AD ________________

MIPR NO: 95MM5548

TITLE: Impact of Smoking on Aerobic and Anaerobic Performance During Upper and Lower Body Exercise in Female Soldiers

PRINCIPAL INVESTIGATOR(S): COL Idelle M. Weisman

CONTRACTING ORGANIZATION: William Beaumont Army Medical Center
El Paso, Texas 79920-5001

REPORT DATE: April 1996

TYPE OF REPORT: Final

PREPARED FOR: U.S. Army Medical Research and Materiel Command
Fort Detrick, Frederick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for public release; distribution unlimited

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 1996	Final (1 Dec 94 - 31 Dec 95)

4. TITLE AND SUBTITLE
Impact of Smoking on Aerobic and Anaerobic Performance During Upper and Lower Body Exercise in Female Soldiers

5. FUNDING NUMBERS
95MM5548

6. AUTHOR(S)
COL Idelle M. Weisman

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
William Beaumont Army Medical Center
El Paso, TX 79920-5001

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick, MD 21702-5012

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

DTIC QUALITY INSPECTED 2

13. ABSTRACT *(Maximum 200 words)*

The impact of smoking on exercise performance of female soldiers is of interest to the military. Objectives. To study in female soldiers: a) the chronic / acute effects of smoking on aerobic / anaerobic performance during lower / upper body exercise, b) the aerobic / anaerobic capacity for lower / upper body exercise and to correlate these values with the Army physical fitness test (APFT). Methods: Healthy female soldiers, 12 smokers, after abstaining from smoking (COHb < 2%) and after smoking (COHb: 6.5%), and 22 non-smokers were studied. Maximal aerobic power and cardiopulmonary variables were measured during lower / upper body exercise using an automated exercise system. Maximal anaerobic power during lower / upper body exercise was evaluated using the Wingate test. Results and conclusions : The chronic / acute effects of light to moderate smoking does not appear to impact the aerobic / anaerobic capacity for lower / upper body exercise; female soldiers have a normal aerobic and anaerobic capacity for upper and lower body exercise with an average level of fitness; they appear to be equally fit for aerobic and anaerobic exercise; no correlation was observed between the APFT and indices of aerobic / anaerobic capacity; maximal aerobic capacity was 60 % of men, 72 % when normalized for body weight.

14. SUBJECT TERMS
Exercise, Smoking, Women, Aerobic, Anaerobic, Army, Cardiopulmonary exercise test, exercise performance, Wingate test

15. NUMBER OF PAGES
49

16. PRICE CODE

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

FOREWORD

Opinions, interpretations, conclusions and recommendations are those of the author and are not necessarily endorsed by the US Army.

N/A Where copyrighted material is quoted, permission has been obtained to use such material.

N/A Where material from documents designated for limited distribution is quoted, permission has been obtained to use the material.

DW Citations of commercial organizations and trade names in this report do not constitute an official Department of Army endorsement or approval of the products or services of these organizations.

N/A In conducting research using animals, the investigator(s) adhered to the "Guide for the Care and Use of Laboratory Animals," prepared by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Resources, National Research Council (NIH Publication No. 86-23, Revised 1985).

DW For the protection of human subjects, the investigator(s) adhered to policies of applicable Federal Law 45 CFR 46.

N/A In conducting research utilizing recombinant DNA technology, the investigator(s) adhered to current guidelines promulgated by the National Institutes of Health.

N/A In the conduct of research utilizing recombinant DNA, the investigator(s) adhered to the NIH Guidelines for Research Involving Recombinant DNA Molecules.

N/A In the conduct of research involving hazardous organisms, the investigator(s) adhered to the CDC-NIH Guide for Biosafety in Microbiological and Biomedical Laboratories.

[signature] 7/26/96

PI - Signature Date

FINAL REPORT

TABLE OF CONTENTS

INTRODUCTION

BACKGROUND

During exercise, muscle contraction requires energy (ATP), which is supplied by both the aerobic and anaerobic metabolism of nutrients. Exercise lasting longer than 3-5 minutes uses energy provided by aerobic metabolism, while short bursts of high intensity exercise utilizes mainly anaerobic energy sources (34).

Advances in military technology have changed the nature of modern warfare. While previous wars were characterized by long marches and extended face to face battles where aerobic capacity was the main physical attributes of the soldier, the Persian Gulf war introduced "minimal personnel engagement with the enemy." When close combat was imminent, soldiers were transported to the scene. As result, anaerobic activities such as short sprints at high speed were also important physical attributes necessary to provide success and survival in these skirmishes.

Physical fitness is required for performance of all military duties. With the expanding role of women in the Army, which includes deployment of women to the field for training and deployment of female soldiers in an increasing number of combat roles (44), their physical readiness has become a crucial issue for the military.

Although several studies have evaluated exercise performance in male soldiers, glaring deficiencies exist in our knowledge of a broad spectrum of female soldier exercise performance issues.

Aerobic fitness levels for lower body exercise in Army soldiers have been previously reported. Most of these studies were performed predominantly in males with only a small number of females (33,.35, 41, 42)

To our knowledge, there have been no previous studies which have fully evaluated the level of fitness for upper body exercise in Army personnel, men or women. The importance of upper extremity work in the performance of military tasks and the anticipated differences between men and women have also not been thoroughly evaluated.

The ability to perform burst or exhaustive sprint type work, which is critical to modern warfare, has only recently received attention and then, only in male soldiers (21, 29). To the best of our knowledge, anaerobic power has never been evaluated in female army personnel.

Another area of interest to the military, especially as it relates to performance, is smoking. Available epidemiological data indicates that military personnel have a higher percentage of smokers than the civilian population. A Department of Defense survey indicates that 51% of military personnel smoke compared to 36% and 29% for males and females, respectively in the civilian population (6). Controversial results have been reported on the effect of smoking on human performance on male Army personnel (5, 10, 11, 17, 18). The results of these studies however are tarnished by the poor characterization of the smoking history of the volunteers and for the lack of differentiation between the chronic and acute effects of smoking in human performance. Furthermore, we are not aware of any study that specifically addresses the effect of smoking on the exercise performance of the female soldier. This protocol will try to overcome some of the deficiencies of previous studies performed in male soldiers, which resulted in conflicting results about the effect of smoking in exercise

Differences between female military personnel and male soldiers are to be expected with respect to lower and upper extremity strength and work capabilities; this may also include anaerobic upper and lower extremity work. How these differences impact on specific military task performance between men and women remain unknown and could be addressed in subsequent task specific focused projects.

Data is needed to help more clearly define gender based performance standards. This work will provide an initial physiologic data base in female soldiers, not only on aerobic upper and lower extremity exercise, but also on anaerobic capacity for upper and lower body exercise. The physiologic data provided by this study will help in the analysis of current training regimens in order to enhance the performance of female soldiers in the field.

This work will provide a preliminary evaluation of the impact of smoking on exercise performance involving upper and lower body aerobic (endurance) and anaerobic (short sprints) exercise in female soldiers.

performance. The design of the protocol will allow the differentiation of the acute from of chronic effect of the smoking on the exercise performance.

PURPOSE OF THE PRESENT WORK

1- To determine the chronic and acute effects of smoking on aerobic and anaerobic performance during lower and upper body exercise.

2- To establish a comprehensive quantitative data base of aerobic (exercise longer than 5 minutes) and anaerobic (short bursts of high intensity exercise) levels of fitness for female army personnel for lower and upper body exercise.

3- To determine if female soldiers are more fit to perform aerobic or anaerobic exercise and upper or lower body exercise.

4- To correlate upper and lower body levels of fitness with Army physical fitness test results.

APPROACH

This is a prospective, controlled, parallel study, which involved healthy active duty female military personnel from Ft. Bliss, TX. Twenty-three smokers (after abstaining from smoking for 12 hours) and 12 non-smokers were studied on 2 different days. The smokers were re-tested on 2 more days after being prompted to smoke to achieve a COHb level of 6 to 8%.

