAT SCENARIO

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Anaerobic power capacity was assessed on 34 infantrymen (mean age 21.9, mean wt, 72.5 kg, mean VO_2max 53.6 ml/kg min) before and after a five-day combat scenario. The objective of this study was to determine the importance of this fitness component with the ability to perform field infantry tasks. Anaerobic performance was assessed for the upper and lower body muscle groups using the Wingate test (WT). To perform the WT, the subject pedals or cranks at maximal RPMs for 30s against a resistance of 75 gm/kg body weight for the lower body and 50 gm/kg body weight for the upper body. A second test, the isokinetic enduranc

test (IET) was administered to assess anaerobic capacity of the elbow flexor and knee extensor muscles. This test utilized the Cybex dynamometer with which the subject performed 50 consecutive maximal arm or leg contractions(C) at an angular velocity of 180 degrees per second. Peak variables were calculated as the mean of the first 5s for the WT and first 4C for the IET. Mean variables were determined for 30s of the WT and 20 arm or 25 leg C of the IET as well as all 50C of the IET. Although different muscle groups were utilized during each procedure, the tests were significantly correlated ($P < .01$) indicating that both describe anaerobic performance. A comparison of pre to post scores revealed a decrease in mean upper body/elbow flexor performance but no change in lower body/knee extensor performance. The decrease observed could possibly be attributed to the constant load bearing of 28 kg as well as a lower state of conditioning in these muscle groups. Both upper body peak and mean power WT were significantly correlated ($r=.463$, $r=.430$, respectively, $p < .01$) with performance rating. In conclusion, upper body muscular endurance as assessed by anaerobic power capacity may play an important role in the ability to sustain infantry tasks over 5 days.

Relationship of Anaerobic Power Capacity to Performance during a 5-day Sustained Combat Scenario

by

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HUMAN RESEARCH

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

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FOREWORD

Physical training requirements and physical fitness standards have traditionally been based on experience and subjective judgement rather than objectively determined requirements for successful performance. For example, passing scores (standards) for the Army Physical Readiness Test (APRT) are currently based on age and gender without consideration of military occupational specialty or operational needs of the unit. Commanders often train their unit to exceed these standards based on a perceived need for a higher level of fitness for morale, readiness, appearance and unit performance. There is a paucity of information indicating actual requirements for physical fitness (exercise capacity) for operational units in the Army which deal in situations such as sustained combat. This information is needed not only to establish actual fitness needs, but also to develop more appropriate and efficient physical training programs.

At a physical training study group meeting held on 19-21 April 1982 at the Army War College, the need to identify the fitness requirements of continuous combat operations was identified as the number one priority in applied fitness research. While this need exists for all types of combat units, it was decided that the requirements of light infantry would be an appropriate starting point as possibly the most demanding seen in the Army. The study reported here, in part, is the result of this decision.

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ABSTRACT

Anaerobic power capacity was assessed on 34 infantrymen (mean age 21.9, mean wt. 72.5 kg, mean VO_2 max 53.6 ml/kg min) before and after a five-day combat scenario. The objective of this study was to determine the importance of this fitness component with the ability to perform field infantry tasks. Anaerobic performance was assessed for the upper and lower body muscle groups using the Wingate test (WT). To perform the WT, the subject pedals or cranks at maximal RPMs for 30s against a resistance of 75 gm/kg body weight for the lower body and 50 gm/kg body weight for the upper body. A second test, the isokinetic endurance test (IET) was administered to assess anaerobic capacity of the elbow flexor and knee extensor muscles. This test utilized the Cybex dynamometer with which the subject performed 50 consecutive maximal arm or leg contractions(C) at an angular velocity of 180 degrees per second. Peak variables were calculated as the mean of the first 5s for the WT and first 4C for the IET. Mean variables were determined for 30s of the WT and 20 arm or 25 leg C of the IET as well as all 50C of the IET. Although different muscle groups were utilized during each procedure, the tests were significantly correlated ($p<.01$) indicating that both describe anaerobic performance. A comparison of pre to post scores revealed a decrease in mean upper body/elbow flexor performance but no change in lower body/knee extensor performance. The decrease observed could possibly be attributed to the constant load bearing of 28 kg as well as a lower state of conditioning in these muscle groups. Both upper body peak and mean power WT were significantly correlated ($r=.463, r=.430$, respectively, $p<.01$) with performance rating. In conclusion, upper body muscular endurance as assessed by anaerobic power capacity may play an important role in the ability to sustain infantry tasks over 5 days.

INTRODUCTION

The soldier in a combat situation is required to perform a spectrum of physical activities ranging from long marches to short, quick bursts of activity. Endurance activities of low intensity, such as long marches, require sufficient aerobic capacity to supply the muscles with adequate energy to sustain the exercise. Aerobic power capacity can be measured in the laboratory by the maximal oxygen uptake test(1). On the other end of the spectrum are activities of high intensity and short duration. This type of exercise requires utilization of anaerobic pathways to supply the muscles with ATP. In the field, these activities would include sprinting (lower body), quickly moving equipment (upper body), or crawling for cover. Many soldiering activities require both aerobic and anaerobic energy pathways. Clearly, the men with high aerobic and anaerobic capabilities will be an asset to the success of combat missions.