These additional tests would allow for a comparison of chronic vs acute effects of cigarette smoking in the same individual. Maximal aerobic power during lower and upper body exercise was evaluated using a maximal incremental exercise test to volitional exhaustion on a cycle and arm crank ergometer, respectively. Metabolic and cardiopulmonary measurements were obtained using an automated exercise system. The maximal anaerobic power during lower and upper body exercise was measured using the Wingate "all-out" 30 sec test on a cycle and arm crank ergometer respectively.

BODY

PROTOCOL AND METHODS

This study was conducted in the Human Performance Laboratory of the William Beaumont Army Medical Center, El Paso TX at an altitude of 1270 m, mean PB 656 mm Hg and average temperature of 23° C.

Twenty-six non-smokers and 19 smokers, active duty, healthy Army female volunteers were recruited from Fort Bliss, Texas. Due to logistical reasons, only 23 non-smokers and 12 smokers were able to complete the study. All volunteers acknowledged voluntary participation in this study by giving informed written consent.

All the subjects completed a health questionnaire. Non-smokers and smokers after abstaining from smoking for 12 hours (to evaluate chronic effect of smoking) undertook 4 exercise tests on 2 days. Smokers had 4 more exercise tests on 2 additional days after being encouraged to smoke, to evaluate the acute effect of smoking. The order of the tests was randomly assigned. The duration of the study was of 2 days for non-smokers (4 tests) and 4 days for smokers (8 tests).

Volunteers who smoked less than 20 packs of cigarettes in a life time were considered non-smokers. Volunteers who were current smokers with at least 5 pack years smoking history were considered smokers. It was difficult to find smokers with a longer smoking history in this young group of soldiers.

Complete pulmonary function testing were measured following the ATS guidelines (2, 3). Spirometry and single breath diffusing capacity for carbon monoxide (DLCO) were determined in a pulmonary function system(Sensor Medics 2200). Lung volumes were determined in a variable pressure body plethysmograph (Gould 2800 Autobox). Reference values for spirometry (13), lung volumes (15) and DLCO (14) for whites, race corrected were used.

A venous blood sample was obtained before every exercise test for determination of baseline COHb and lactate. In the morning blood sample, a pregnancy test was also performed to document that the volunteer was not pregnant.

A carboxyhemoglobin (COHb) value of less than 2% was used as criteria for testing non-smokers and smokers during the nonsmoking day. A value between 6% to 8% was chosen as a criteria for testing smokers during the smoking day. For the non-smoking day, smokers were asked to refrain from smoking from the afternoon of the previous day. If the morning of the test COHb was more than 2%, 100% O2 was administered for 40 minutes to washout half the CO from the blood. This procedure was only used on two occasions. For the smoking day, smokers were prompted to smoke normally the day before and to keep smoking before the tests a sufficient number of cigarettes to reach the expected blood levels of (COHb).

EXERCISE PROTOCOLS:

Day 1 - Morning

The maximal aerobic power for lower body exercise was determined using a maximal incremental exercise test to volitional exhaustion (approximately 10 min), on an electronically braked cycle ergometer. (Mijnhart Kem III). Metabolic and cardiopulmonary measurements were obtained in a breath by breath mode (8) using an automated system (Medical Graphics Corp. CPX) which integrates flow (Pneumotachometer Hans Rudolph No. 3800)and respiratory gases, measured with a mass spectrometer (Perkin-Elmer, MGA-1100). Heart rate and electrocardiogram were recorded in an electrocardiograph (Quinton 4000). At the end of the test, subjective evaluation of perceived exertion was performed using the Borg scale (9).

Five minutes post exercise a venous blood sample (1 ml) was obtained for determination of lactate (YSI 1500 Sport) and COHb (OSM 3 Hemoximeter, Radiometer).

Three hours were allowed for lunch and rest before the afternoon test.

Day 1 - Afternoon

The maximal aerobic power for upper body exercise was measured using an incremental arm crank exercise protocol to volitional exhaustion (approximately 8 min.). A modified electronically braked cycle ergometer was used (30). Metabolic and cardiopulmonary variables were also determined. At the end of the test, subjective evaluation of perceived exertion was performed using the Borg scale. Five minutes post exercise a venous blood sample (1 ml) was obtained for determination of lactate and COHb.

Day 2 - Morning

The maximal anaerobic power for lower body exercise was determined utilizing the Wingate test (7). Subjects pedaled "all out" for 30 seconds on a mechanically braked cycle ergometer (Monark - 814 E) against a constant workload. The resistance for each volunteer was calculated as 0.09 kg x body weight in kg. The mean resistance was 5.3 $\pm$ 1.2 kg for both groups. Peak anaerobic power, mean anaerobic power and percent fatigue (difference between peak power and the lowest power, expressed as a percentage of peak power) were measured. At the end of the test, subjective evaluation of perceived exertion was performed using the Borg scale. Five minutes post exercise a venous blood sample (1 ml) was obtained for determination of lactate and COHb. Three hours were allowed for lunch and rest before the afternoon test.

Day 2 - Afternoon

The maximal anaerobic power for upper body exercise was evaluated using a modified Wingate protocol for arm-crank ergometry. The resistance for each volunteer was calculated set at 0.048 x body weight in kg (7). The mean resistance was 3.0 $\pm$ 0.4 kg for both groups. Peak anaerobic power, mean anaerobic power, and percent fatigue were determined. At the end of the test, subjective evaluation of perceived exertion was performed using the

Borg scale. Five minutes post exercise a venous blood sample (1 ml) was obtained for determination of lactate and COHb.

Day 3 and 4 for Smokers

Smokers were asked to repeat the 4 exercise tests on 2 more days, after smoking as usual and after reaching the expected range of COHb (6 to 8%) in the baseline venous blood.

Statistical Analysis: The SPSS for windows ver 7.0 statistical program was used for the analysis of the data, which will include descriptive statistics, ANOVA, Student *t* test, Pearson correlation coefficients, and linear regressions. A level of $p < 0.05$ was chosen for significance.

RESULTS

The anthropometric characteristics and smoking history of the studied volunteers grouped as non-smokers and smokers are presented in Table 1. Both groups are comparable in age, height and weight. The results of the most recent Army physical fitness test are reported in Table 2. No statistical differences were observed for any of the Army physical fitness tests between smokers and non-smokers. The pulmonary function tests, that included spirometry, lung volumes and diffusing capacity, were within the normal limits for both groups, no statistical differences were demonstrated between both groups except for FVC, which was higher in smokers (Table 3).

The chronic and acute effect of smoking on the aerobic performance of lower body exercise of female soldiers is presented in Table 4. No differences were observed between non-smokers and smokers during non smoking day for power, VO_2,VO_2/kg, HR and LT; only VE was slightly lower on smokers during non-smoking day. A similar response was demonstrated for smokers between non-smoking and smoking day.

Similarly, in Table 5 the cardiopulmonary results of the maximal aerobic arm crank exercise for non-smokers and smokers during non-smoking and smoking days are presented. No statistically significant differences were observed between the non-smokers and smokers during the non-smoking day for any of the cardiopulmonary variables measured. The comparison in smokers, of non-smoking vs smoking day demonstrated a small but statistically significant difference in power (88 vs 80 watts respectively), no difference being observed for any of the other variables.

The results of the anaerobic capacity- evaluated by the Wingate test - for lower body exercise of non-smokers and smokers are shown in Table 6. No statistically significant differences were observed between the non-smoker and smoker (non smoking day) groups for any of the Wingate test variables measured. Similarly, no significant differences were observed for any of the variables measured in the smoker group between non-smoking and smoking days.

Likewise, the results of the anaerobic capacity, evaluated by the Wingate test, for upper body exercise of non-smokers and smokers are presented in Table 7. No statistically significant differences were observed between the non-smoker and smoker (non smoking day) groups for any of the Wingate test variables measured. Similarly, no significant differences were observed for any of the variables measured in the smokers group between non-smoking and smoking days .

The relationships between maximal aerobic and anaerobic capacity, for leg and arm exercise are presented in Table 8. Although, the majority of the correlations were statistically significant, the r values were low and inconsistent.

The correlations between the several variables of the Army physical fitness test and the aerobic (VO_2 max) and anaerobic capacity (Wingate test) are shown in Table 9.

For reference purposes, maximal cardiopulmonary leg exercise responses were pooled for female non-smokers and smokers and then compared with historical data obtained in our laboratory in healthy young male soldiers (Table 10). The maximal power achieved by females for leg and arm exercise was approximately 65%of the maximal power achieved by males. The maximal VO_2 in absolute values attained by females was 60% and 65% of the values achieved by males for leg and arm exercise, respectively. However, when VO_2 was corrected for body weight and expressed as VO_2/kg the gender difference narrowed to 72% and 77% of the values achieved by males at maximal leg and arm exercise, respectively.

DISCUSSION

Despite the significant effort employed in recruiting volunteers, we were unable to reach our target number of smoking female soldiers. Possibly, this was related to the Fort Bliss antismoking campaigns, which make it unpopular for smokers to identify themselves as such. Also, for smokers the participation in the study required 4 days, interfering many times with their working or training schedules.

Although we recruited 26 non-smokers and 19 smokers, due to logistical problems (especially follow up appointments) we were able to complete all the tests in 22 non smokers and 12 smokers female Army personnel. Both groups have similar anthropometric characteristics (Table 1) and level of fitness evaluated by the Army physical fitness test (Table 2). According to the smoking history, the smoking group would be characterized as light to moderate smokers. Also, although not statistically different, the smokers were slightly older than the non-smokers.

Non-smokers and smokers had normal pulmonary function tests; with values that were within the normal range of the reference values (Table 3). No statistical differences in pulmonary function tests were observed between groups with the exception of FVC which was higher in smokers. Although within the normal range, the smoking group had lower FEV_1/FVC and lower $FEF_{25-75\%}$, suggesting some early airway dysfunction.

Chronic Effect of Smoking on Aerobic Capacity.

The comparison of the maximal cardiopulmonary response to maximal incremental cycle ergometry exercise between non smokers and smokers during a non smoking day (COHb < 2 %) can provide potentially helpful information about the chronic effect of smoking on the aerobic capacity of asymptomatic females (Table 4, Figure1). Tobacco smoke contains more than 4,000 components, many of them with harmful effects on the cardiopulmonary system (24). Smoke induces inflammation of the airways, increases bronchial hyper reactivity, produces alterations of the structure of the small airways and lung parenchyma with potential for airway obstruction(25). The airway obstruction decreases the ventilatory capacity thus contributing to the limitation of exercise performance. Smoking also induces gas exchange abnormalities due to reduction in diffusing capacity and ventilation perfusion inequalities which will result in hypoxemia and reduction in O_2 availability for muscular exercise (43). Multiple studies have convincingly demonstrated that cigarette smoking is the strongest determinant of chronic obstructive pulmonary disease (20). Apparently, the host factor plays an important role, since it is unclear why only 15 % of smokers develop COPD (19). It is also well established that smoking is a major factor in the development of heart disease. The two major forms of cardiovascular disease associated with smoking are coronary artery disease and peripheral vascular disease (32). It has also been postulated that small airway disease can be an early manifestation of pulmonary disease in smokers; however all the attempts to convincingly demonstrate small airways disease through early detection has been unsuccessful. Also, it is unclear the duration of smoking which is necessary to induce pathological abnormalities sufficient to induce deterioration of the exercise capacity of the smoker. Smokers who already have developed COPD have exercise intolerance with significant reduction in aerobic capacity as compared to normals (27).

The comparability of the cardiopulmonary results between smokers and non-smokers during the non-smoking day, with the exception of minute ventilation -whose physiological significance is not clear -, would imply that in healthy individuals, 12 pack years of smoking does not significantly impact on the maximal leg exercise aerobic capacity. The effect of chronic, cigarette smoking on the aerobic capacity of asymptomatic smokers is extremely controversial. Although several investigators have shown consistent differences in exercise performance between smokers and non smokers (39, 17,18), the results of these studies are tarnished by poor characterization of the studied groups with respect to level of fitness, smoking histories, levels of COHb, resting pulmonary function tests, etc. The results of a large study carried out in Army male personnel (n: 685) by Daniels and collaborators(18) demonstrated a 5 % reduction in VO_2 max in smokers as compared to non-smokers. The same author in a previous study in Army male personnel (17), reported differences up to 10 % in VO_2 max between older (mean age: 44 yrs) smokers versus non-smokers, however no differences in VO2 max was detected between young (mean age: 22 yrs) smokers versus non-smokers; the authors concluded that smoking had little effect on aerobic fitness in a young, healthy and active population. Bahrke et al (5) did not observe difference in the 2-mile running time between 50 military personnel smokers and 97 non-smokers. Cooper (11) studied the effect of cigarette smoking on endurance performance in 419 young airmen. Significant differences in a 12 minute maximum running test were reported in smokers vs. non-smokers. As part of the same study, he compared the aerobic capacity (VO_2 max) between 25 non-smokers and 22 smokers during a maximal treadmill exercise test. No differences in VO_2 max between the 2 groups was observed. We are not aware of any study that has investigated the impact of smoking on the aerobic capacity of women. In summary, our results suggest that similar to men, light to moderate smoking does not have or have very little effect on the aerobic capacity of young, healthy and active women.

Similar results to leg exercise had been obtained for the maximal aerobic capacity during arm exercise of non-smokers and smokers during the non smoking day (Table 5, Figure 1). The lack of significant differences between non-smokers and smokers for the different cardiopulmonary variables measured, strengthen the finding that the chronic effect of mild to moderate smoking in young female soldiers does not appear to impact significantly on the aerobic capacity for lower and upper body exercise.

Acute Effect of Smoking on Aerobic Capacity.

The comparison of exercise results in smokers obtained during the non smoking day, in which they have abstained from smoking for at least 15 h and the level of COHb was less than 2%, with those of the smoking day in which smoking occurred as usual appears in Figure 1. In some cases smokers were encouraged to smoke on the smoking day in order to reach the minimum value of COHb of 6%; this allowed us to objectively determine the acute effect of smoking on healthy, young, female soldiers, physically active with light to moderate smoking habit. No statistically significant change was observed between the non smoking and smoking day for any of the cardiopulmonary variables measured at maximal incremental cycle ergometry exercise (Table 4). Likewise, no differences were observed between the smoking and non smoking day for the variables measured at maximal arm crank exercise, with the exception of power which was slightly lower (8 watts) during smoking day (Table 5). These results would imply that mild to moderate acute smoking does not appear to measurably impact the aerobic capacity for lower and upper body exercise of healthy, young females. Theoretically, acute smoking could negatively impact the exercise performance of the volunteers through several mechanisms. It is well appreciated, that from all the factors of acute smoking that can affect exercise performance , carbon monoxide and nicotine are maybe the most important. Increased levels of COHb reduce O_2 content of blood and decreases O_2 delivery to the muscles; CO also shift the O_2 dissociation curve to the left thereby reducing O_2 unloading to the tissue. CO binds to myoglobin which may contribute to impaired O_2 delivery. Also CO impacts the function of respiratory enzymes and affects O_2 utilization (4, 40). Nicotine may also impact exercise performance by increasing heart rate and myocardial contractility and as a consequenc, increase myocardial O_2 demand.