This report discusses physical fitness at the anaerobic end of the spectrum. Anaerobic power capacity, by definition, includes all energy yielding processes not requiring oxygen. These include the immediate reaction of splitting stored ATP and CP (phosphagen splitting) as well as the more dominant process of glycolysis(7). Anaerobic pathways are only significant contributors of energy during the first minutes of exercise and dominate within the first 30 seconds. Unlike the direct measurement of the VO_2 max test, anaerobic power is measured indirectly via performance tests. Traditionally such tests have utilized exercise modes such as stairclimbing(2), vertical jumping(3), and treadmill sprint running(4). Two more recently developed laboratory performance tests were utilized in this study. These were the Wingate Test(5) and the Cybex Isokinetic Endurance test(6).

Anaerobic power capacity was assessed before and after a five day sustained combat-simulated scenario. Changes in capacity from pre to post scenario will be discussed along with the relationship between initial anaerobic capacity and individual performance of field exercises. The overall purpose of the project was to determine the level and type of fitness components commensurate with the ability to sustain combat activity for five days. This report looks at one of these fitness components, anaerobic power capacity, or more commonly referred to as muscular endurance.

STUDY DESIGN

The study was carried out at Ft. Lewis, Wa. where thirty-four soldiers from the 2nd Battalion, 47th Infantry Regiment, 9th Infantry Division volunteered following an informed consent briefing. The infantrymen aged 18 to 29, average age of 21.9 years, represented 4 squads of 7-9 soldiers each. Their physical characteristics are described in Table 1. All 34 subjects performed a variety of physiological tests during three pre-scenario test days. These tests included aerobic capacity, anaerobic capacity, anthropometry, reaction time, isometric and isokinetic muscular strength and dynamic lift capacity. This report will discuss only the anaerobic capacity test results and their implications.

TABLE 1. Physical Characteristics of Subjects (n=34).

	MEAN	SD	RANGE
HEIGHT (cm)	179.9	7.4	155.8-189.9
WEIGHT (Kg)	72.5	10.5	50.1-99.4
AGE	21.9	2.9	18.0-29.0
% BODY FAT	14.1	6.9	2.7-29.2 *
LEAN BODY MASS (Kg)	62.4	10.4	41.5-84.2 *
VO_2 MAX (ml/kg min)	53.6	5.5	44.2-63.3 **

*Determined by hydrostatic weighing.
**n=33, Treadmill protocol.

Following baseline pre-scenario measurements, a five day high intensity sustained combat scenario was initiated. Each squad performed different missions in different sectors of the Ft. Lewis training area on each day. They were required to execute both offensive and defensive maneuvers on a near continuous basis with one four hour block of uninterupted sleep scheduled each twenty-four hour period. During each mission of the scenario, evaluators were present to score and comment on squad and individual performance.

On day six, within the first six hours following the scenario and without intervening sleep, selected physiological tests were repeated in order to determine any decrement. These tests were anaerobic power capacity, isometric and isokinetic muscular strength, reaction time and dynamic lift.

METHODS

Two tests of anaerobic power capacity were administered, measuring both the upper and lower body muscle groups. The first procedure was a 30-second(s) all-out cycle ergometer test termed the Wingate Test (WT). The second was an Isokinetic Endurance Test (IET) performed with the Cybex dynamometer. All soldiers completed both tests on the upper and lower body during the pre-scenario test days; however, due to time limitations, they were post-tested on either the upper or lower body WT and IET. Prior to post-testing, the soldiers were divided into 2 groups. One group performed the upper body WT and the leg IET, while the other group performed the lower body WT and the arm IET. The post testing of both muscle groups was conducted on the same day. Selection for the post-test category (upper or lower body) was based on pre-test performance so as to result in two equally numbered groups with varying ranges of anaerobic ability.

WINGATE TEST

The WT was performed on a Monark ergometer that had been modified with a lever arm for instantaneous application of resistance and a computerized counter fixed at the flywheel(8). The subject was seated at the ergometer such that there was a slight bend in the elbow or knee upon full extension of the limb. He was then instructed to pedal or crank at an approximate rate of 120 RPM without resistance on the flywheel. On the command "Ready,Go", the subject pedaled/cranked as fast as possible, enabling him to overcome the inertial resistance of the flywheel. Upon attaining maximal pedal revolutions, the lever arm was lowered, applying resistance and, simultaneously, triggering the computer to start timing the test and counting flywheel revolutions. The resistance applied was 75 gm/kg body weight (BW) for the lower body(leg pedalling) and 50 gm/kg BW for the upper body(arm cranking). Strong verbal encouragement was given to the subject throughout the duration of the test, but he was not allowed to sit up and out of the seat. At the end of 30s, the lever arm was lifted and the subject told to pedal/crank at a comfortable rate with no resistance applied until he had sufficiently recovered. Figures 1 and 2 depict the upper and lower body Wingate test, respectively.