We are aware of only one paper, published in abstract form, that has studied the acute effect of smoking on exercise performance. Hirsch et al (23) performed cycle ergometry on 9 smokers on 2 different occasions, the first during the smoking day (mean COHb level of 6.6 %) and the second during the non-smoking day (COHb level of 1.8 %). Lower VO_2 max, anaerobic threshold and O_2 pulse, but higher heart rate and systolic blood pressure at maximal exercise was reported on the smoking day as compared to the non-smoking day. The differences in the results between this study and the present work could be explained by several factors, the first of which is the type of population studied. Hirsch does not mention the level of fitness of the men studied. The volunteers in our study were healthy, physically active females. Also, the differences between both studies are more apparent than real, because Hirsch reported a reduction in VO_2 max between smoking and non smoking days of 4 % and we reported 2 %. In addition, it should be considered that the reproducibility of VO_2 max is $\pm$ 5 %. In summary both studies demonstrate a minimal or no change at all in maximal aerobic capacity. This is probably due to the large reserve for cardiac and respiratory function available in healthy young individuals. The reduction in O_2 content and O_2 unloading caused by smoking is probably compensated by increase in cardiac output and/or redistribution of blood flow to the exercising muscles, etc. It has been postulated that in a normal person when the level of COHb is less than 10 %, no significant decrement in exercise performance is detected.

Chronic Effect of Smoking on Anaerobic Capacity.

There is no readily apparent physiological reason for healthy asymptomatic smokers, with normal resting cardiopulmonary function tests, to have a reduced anaerobic capacity. It was no surprise that the results of the present study (Table 6 and 7) demonstrate no difference in any of the variables of the maximal anaerobic capacity (Wingate test), for leg and arm exercise, between non-smokers and smokers during non-smoking day (Figure 2). Our volunteers have a smoking history of only 12 pack years of smoking, which may not have been enough to induce measurable changes in the variables of the Wingate test.

Acute Effect of Smoking on Anaerobic Capacity.

From all the variables of the Wingate test measured during leg and arm exercise, maximal power during arm exercise was the only difference noted between non smoking and smoking days in smokers (Table 6 and 7). This small difference albeit statistically significant does not have physiological or clinical relevance. It would not have been unreasonable to expect differences between smoking and non-smoking days, because although the Wingate test utilizes basically anaerobic metabolism, it has been postulated that 9 to 44 % of the energy requirements for this test comes from aerobic metabolism (26, 38). Since COHb through several mechanisms described above, decreases O_2 delivery and utilization, COHb could also impact in the Wingate test. However it appears that in normal individuals the functional reserve provide a sufficiently adequate level of oxygenation to the exercising muscles and, as such, a normal Wingate test. Since no significant differences were observed for the Wingate anaerobic test between smokers and non-smokers, we pooled the data to compare with the values reported by Maud and Shultz (31) in 69 young, physically active college women. The Wingate mean power measured in the present study (401 W) was slightly higher, although not statistically different to that (381 W) reported by Maud. The values were almost the same (6.7 vs 6.4 W/kg) when normalized for body weight

Level of Fitness of the Female Soldiers Studied.

Considering that practically no differences were observed between smokers and non smokers in aerobic and anaerobic capacity for upper and lower body exercise, we pooled all the data together to increase the statistical power of the sample size. The comparison of the cardiopulmonary variables measured at maximal cycle ergometry exercise with appropriate reference values for females (22) revealed a VO_2, VO_2/kg, and HR around 100 % of the predicted values. V_E was only 75 % of the reference value, indicating a normal breathing reserve. Also the power achieved was higher than the predicted values. Using as a reference a widely used table from the American Heart Association (1) for level of fitness, the, female soldiers studied can be characterized as having an average level of fitness. In a classic and largest study of aerobic capacity in the Army, Vogel and collaborators (41) measured the aerobic capacity of 1,514 men and 375 Army women. The VO_2/kg max reported by these authors on 212 females before basic training was 37.5 ml/kg/min. The value that was measured in the present work in 34 women was 32.7 ml/kg/min. It is known that VO_2 max measured on the treadmill is 7 to 11 % higher than that obtained on the cycle ergometer (45). Cycle ergometry was used in the present work and treadmill in Vogel's study. If the VO_2/kg measured in the present study is multiply by 10 % to correct for the difference between cycle ergometry and treadmill, the value would be 35.4 ml/kg/min very close to the value of 37.5 ml/kg/min reported by Vogel. Additionally, the discontinuous protocol used by Vogel vs. the continuous incremental of the present work, may also have contributed to the slightly larger VO_2 max. The data from this study reinforce the characterization of the level of fitness of the female soldiers as average.

Although the correlations, between indices of maximal aerobic and anaerobic capacity are statistically significant, the values are not as high as would be expected, and with inconsistencies noted, meaningful conclusions are difficult to make. The trend appears to be, that the women who have high aerobic capacity for leg exercise also have high aerobic capacity for arm exercise. Likewise, the women who have a high anaerobic capacity for leg exercise also possess a high anaerobic capacity for arm exercise. However, it appears that the relationship between aerobic and anaerobic capacity is weak and inconsistent.

In general, the lack of correlation between the several variables of the Army physical fitness tests (APFT) and the aerobic and anaerobic capacity are surprising. Several authors (33, 36) have demonstrated a significant correlation between the 2 mile run time and VO_2 max for lower body exercise. Cooper (12) using a similar principle, demonstrated a good correlation between the distance covered in a 12 min run and VO_2 max. Knapik (28) in a review article about the Army physical fitness test presents a summary table of several studies related to running performance and VO_2 max. Although the majority of studies showed a good correlation there were 3 studies with correlation lower than - 0.5. It is important to mention that the study with the worst correlations was performed in young college women (16), the studied population and results are similar to the present work. We do not believe that that the discrepancies with previous papers is due to differences in the gender of the volunteers studied, but rather, are at least partially due to the narrow range in the values of the APFT and VO_2 max. Another very likely explanation is that during the APFT the female soldiers do not push themselves to the maximum of their capabilities, but rather exert themselves to achieve the minimum requirements to pass the 2 mile run portion of the APFT.

The comparison of the cardiopulmonary response to maximal aerobic exercise for legs (Table 10, Figure 3) between the pooled data of the female soldiers studied and the data obtained in our laboratory in a previous study (30) in male soldiers using the same equipment and methodology demonstrated that the maximal aerobic power (VO_2 max) of women was 60 % of men when expressed in absolute values, and when normalized for body weight women were 72 % from men. The difference in minute ventilation was proportional to the difference in VO_2. The maximal heart rate was similar for men and women as has been previously described (37). Similar to the present work, Vogel and collaborators (41) found that women soldiers achieved 61 % of the VO2 max achieved by male soldiers when expressed in absolute values and 73 % when normalized for body weight.

A similar comparison of the cardiopulmonary response to maximal aerobic exercise for arms (Table 11, Figure 3) between the female soldiers and the data obtained in our laboratory in a previous study in male soldiers (30) using the same equipment and methodology demonstrated that the maximal aerobic power for arms (VO_2 max) of women was 65 % of men when expressed in absolute values and when normalized for body weight women were 77 % from men. The lower values in minute ventilation in females were proportional to the lower values in VO_2 max. As in upper body exercise, the maximal heart rate was similar between male and females soldiers.

CONCLUSIONS

1. The chronic effect of light to moderate smoking in young, healthy, physically active, females, does not appear to impact the aerobic capacity for lower and upper body exercise.
2. The acute effect of moderate smoking, mainly due to high levels of nicotine and COHb (6 %) does not negatively impact the aerobic capacity for lower and upper body exercise of young, healthy, physically active women.
3. The chronic and acute effect of smoking does not appear to impact the anaerobic capacity for lower and upper body exercise of young, healthy, physically active women.
4. The cardiopulmonary responses to maximal aerobic exercise of young female soldiers were approximately 100 % of the reference values for matched sex, age, height, and weight.
5. The level of fitness for aerobic exercise of female soldiers can be characterized as average which is comparable to other reported studies.
6. The anaerobic capacity of the female soldiers was comparable to the values reported in the literature in normal young physically active females.
7. The female soldiers appears to be equally fit to perform aerobic and anaerobic exercise.