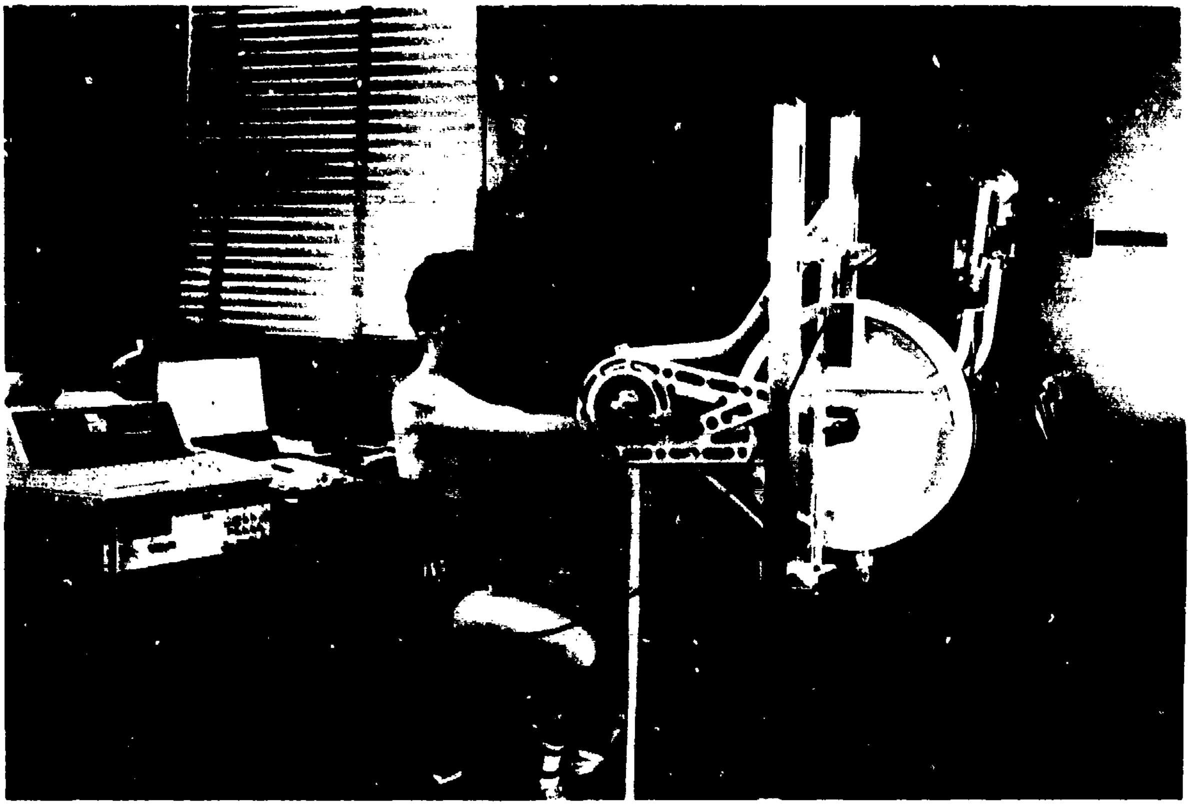

Figure 1. Upper Body Wingate Test

Figure 2. Lower Body Wingate Test

From the data collected during the WT, 3 indices of anaerobic performance were calculated. The first, peak power(PP), is the mean power output in watts(W) of the highest 5s period (usually the first 5s). It is referred to as "maximal anaerobic power" and is thought to represent the phosphagen-splitting mechanism of ATP and CP. This reaction is the most immediate source of energy production but is self-limiting without oxidative resynthesis, therefore is short-lived. The second indice is mean power(MP) which is the mean power output in watts over the 30s period. It is considered one's "anaerobic capacity" because it presumably reflects both the phosphagen-splitting mechanism as well as anaerobic glycolysis. Finally, percent decline(PD) describes the loss in power capacity or "fatigue"(5). These parameters and their calculations are shown in Table 2.

ISOKINETIC ENDURANCE

To perform the isokinetic endurance test(IET), subjects were seated in a Cybex chair with the appropriate limb (arm or leg) attached to the lever arm of the Cybex dynamometer(6). Limb movement was isolated by means of straps across the chest and thighs for the leg and clamps on the shoulders for the arm(9). The subject was instructed to perform 50 consecutive maximal contractions at an angular velocity of 180 degrees per second. The Cybex device allowed the elbow flexors or knee extensors to develop maximal torque throughout the range of motion. This same test was originally developed by Thorstensson et al(6) for the leg. Figures 3 and 4 illustrate the arm and leg IET, respectively.