8. It appears that indices of maximal aerobic capacity cannot reliably predict anaerobic capacity.
9. No correlation was observed between the indices of the Army physical fitness test and the maximum values of aerobic and anaerobic capacity for upper and lower body exercise.
10. The maximal aerobic power (VO_2 max) of women was 60 % of men when expressed in absolute values, however when normalized for body weight it was 72 % of men, consistent with another studies.
11. The maximal aerobic capacity of the female soldiers and the difference from male soldiers does not appear to have changed since 1986 (41).

REFERENCES

1. American Heart Association. Exercise testing and training of apparently healthy individuals: A Handbook for Physicians. Dallas, American Heart Association, 1972.

2. American Thoracic Society. Standardization of spirometry . 1987 update. Am Rev Respir Dis 1987; 136: 1285-1298.

3. American Thoracic Society. Single-breath carbon monoxide diffusing capacity (transfer factor). Recommendations for a standard technique. Am Rev Respir Dis 1987; 136: 1299-1307.

4. American Thoracic Society. Health effects of outdoor air pollution. Am J Respir Crit Care Med 1996; 153: 477-498.

5. Bahrke MS, Baur TS, Connors DF. Cigarette smoking and performance on the US army physical fitness test. Med Sci Sports Exerc 1986; 18:S30.

6. Ballweg JA, Li L. Comparison of health habits of military personnel with civilian populations. Public Health Rep 1989; 104:498-509.

7. Bar-Or O. The wingate anaerobic test. An update on methodology, reliability and validity. Sports Med 1987; 4:381-394.

8. Beaver WL, Wasserman K, Whipp BJ. On-line computer analysis and breath-by-breath graphical display of exercise function tests. J Appl Physiol 1973; 34:12)8-132.

9. Borg GAV. Psychophysical bases of perceived exertion. Med Sci Sports Exerc 1982; 14:377-381.

10. Conway TL, Cronan TA. Smoking and physical fitness among navy shipboard men. Mil Med 1988; 153:589-594.

11. Cooper KH, Gey GO, Bottenberg RA. Effects of cigarette smoking on endurance performance. JAMA 1968; 203:189-192.

12. Cooper KH. A means of assessing maximal oxygen intake. Correlation between field and treadmill testing. JAMA 1968, 203: 201-204.

13. Crapo RO, Morris AH, Gardner RM. Reference spirometric values using techniques and equipment that meet ATS recommendations. Am Rev Respir Dis 1981; 123: 659-664.

14. Crapo RO, Morris AH. Standardized single breath normal values for carbon monoxide diffusing capacity. Am Rev Respir Dis 1981; 123: 185-189.

15. Crapo RO, Morris AH, Clayton PD, Nixon CR. Lung volumes in healthy nonsmoking adults. Bull Eur Physiopathol Respir 1982; 18: 419-425.

16. Custer SJ, Chaloupka EC. Relationship between predicted maximal oxygen consumption and running performance of college females. Res Q 1977; 48: 47-50.

17. Daniels WL, Patton JF, Vogel JA, Jones BH, Zoltick JM, Yaney SF. Aerobic fitness and smoking. Med Sci Sports Exerc 1984; 16:195-196.

18. Daniels WL, Fitzgerald P, Dziados J, Melllo H, Vogel JA. Effects of smoking on physical performance in military personnel. Physiologist 1986; 29:161.

19. Department of Health and Human Services. The health consequences of smoking: chronic obstructive lung disease. A report of the surgeon general. Washington, DC: Government Printing Office, DHHS (PHS) 84-50205, 1984.

20. Griffith DE, Garcia JGN. Tobacco cigarettes, smoking, smoking cessation, and chronic obstructive pulmonary disease. Semin Respir Med 1989; 10: 356-371.

21. Hackney AC, Kelleher DL, Coyne JT, Hodgdon JA. Military operations at moderate altitude: effects on physical performance. Mil Med 1992; 157:625-629.

22. Hansen JE, Sue DY, Wasserman K. Predicted values for clinical exercise testing. Am Rev Respir Dis 1984; 129: S49-S55.

23. Hirsch GL, Sue DY, Robinson TE, Hansen JE. Immediate effects of cigarette smoking on exercise. Chest 1983; 84: 328.

24. Huber GL. Physical, chemical, and biologic properties of tobacco, cigarette smoke, and other tobacco products. Semin Respir Med 1989; 10:297-332.

25. Janoff A, Pryor WA, Bengali ZH. Effects of tobacco smoke components on cellular and biochemical process in the lung. Am Rev Respir Dis 1987; 136: 1058-1064.

26. Kavanagh MF, Jacobs I. Breath-by-breath oxygen consumption during performance of the Wingate test. Can J Sports Sci 1988; 13: 91-93.

27. Killian KJ, Leblanc P, Martin DH, Summers E, Jones NL, Campbell EJM. Exercise capacity and ventilatory, circulatory, and symptom limitation in patients with chronic airflow limitation. Am Rev Respir Dis 1992; 146: 935-940.

28. Knapik J. The army physical fitness test (APFT): a review of the literature. Mil Med 1989; 154: 326-329.

29. Knapik J, Daniels WL, Murphy M, Fitzgerald P, Drews F, Vogel J. Physiological factors in infantry operations. Eur J Appl Physiol 1990; 60:233-238.

30. Martin TW, Zeballos RJ, Weisman IM. Gas exchange during maximal upper extremity exercise. Chest 1991; 99: 420-425.

31. Maud PJ, Shultz BB. Norms for the wingate anaerobic test with comparison to another similar test. Res Q Exerc Sport 1989; 60: 144-151.

32. McGill HC. The cardiovascular pathology of smoking. Am Heart J 1988; 115: 250-257.

33. Mello RP, Murphy MM, Vogel JA. Relationship between a two mile run for time and maximal oxygen uptake. J Appl Sport Sci Res 1988; 2:9-12.

34. Miller WC. The biochemistry of exercise and metabolic adaptation. Dubuque: Brown and Benchmark, 1992.

35. Patton JF, Daniels WL, Vogel JA. Aerobic power and body fat of men and women during army basic training. Aviat Space Environ Med 1980; 51:492-496.

36. Shaver LG. Maximal aerobic power and anaerobic work capacity prediction from various running performances of untrained college men. J Sports Med Phys Fitness 1975; 15: 147-150.

37. Spiro SG. Exercise testing in clinical medicine. Br J Dis Chest 1977; 71: 145-172.

38. Stevens GHJ, Wilson BW, Ravin PB. Aerobic contribution to the Wingate test. Med Sci Sports Exerc 1986; 18 (suppl): 2.

39. Sue DY, Oren A, Hansen JE, Wasserman K. Lung little effect on aerobic fitness in young healthy and active population. function and exercise performance in smoking and nonsmoking asbestos-exposed workers. Am Rev Respir Dis 1985; 132: 612-618.

40. Turino GM. Effect of carbon monoxide on the cardiorespiratory system. Circulation 1981; 63:253A-259A.

41. Vogel JA, Patton JF, Mello RP, Daniels WL. An analysis of aerobic capacity in a large United States population. J Appl Physiol 1986; 60:494-500.

42. Weisman IM, Zeballos RJ, Martin TW, Johnson BD. Effect of army basic training in sickle-cell trait. Arch Int Med 1988; 148:1140-1144.

43. Weisman IM, Zeballos RJ. An integrated approach to the interpretation of cardiopulmonary exercise testing. Clin Chest Med 1994; 15: 421-445.

44. Women's Research and Education Institute, 1991. Facts about women in the military, 1980-1990. 1700 18th Street, N.W., Suite 400, Washington, D.C..