Both tests, the Wingate and the Isokinetic Endurance, are thought of as indicators of anaerobic power capacity. In order to compare the two tests, torque indices for the IET were calculated on the same time basis as the WT. Highest peak torque (HPT) was calculated using the first four contractions which take approximately 5s; this variable corresponds to peak power WT. Because there is a greater range of motion for the arm than the leg, less contractions can be performed per unit time during the arm test. Therefore, mean peak torque (MPT) was calculated for 20 arm contractions (MPT20) and 25

Figure 3. Isokinetic Endurance Test of the Elbow Flexors using the Cybex Dynamometer.

Figure 4. Isokinetic Endurance Test of the Knee Extensors using the Cybex Dynamometer.

leg contractions (MPT25), both of which represent approximately 30s. This value is similar in time to mean power WT. MPT was also calculated for 50 contractions of both arm and leg (MPT50). Decline in peak torque (DPT) was calculated as a percent for 50 arm and leg contractions (DPT50) as well as 20 arm contractions (DPT20) and 25 leg contractions (DPT25), corresponding to percent decline WT. Refer to Table 2 for the calculations of these parameters.

TABLE 2. Anaerobic Power Indices: Calculations.

Wingate Test

Peak Power(PP)(W)= (W1s+W2s+W3s+W4s+W5s)/5*

Mean Power(MP)(W)= (W1s+W2s.....+W30s)/30

$$\text{Power Decrease}(\%PD)(W) = \frac{PP-(W26s+W27s...+W30s)/5}{PP} \times 100$$

Isokinetic Endurance Test

Highest Peak Torque(HPT)(Nm)= (C1+C2+C3+C4)/4**

Mean Peak Torque(MPT50)(Nm) = (C1+C2+C3...+C50)/50

Arm(MPT20) = (C1+C2+C3...+C20)/20

Leg(MPT25) = (C1+C2+C3...+C25)/25

$$\%\text{Decline Pk Torque}(DPT) = \frac{HPT-(C47+C48...+C50)/4}{HPT} \times 100$$

$$\text{Arm}(DPT20) = \frac{HPT-(C17+C18...+C20)/4}{HPT} \times 100$$

$$\text{Leg}(DPT25) = \frac{HPT-(C22+C23...+C25)/4}{HPT} \times 100$$

*W=Watts for each second

**C=Torque of each contraction

COMBAT SCENARIO

The scenario was executed in a tactical training area at Ft. Lewis, Wa. The terrain was generally flat but wooded with underbrush. Each day the squads operated in a different sector of the tactical area where they undertook and completed a series of missions. The first day's scenario, regardless of sector, was preceeded by a 10Km march. The 4 squads rotated through 4 sectors, repeating a sector on the fifth day. The missions for each sector are listed in Table 3. Each man carried 3 C-rations and basic ammo load as provided during resupply. The mean weight of the load carried was 28.1 Kg. Sleep was scheduled during 0100 and 0500*. Daily temperature ranged between 60-75 degrees F. The entire rainfall for the 5-day period was 0.34 inches with 0.31 inches falling on Wednesday.

Twenty-five experienced infantry NCOs were utilized as evaluators to grade performance during the scenario. The chief evaluator and NCOIC rotated on a 12 hr. basis and oversaw the project. There were 2 evaluators with each squad at all times, ensuring that the squad adhered to the scenario. They were responsible for orienting squad leaders and issuing mission situatuions as well as evaluation. Military task performance was rated on a scale of 1 to 10. Each individual was rated for each mission performed throughout the week (see table 3). The mean for all the missions represents the individual's performance rating during the scenario. Evaluations of squad 2 on day 2, sector 3 are missing, and therefore, not included in the analyses.

*subsequent analysis indicated that actual sleep time was closer to 5 hours.

TABLE 3. Sector, Mission and Time Schedule of Scenario.

SECTOR	MISSION	TIME
1	RAID	0600
	ROADBLOCK AND VEHICULAR AMBUSH	1300
	POINT RECONNAISSANCE/RAID	1700
	ESTABLISH PATROL BASE	2300
	STAND DOWN	0100
	STAND TO AND MOVE TO RESUPPLY POINT	0500
2	AREA RECONNAISSANCE/AMBUSH	0600
	DEFEND EASTMAN AND FOLSOM HILLS	1600
	STAND DOWN	0100
	STAND TO AND MOVE TO RESUPPLY POINT	0500
3	SECURE SITE AND RESUPPLY	0600
	MOVEMENT TO CONDUCT	0630
	VEHICULAR AMBUSH	1100
	AREA RECONNAISSANCE/ATTACK AND DEFEND	1400
	ESTABLISH PATROL BASE	2230
	STAND DOWN	0100
	STAND TO AND MOVE TO PARTISAN LINK- UP	0500
4	PARTISAN LINK-UP AND RESUPPLY	0600
	RAID/RESCUE AND EVACUATE WOUNDED/PARTISAN	0800
	SECURE AND HOLD LANDING STRIP/DEFEND	1600
	STAND DOWN	0100
	STAND TO AND MOVE TO RESUPPLY POINT(SECTOR 1)	0500

STATISTICAL ANALYSIS

A student's paired t-test was used to compare the means of the pre-scenario WT and IET to their respective post-scenario means. Pearson correlation analyses was used to determine the relationship between the WT and IET as tests of anaerobic power capacity. Performance rating was used in a correlation matrix vs 96 fitness components measured pre-scenario, then a multiple stepwise regression was performed using the significantly correlating variables.