45. Zeballos RJ, Weisman IM. Behind the scenes of cardiopulmonary exercise testing. Clin Chest Med 1994; 15: 193-213.

APPENDIX

Table 1
Anthopometric Characteristics and Smoking History of Female Volunteers (mean ± SD)

	Non-Smokers (n = 22)	**Smokers** (n = 12)	**Total** (n = 34)
Age (yrs)	26 ± 6	30 ± 7	27 ± 6
Height (cm)	162.3 ± 10	163.9 ± 5	162.8 ± 9
Weight (kg)	60.1 ± 9	59.3 ± 7	59.8 ± 8
Smoking (pk yrs)	0.0 ± 0	12 ± 8	

* $p \leq 0.05$, 2 tailed, independent *t*-test

Table 2

Army Physical Fitness Test Results (mean ± SD)

	Non-Smokers (n = 22)	Smokers (n = 12)	Total Group (n = 34)
Push Ups	39 ± 19	37 ± 7	38 ± 17
Sit Ups	64 ± 17	65 ± 18	64 ± 16
Total Score	247 ± 40	250 ± 30	248 ± 37
2' Run Time	17:31± 2:05	17:58 ± 2:08	17:01± 2:03

* $p \leq 0.05$, 2 tailed, independent *t*-test

Table 3
Pulmonary Function Tests† (mean ± SD)

	Non-Smokers		Smokers		Total Group	
	(n = 20)	% Pred	(n = 10)	% Pred	(n = 30)	% Pred
FVC (L)	3.58 ± 0.57	103%	4.01 ± 0.13*	108%	3.72 ± 0.55	105%
FEV_1 (L)	2.99 ± 0.41	100%	3.16 ± 0.41	98%	3.05 ± 0.41	99%
FEV_1/FVC (%)	83% ± 7.6%		79% ± 6.4%		84% ± 7.0%	
FEF_{25-75}	3.33 ± 0.57	93%	3.01 ± 0.86	80%	3.22 ± 0.68	89%
MVV (L)	128 ± 19		126 ± 20		127 ± 19	
TLC	5.07 ± 1.07	111%	5.18 ± 0.78	105%	5.11 ± 1.0	109%
RV	1.50 ± 0.62	123%	1.84 ± 1.5	103%	1.62 ± 1.0	117%
D_LCO	23.9 ± 3.6	90%	24.2 ± 3.0	84%	24.0 ± 3.4	88%

* $p \leq 0.05$, 2 tailed, independent *t*-test

† Predicted values are race corrected

Table 4
Cardiopulmonary Variables at Maximal Incremental Leg Exercise Test (mean ± SD)

	Non-Smokers (n = 22)	Smokers Non-Smoking (n = 11)	Smokers Smoking (n = 12)	Total** Group (n = 33)
COHb (pre)	1.1 ± 0.4	1.4 ± 0.5	6.5 ± 1.2†	1.2 ± 0.5
Power (watts)	166 ± 23	162 ± 11	163 ± 20	164 ± 20
% Pred Power	*149%*	*146%*	*147%*	*148%*
VO_2(L/min)	1.96 ± 0.34	1.92 ± 0.16	1.88 ± 0.25	1.95 ± 0.28
% Pred VO_2	*108%*	*105%*	*103%*	*107%*
VO_2 (ml/kg/min)	32.9 ± 6.1	32.3 ± 3.4	31.2 ± 4.9	32.7 ± 5.3
V_E (L/min)	94 ± 17	83 ± 7.4*	89 ± 20	90 ± 16
% Pred V_E	*78%*	*68%*	*73%*	*75%*
HR	180 ± 12	182 ± 7	181 ± 13	181 ± 11
% Pred HR	*93%*	*95%*	*94%*	*94%*
LT	8.3 ± 1.5	8.7 ± 2.2	7.8 ± 1.8	8.4 ± 1.7

* $p \leq 0.05$, 2 tailed, independent *t*-test, Non-smokers vs Smokers (non-smoking days)

† $p \leq 0.05$, 2 tailed, independent *t*-test, Smokers (non-smoking) vs Smokers (smoking) Tests

** For reference only, no stats - All non-smoking tests

Table 5
Cardiopulmonary Variables at maximal Incremental Arm Crank Exercise Test (mean ± SD)

	Non-Smokers (n = 22)	Smokers Non-Smoking (n = 9)	Smokers Smoking (n = 11)	Total Group (n = 31)
COHb (pre)	1.1 ± 0.6	1.5 ± 0.6	6.9 ± 1.3†	1.2 ± 0.6
Power (watts)	88 ± 14	88 ± 13	80 ± 10†	87 ± 14
VO_2(L/min)	1.41 ± 0.24	1.36 ± 0.24	1.30 ±0.20	1.40 ± 0.24
VO_2 (ml/kg/min)	23.6 ± 4.5	21.3 ± 3.7	21.2 ± 3.4	23.5 ± 4.4
V_E (L/min)	68 ± 13	67 ± 13	66 ± 12	67 ± 13
HR	173 ± 15	180 ± 10	178 ± 13	175 ± 14
LT	6.4 ± 1.7	7.3 ± 1.7	6.6 ± 1.3	6.7 ± 1.7

* $p \leq 0.05$, 2 tailed, independent *t*-test, Non-smokers vs Smokers (non-smoking days)

† $p \leq 0.05$, 2 tailed, independent *t*-test, Smokers (non-smoking) vs Smokers (smoking) Tests

** For reference only, no stats - All non-smoking tests

Table 6
Results of the Maximal Anaerobic Capacity (Wingate) Test for Leg Exercise (mean ± SD)

	Non-Smokers (n = 20)	Smokers Non-Smoking (n = 12)	Smokers Smoking (n = 11)	Total Group (n = 32)
COHb (pre)	------------	1.4 ± 0.5	6.9 ± 1.4†	----------
Max Power	618 ± 106	584 ± 96	590 ± 69	607 ± 103
Max Power/kg	10.3 ± 1.7	10.2 ± 1.1	9.8 ± 1.1	10.2 ± 1.5
Min Power	280 ± 55	261 ± 46	264 ± 51	275 ± 53
Min Power/kg	4.7 ± 1.0	4.5 ± 0.7	4.4 ± 1.0	4.7 ± 0.9
Mean Power	413 ± 60	374 ± 49	383 ± 45	401 ± 59
Mean Power/kg	6.8 ± 1.1	6.5 ± 0.7	6.4 ± 0.9	6.7 ± 1.
% Fatigue	54% ± 10%	55% ± 8%	54% ± 11%	54% ± 10%
Max HR	175 ± 12	170 ± 7	178 ± 10	176 ± 11
Max LT	8.6 ± 2.0	8.7 ± 1.5	7.4 ± 1.4	8.6 ± 1.8

* $p \leq 0.05$, 2 tailed, independent *t*-test, Non-smokers vs Smokers (non-smoking days)

† $p \leq 0.05$, 2 tailed, independent *t*-test, Smokers (non-smoking) vs Smokers (smoking) Tests

** For reference only, no stats - All non-smoking tests

Table 7
Results of the Maximal Anaerobic Capacity (Wingate) Test for Arm Exercise (mean ± SD)

	Non-Smokers (n = 20)	Smokers Non-Smoking (n = 12)	Smokers Smoking (n = 11)	Total Group (n = 32)
COHb (pre)	----------	1.5 ± 0.6	6.4 ± 1.1†	---------
Max Power	323 ± 55	327 ± 36	302 ± 27†	324 ± 48
Max Power/kg	5.4 ± 0.6	5.4 ± 0.4	5.0 ± 0.5	5.4 ± 0.5
Min Power	162 ± 34	151 ± 31	148 ± 27	158 ± 32
Min Power/kg	2.7 ± 0.6	2.6 ± 0.4	2.5 ± 0.5	2.7 ± 0.8
Mean Power	228 ± 38	226 ± 21	209 ± 23	227 ± 33
Mean Power/kg	3.8 ± 0.6	3.7 ± 0.3	3.5 ± 0.4	3.8 ± 0.5
% Fatigue	49% ± 10%	51% ± 11%	50.9% ± 9%	50% ± 10%
Max HR	173 ± 13	178 ± 7	178 ± 10	175 ± 11
Max LT	6.9 ± 1.5	7.3 ± 1.7	7.6 ± 2.2	7.1 ± 1.6