RESULTS AND DISCUSSION

PRE-SCENARIO ANAEROBIC POWER CAPACITY

The mean pre-scenario scores for the lower body WT and the leg IET are lower than previously noted in this laboratory. In an earlier study, 19 enlisted men, mean age 25.1, mean weight 75.5 kg, mean body fat 17.0%, mean VO_2 max 3.52 l min-1, were measured on both tests. These subjects were stationed at Natick Labs for the purpose of being test subjects. They were highly motivated and experienced with laboratory testing procedures(16). The comparison of their anaerobic capacity scores to those obtained at Ft. Lewis are presented in Table 4. Previous data for comparison of upper body scores are unavailable.

TABLE 4. Comparison of Lower Body Anaerobic Capacity Data at Ft. Lewis vs. Previous data.

	WINGATE TEST			
	FT. LEWIS DATA(n=34)		PREVIOUS DATA(n=19)	
	X	SD	X	SD
PEAK POWER (Watts)	632.0	124.7	769.4	95.1
MEAN POWER (Watts)	439.9	100.9	555.4	88.8
	ISOKINETIC ENDURANCE TEST			
	FT. LEWIS DATA(n=34)		PREVIOUS DATA(n=19)	
	X	SD	X	SD
HIGHEST PEAK TORQUE (Nm)	119.6	26.2	141.8	26.2
MEAN PEAK TORQUE(Nm)	78.0	17.3	106.4	15.8

The pre-scenario anaerobic power capacity data as measured by both the Wingate Test (WT) and the Isokinetic Endurance Test (IET) are presented in Table 5. Examination of the comparison between upper and lower body reveals a much wider discrepancy in scores on the IET test than on the WT. HPT and MPT for the leg IET test was 69.1% and 70.9% higher than that for the arm test, respectively. These values are consistent with those obtained in

TABLE 5. Descriptive Statistics of Pre-Scenario Anaerobic Power Capacity.

(n=34)	UPPER BODY			LOWER BODY			
WINGATE TEST	X	SD	RANGE	X	SD	RANGE	%DIFF
Peak Power(W)	587.2	111.8	426.3 - 875.4	632.0	124.7	393.0 - 945.0	7.1
Mean Power(W)	424.3	72.8	301.5 - 567.3	439.9	100.5	237.7 - 683.1	3.5
Power Decrease(%)	47.5	7.6	23.4 - 59.2	48.6	8.6	32.5 - 5.7	2.2
ISOKINETIC ENDURANCE TEST	ELBOW FLEXORS			KNEE EXTENSORS			
Highest Peak T.(Nm) 50C	37.0	11.9	22.8 - 83.8	119.6	26.2	74.5 - 172.8	69.1
Mean Peak T.(Nm) 50C	22.7	6.9	12.4 - 51.5	78.0	17.3	51.7 - 120.5	70.9
Decrease Peak T. (%) 50C	65.8	10.6	44.2 - 85.8	63.9	7.4	47.2 - 75.9	3.0
Mean Peak T.(Nm) 20/25C	30.8	9.8	18.5 - 71.3	101.1	21.9	66.7 - 147.6	69.6
Decrease Peak T. (%)20/25C	30.1	8.9	8.0 - 45.0	33.3	8.6	5.0 - 48.0	9.6

previous studies where the percent difference between arm and leg IET was 69.2% for MPT (10). The WT, however, exhibited a very small discrepancy between lower and upper body. The lower body PP and MP were only 7.1% and 3.5% higher than that for the upper body, respectively. Such a large discrepancy between the IET test and the WT indicates that although both tests were measuring anaerobic capacity, different muscle groups were being assessed. During the IET test, the Cybex chair along with its straps and braces function well to isolate the muscle group involved such that only the elbow flexor and knee extensor muscles are used. However, during the WT, the nature of the pedalling or cranking exercise and the lack of an isolation mechanism require the use of many large muscle groups. Because both the upper and lower body WT involve these large muscle groups, there is a small percent difference in scores. On the other hand, the knee extensor muscles are much larger than the elbow flexors resulting in a large percent difference in the IET scores.

PRE VS. POST SCENARIO ANAEROBIC POWER CAPACITY

The statistical comparison of pre to post scenario values for upper body/arm and lower body/leg WT and IET tests is presented in Table 6. There was a significant ($p<.05$) decrease from pre to post scenario values in MP WT and HPT, MPT20, DPT20, DPT50 IET test for both upper body/arm anaerobic tests. These results suggest not only a decrement in mean anaerobic power capacity but also a lower fatigue rate in the IET as measured by percent decline. This lower rate, however, may be simply attributed to a lower initial peak torque.