* $p \leq 0.05$, 2 tailed, independent *t*-test, Non-smokers vs Smokers (non-smoking days)

† $p \leq 0.05$, 2 tailed, independent *t*-test, Smokers (non-smoking) vs Smokers (smoking) Tests

** For reference only, no stats - All non-smoking tests

Table 8

Correlations between Maximal Aerobic and Anaerobic Capacity

	VO_2 Arm	Wingate Mean Power Leg	Wingate Mean Power Arm
VO_2, Leg	0.62**	0.51**	0.45*
VO_2, Arm		0.33	0.31
Mean Power, Leg	0.33	0.73**	
Mean Power, Arm	0.31		

* correlation (r) is significant at the 0.05 level (2-tailed)

** correlation (r) is significant at the 0.01 level (2-tailed)

Table 9

Correlations between the Army Physical Fitness Test and Aerobic and Anaerobic Capacity

	VO_{2max} Leg	VO_{2max} Arm	Wingate Leg Mean Power	Wingate Arm Mean Power
2 mile run time	-0.02	-0.05	-0.26	-0.36
Push Ups	0.37	0.33	0.03	0.42
Sit Ups	0.62*	0.34	0.37	0.61*
Total Score	0.42*	0.27	0.25	0.28

* correlation (r) is significant at the 0.05 level (2-tailed)

** correlation (r) is significant at the 0.01 level (2-tailed)

Table 10

Comparison of Cardiopulmonary Variables at Maximal Leg Exercise in Female Soldiers (pooled data) with Historical Values obtained in our Laboratory in Male Soldiers (mean ± SEM)

	Men[1] (n = 16)	**Women** (n = 34)	**% Difference Women vs Men**
Power (W)	253 ± 10	164 ± 4*	65%
VO_2 (L/min)	3.26 ± 0.14	1.95 ± 0.05*	60%
VO_2/kg (ml/kg/min)	45.3 ± 1.3	32.7 ± 0.9*	72%
V_E (L/min)	144 ± 8	90 ± 3*	63%
HR	189 ± 3	181 ± 2	96%

[1]Chest 99: 420-425, 1991.

Table 11

Comparison of Cardiopulmonary Variables at Maximal Arm Crank Exercise in Female Soldiers (pooled data) with Historical Values obtained in our Laboratory in Male Soldiers (mean ± SEM)

	Men[1] (n = 19)	Women (n = 34)	% Difference Women vs Men
Power (W)	129 ± 2	87± 14*	67%
VO_2 (L/min)	2.17 ± 0.04	1.40 ± 0.04*	65%
VO_2/kg (ml/kg/min)	30.5 ± 0.8	23.5 ± 0.8*	77%
V_E (L/min)	101 ± 2	67 ± 3*	66%
HR	168 ± 3	175 ± 2	104%

[1]Chest 99: 420-425, 1991.

Figure 1. Comparison of Maximal Aerobic Capacity ($VO_{2\,max}$) between Female Smokers and Non-Smokers for Arm and Leg Exercise (mean + SEM)

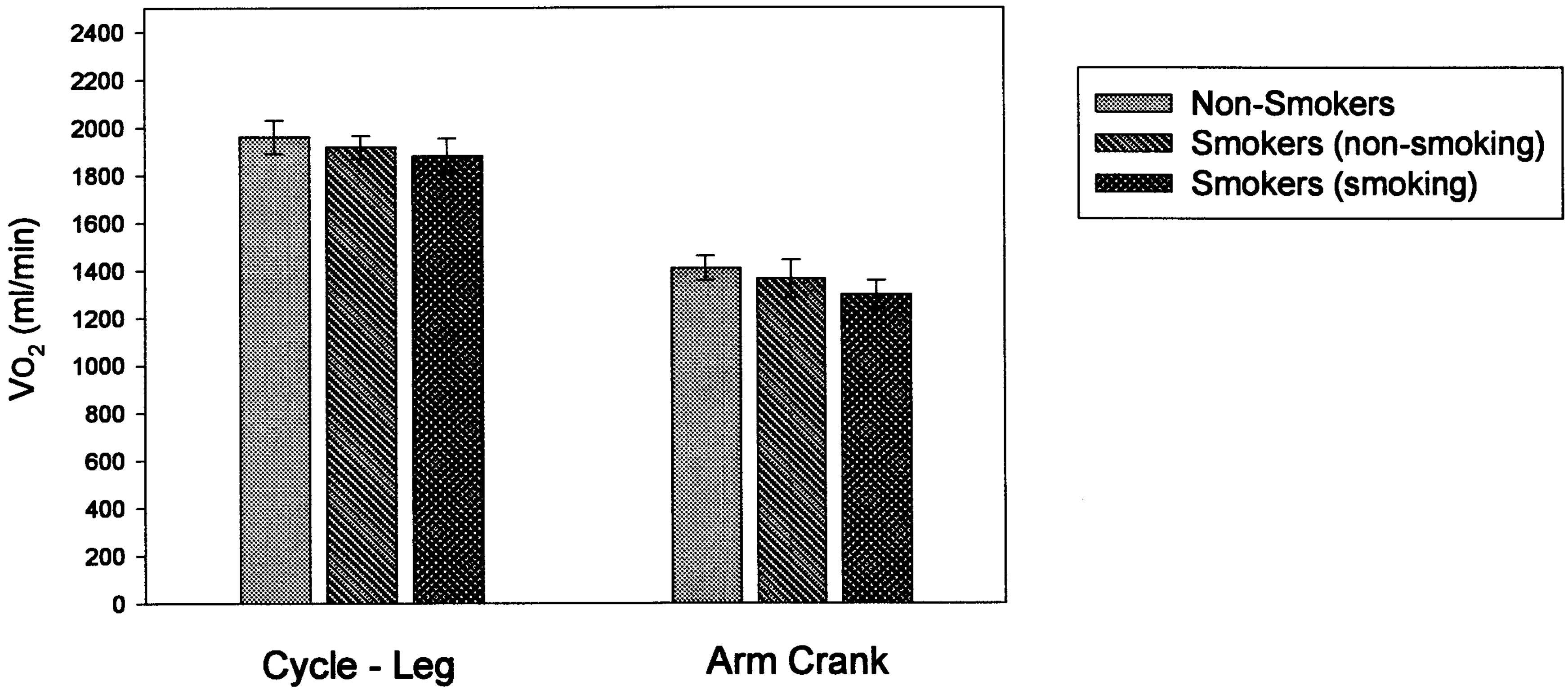


Figure 2. Comparison of Maximal Anaerobic Capacity (Wingate Test) between Female Smokers and Non-smokers for Arm and Leg Exercise (mean + SEM)