The lower body/leg anaerobic tests showed no significant change from pre to post scenario in MP WT and MPT25 IET, which are based on the same time sequence, 30s. MPT50 IET, however, decreased. These results would be expected because the work performed represents a longer duration (60s); thus, the soldiers fatigued faster in the last half of the contractions during the post test. Both percent decline variables of the IET, DPT50 and DPT25, significantly increased over time indicating a higher fatigue rate in the post-test session. The final significantly changing variable was PP WT. The increase in PP from pre to post WT was a conflicting result, especially because it was not reflected in the IET test. It is possible that this increase could represent an "experience" effect in the WT.

In order to overcome this "experience" effect, a practice run could have been administered. Because previous testing yielded high reliability estimates(16), a practice run was not given. From the results of this study, however, it appears that practicing the first 5 sec of the test, especially the application of resistance, may be necessary in order to better aquaint the subject with the procedure. The resistance is so intense and so suddenly applied, that at first the subject may be stunned, inhibiting maximal performance, especially in the first 5 sec. For this reason, the mean PP may have been higher on the post test because the subjects were familiar with the technique and could better anticipate the start. If the change in PP WT

TABLE 6. Pre vs. Post-Scenario Anaerobic Power Capacity of Upper and Lower Body.

		Upper Body					Lower Body			
		Pre		Post			Pre		Post	
Wingate Test	n	X	SD	X	SD	n	X	SD	X	SD
Peak Power (Watts)	15	578.7	105.1	570.8	98.6	17	656.4	139.3	707.2	149.7 *
Mean Power (Watts)	15	416.6	73.9	397.2	59.7 *	17	454.3	104.6	482.9	106.8
Power Decrease (%)	15	47.9	7.6	49.6	8.4	17	48.3	8.3	52.1	8.5
Isokinetic Endurance Test		Elbow Flexors					Knee Extensors			
Highest Peak Torque (Nm) 50 C	16	37.4	8.8	33.6	8.4 **	14	112.2	24.4	115.84	27.2
Mean Peak Torque (Nm) 50 C	16	22.3	5.0	21.7	8.4	14	75.4	17.6	70.4	17.7 **
Decrease Peak Torque (%) 50 C	16	68.9	10.9	62.2	8.4 **	14	61.4	8.9	58.9	5.9 **
Mean Peak Torque (Nm) 20/25 C	16	30.7	6.7	29.0	6.8 **	14	95.8	20.6	94.4	23.2
Decrease Peak Torque (%) 20/25 C	16	31.6	9.9	25.2	10.1 *	14	31.1	11.1	38.6	4.3 *

*P<.05 **P<.01

truly represented an "experience" effect, then one would have expected to witness the same effect in the upper body test. From our results, however, it is impossible to determine wether tnis effect existed because it may have been masked by the significant decrease from pre to post scenario. Further study is needed to verify the existence of any "experience" effects.

Concerning the Wingate test, it appears that of the 3 indices measured, mean power may best describe anaerobic power capacity. Because the time sequence is 30 s in duration, both the ATP-CP system and anaerobic glycolysis are being taxed. These two systems complete the spectrum of anaerobic metabolism. In addition, mean power may be a more reliable measure than peak power due to the "experience" effect previously discussed.

The results of the pre to post comparison indicate that performance of the upper body anaerobic tests decreased, whereas performance of the lower body remained unchanged. It is possible that partial sleep deprivation during the scenario could have been a confounding factor in our results. Although the effect of sleep loss on anaerobic metabolism has not been established, it has been shown that psycological rather than physiological performance is generally affected (11,12,13). Cognitive and vigilence tasks rapidly deteriorate within the first 4 days of partial sleep loss, and behavioral or mood changes are evident such as a lack of motivation or decreased effort exerted (12,13). It is possible that 5 continual nights of only 4-5 hours sleep per night during the scenario could have elicited these behavioral changes during tasks which the soldiers may have considered uninteresting such as laboratory performance tests.

This reduction in motivation, however, may be manifest only in a laboratory situation which represents an artificial atmosphere. In reality, combat presents a life-threatening situation for the soldier. In such fearful situations, the sympathetic nervous system is stimulated by the release of adrenaline and noradrenaline to increase heart rate, blood pressure, blood flow to the muscles and lungs, and increase blood glucose. All these reactions help mobilize the physical resources of the body to escape the precipitating danger. This reaction would offset a lack of motivation due to sleep loss. It appears that a more important issue than the loss of anaerobic ability pre to post scenario is the soldiers' initial level of anaerobic power capacity and its relation to field performance.

FITNESS COMPONENTS VS PERFORMANCE RATING

Table 7 summarizes the significant correlations between the 96 fitness variables measured and performance ratings. Among these variables, both peak and mean power of the upper body Wingate were the most significant correlates. It is interesting that all five significant variables measure an aspect of upper body performance. This observation is consistent with the fact that only upper body/arm anaerobic power capacity decreased from pre to post scenario. Apparently, upper body exercise capacity is an essential fitness requirement for the ability to perform sustained infantry tasks and may be subject to decrement over time. This aspect of training is not currently emphasized as much as aerobic and lower body conditioning. Furthermore, if, in fact, the upper body muscles are less well conditioned than the lower body with respect to the load demand during sustained operations, then the decrement from pre to post scenario in upper body anaerobic capacity could partially be due to insufficient training. Our results suggest a reevaluation of the present training requirements.

An explanation for this relationship to upper body performance could be the weight of the load carried by the soldiers. The mean load of 28.1 kg included uniform, rifle, ruck sack and other small equipment. If a soldier possessed insufficient upper body capacity, the weight of his load could affect his overall performance in the field. In addition, continual load bearing over days may have a debilitating effect on this capacity.

Although these correlations are statistically significant, their magnitude is very low. We could not obtain an adequate multiple regression equation to explain the majority of variation in performance ratings. The only variable entered into the equation was peak power Wingate, and this equation only explained 25% of the variation in performance. The most plausible reason for these observations is the inadequacy of the rating procedure to provide variability in performance ratings. Although the rating scale ranged from 1 to 10, the actual recorded scores did not vary enough to result in high correlations. For example, individual scores ranged from a minimum of 4.1 to a maximum of 7.1 with a mean of 6.01 and standard deviation 0.82. In order to accurately determine the role of fitness variables on field performance by means of statistics, an enhanced rating procedure must be developed. This procedure would include a more integrated rating scale which would result in a high variability of scores between subjects.

TABLE 7. Significant Correlations of all Fitness Components with Performance Rating.

VARIABLE	r
Peak Power Wingate(Upper Body)	0.463 **
Mean Power Wingate(Upper Body)	0.430 **
Static Strength Arm	0.365 *
Upright Pull	0.358 *
Dynamic Lift	0.357 *

* P<.05 ** P<.01

CORRELATION IET VS. WT

A correlation matrix of the IET tests and the WT is presented in Table 8. There were significant correlation coefficients among all the variables except those involving percent decline (WT and IET). The highest relationships were among the MP WT and the MPT IET test as well as the MP WT and HPT IET test. Similar correlation coefficients were reported by Inbar et al between the WT and the IET test with 50 contractions. They reported high correlations with IET vs. MP WT and PP WT and very low correlations with IET vs PD WT(14). These results offer further support to our conclusion that both tests measure the same physiological indice, anaerobic power capacity. However, because only 64% of the variance is explained at best, the two tests must be measuring somewhat different factors (i.e. muscle groups).

The correlations of the WT vs IET using 50 contractions (approximately 1 min) were consistently lower than the correlations of the WT vs. IET using 20/25 contractions (approximately 30 sec). Although the magnitude of this difference was slight, it is more reasonable, physiologically, to use the 30 sec. time frame to quantify anaerobic power capacity. At 30 sec duration of exercise, approximately 80% of the energy used is supplied by anaerobic processes and 20% is contributed aerobically. This percentage decreases as the duration of exercise increases, so that at 1 minute only 70% of the energy yield is supplied anaerobically(15). In addition, decreasing the length of the test from 50 contractions (1 min) to 20/25 contractions (30 sec) reduces stress on the subject.

TABLE 8. Correlation Matrix of Wingate Variables vs. Isokinetic Endurance Variables.

Wingate Test	Isokinetic Endurance (50 C)						Isokinetic Endurance (20/25 C)			
	MPT(Nm)		HPT(Nm)		DPT(%)		MPT20/25 (Nm)		DPT20/25 (Nm)	
	leg	arm	leg	arm	leg	arm	leg	arm	leg	arm
Mean Power (W)										
Lower Body	0.79**	0.67**	0.71**	0.67**	-0.14	-0.01	0.80**	0.66**	-0.23	0.07
Upper Body	0.68**	0.51**	0.67**	0.58**	-0.04	0.14	0.69**	0.56**	-0.01	0.15
Peak Power (W)										
Lower Body	0.65**	0.54**	0.61**	0.50**	-0.19	-0.09	0.67**	0.52**	-0.10	-0.10
Upper Body	0.52**	0.38**	0.55**	0.42**	0.09	0.04	0.55**	0.41*	0.12	0.09
Power Decrease(%)										
Lower Body	-0.28	-0.19	-0.20	-0.28	-0.13	-0.24	-0.27	-0.25	0.24	-0.13
Upper Body	-0.22	-0.10	-0.09	-0.19	0.27	-0.23	-0.17	-0.15	0.34*	-0.17

*P<.05 **P<.01

CONCLUSION

Anaerobic power capacity represents one's ability to perform high intensity short duration exercise. In the realm of combat, it is an important fitness component. Typically, soldiers are required to react quickly and mobilize into defensive or offensive positions immediately. Those soldiers with a higher anaerobic power capacity will be able to move quicker and sprint faster than those with a low anaerobic power capacity. Inevitably, this ability should enhance performance of field infantry tasks.