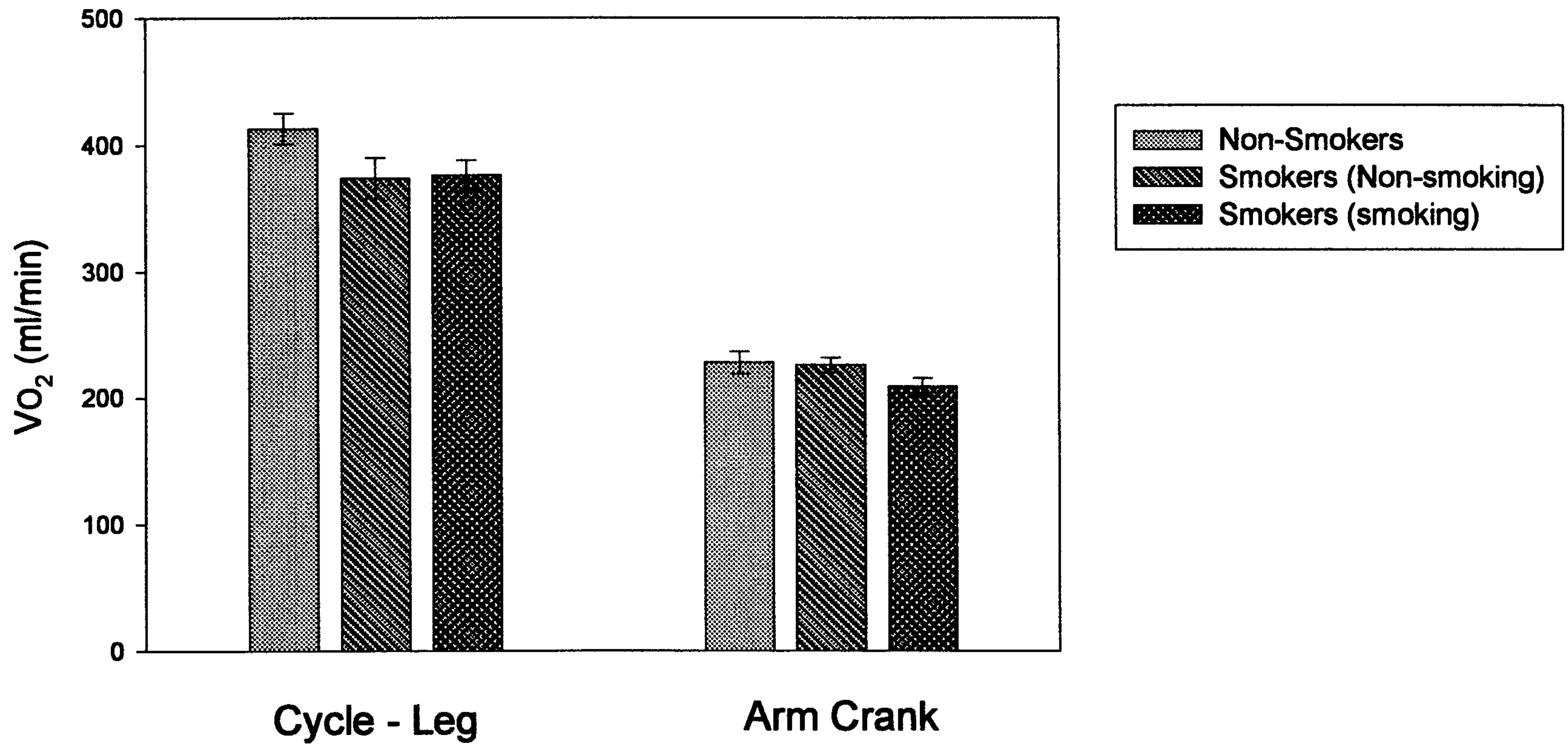
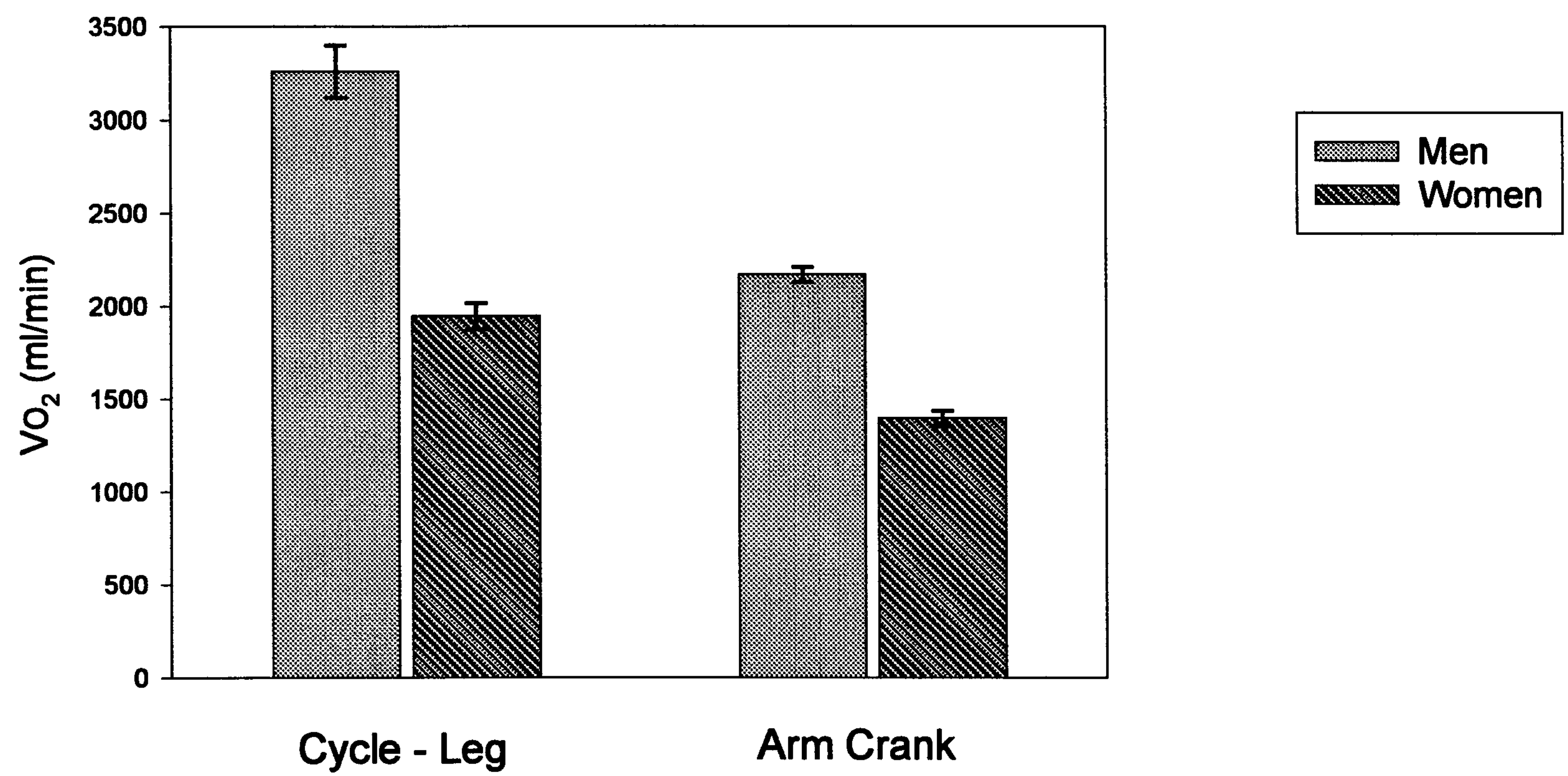


Figure 3. Comparison of Maximal Aerobic Capacity ($VO_{2\,max}$) between Male and Female Soldiers (mean + SEM)



SCIENTIFIC PRESENTATIONS

Connery SM, Zeballos RJ, Pusateri AE, Taylor MB, Weisman IM. $\Delta VO_2 / \Delta WR$ during cycle and arm crank ergometry in women.
Presented at the FASEB annual meeting, Washington, D.C., April 14-17, 1996

ABSTRACTS PUBLISHED

Connery SM, Zeballos RJ, Pusateri AE, Taylor MB, Weisman IM. $\Delta VO_2 / \Delta WR$ during cycle and arm crank ergometry in women. FASEB J 1996; 10: A377.

PERSONNEL PAID BY GRANT

R. Jorge Zeballos, M. D.
Sean M. Connery, M.S.