The following is a summary of major conclusions on anaerobic power capacity from this study:

1) Comparison of pre to post scores of anaerobic power capacity reveal a decrease in mean upper body/elbow flexor performance and no change in lower body/knee extensor performance.

2) The decrease in upper body/elbow flexor performance from pre to post scenario may be attributed to a lower conditioning state of these muscle groups with respect to the continual load bearing of 28 kg over 5 days.

3) The increase observed in peak power Wingate from pre to post scenario could be an artifact due to an "experience effect". For this reason and the fact that it takes 30s to completely test both anaerobic glycolysis and ATP-CP, mean power proves to be a more reliable and comprehensive variable of anaerobic power capacity.

4) Significant correlations between the WT and the IET test for mean and peak variables support the idea that both tests measure the same indice, anaerobic power capacity. The difference in scores, however, indicate that other factors (ie. different muscle groups) are tested in each procedure.

5) Higher correlations of WT with IET25 suggests the reduction of the IET test from 50 to 20/25 contractions. The time sequence (30s) of 20/25 contractions more accurately tests anaerobic power capacity and tends to reduce subject stress.

6) Anaerobic power, as measured by the Wingate test, appears to play an important role in the ability to sustain infantry combat activities over 5 days as evidenced by significant correlations of PP and MP WT to performance.

7) In order to more accurately assess which fitness components are commensurate with successful performance in the field, an improved method of assessing performance must be developed.

REFERENCES

1) Mitchell, J.H., B.J.Sproule, C.B.Chapman. The Physiological Meaning of the Maximal Oxygen Intake Test. J. Clinical Investigation. 37:538-547, 1958.

2) Margaria,R., P. Aghemo, E. Ravelli. Measurement of Muscular Power (anaerobic) in Man. J. Applied Physiology. 21:1662-1664, 1966.

3) Bosco,C., P.Luhtanen, V.Komi. A Simple Method for Measurement of Mechanical Power in Jumping. Eur. J. Appl. Physiol. 50:273-282, 1983.

4) Cunningham, D.A., J.A. Faulkner. The Effect of Training on Aerobic and Anaerobic Metabolism During a Short Exhaustive Run. Med. Sci. Sports. 1:65-69, 1969.

5) Bar-or. A New Anaerobic Capacity Test - Characteristics and Applications. Proc. World Congr. Sports Med. 21st Brasilia, 1978.

6) Thorstensson,A. Muscle Strength, Fibre Types, and Enzyme Activities in Man. Acta Physiologica Scandinavia. Supplementum 443, 1976.

7) McArdle,W.D., F.I. Katch, V.L. Katch. Exercise Physiology: Energy, Nutrition, and Human Performance. Philadelphia, Lea & Febiger, 1981.

8) Frederick,F.A., R.C.Langevin, J.Miletti, M.Sacco, M.M.Murphy, J.F.Patton. Development and Assessment of the Monark Cycle Ergometer for Anaerobic Muscular Exercise. USARIEM Technical Report. T6/83, 1983.

9) Ramos,M., J.Knapik. Instrumentation and Techniques for the Measurement of Muscular Strength and Endurance in the Human Body. USARIEM Technical Report. T2/80, 1980.

10) Wright,J.E, J.A.Vogel, J.B. Sampson, J.J.Knapik, J.F.Patton, W.L.Daniels. Effect of Travel Across Time Zones (Jet Lag) on Exercise Capacity and Performance. Aviation,Space,and Environmental Medicine. 54(2):132-137,1983.

11) Martin,B.J., G.M.Gaddis. Exercise after Sleep Deprivation. Medicine and Science in Sports and Exercise. 13(4):220-223, 1981.

12) Sutton,J.S., S.A.Fisher. The Effects of Continuous Day and Night Operations on the Performance of the Soldier. APRE Report 4/70, 1970.

13) Haslam,D.R. The Military Performance of Soldiers in sustained Operations. Aviation, Space and Environmental Medicine. 55(3):216-21, 1984.

14) Inbar,O., P.Kaiser, P.Tecsh. Relationships Between Leg Muscle Fiber Type Distribution and Leg Exercise Performance. International J. Sports Medicine. 2:154-159, 1981.

15) Astrand,P., K.Rodahl. Textbook of Work Physiology. 2nd Edition. New York, McGraw-Hill Inc., 1977. PP.315-318.

16) Murphy,M.M.,F.A.Frederick,J.F.Patton. Evaluation of the Wingate Test of Anaerobic Capacity : Development and Evaluation of the Wingate Procedure. USARIEM Annual Progress Report. FY 83.