(2)

ESL-TR-86-05

PHYSICAL FITNESS STATUS OF USAF FIREFIGHTERS

L. G. MYHRE J. L. WALKER P. CAMPBELL
G. VAN KIRK W. GRIMM

USAF SCHOOL OF AEROSPACE MEDICINE
BROOKS AFB TX 78235

SEPTEMBER 1986

FINAL REPORT

JANUARY 1983 - JUNE 1984

AFESC

ENGINEERING & SERVICES LABORATORY
AIR FORCE ENGINEERING & SERVICES CENTER
TYNDALL AIR FORCE BASE, FLORIDA 32403

NAVAIR

NAVAL AIR SYSTEMS COMMAND
DEPARTMENT OF NAVY,
WASHINGTON DC 20361

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release. Distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S) ESL-TR-86-05
6a. NAME OF PERFORMING ORGANIZATION USAF School of Aerospace Medicine 6b. OFFICE SYMBOL (If applicable) USAFSAM/VNC	7a. NAME OF MONITORING ORGANIZATION Air Force Engineering and Services Center
6c. ADDRESS (City, State, and ZIP Code) Brooks AFB TX 78235	7b. ADDRESS (City, State, and ZIP Code) HQ AFESC/RDCF Tyndall Air Force Base, Florida 32403
8a. NAME OF FUNDING/SPONSORING ORGANIZATION HQ AFESC/RD and NAVAIR 8b. OFFICE SYMBOL (If applicable) Code 511 J1	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER Project Order F85-50
8c. ADDRESS (City, State, and ZIP Code) Tyndall AFB FL 32403-6001	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO: PROJECT NO.: 83 TASK NO.: 146 WORK UNIT ACCESSION NO.:

11. TITLE (Include Security Classification)
Physical Fitness Status of USAF Firefighters

12. PERSONAL AUTHOR(S)
L. G. Myhre, G. Van Kirk, Joseph L. Walker, Wade Grimm, Phyllis Campbell

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 8301 TO 8406	September 1986	22

16. SUPPLEMENTARY NOTATION
Availability of this report is specified on reverse of front cover.

17. COSATI CODES		
FIELD	GROUP	SUB GROUP
13	12	
06	14	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
aerobic capacity, body fat, cycle ergometer, firefighters, cardiotachometer, stress

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A project was initiated at the request of MAJCOM/DEs and the US Navy to determine the metabolic costs of performing selected USAF firefighting activities to (1) collect data representative of the workloads imposed on USAF firefighters, and (2) develop valid laboratory protocols to simulate the physical stresses of firefighting activities. These protocols could then be used to evaluate firefighter protective equipment, e.g., self-contained breathing apparatus and the entire firefighter protective ensemble, under simulated field conditions.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL WADE H. GRIMM	22b. TELEPHONE (Include Area Code) (904) 283-6194 22c. OFFICE SYMBOL HQ AFESC/RDCF

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

PREFACE

This report was prepared by USAF School of Aerospace Medicine (USAFSAM/VNC), Brooks AFB TX 78235, under Contract Number FO8635-84-C-0270, for the Air Force Engineering and Services Center, Engineering and Services Laboratory (AFESC/RDCF), Tyndall Air Force Base, Florida 32403-6001. This work was sponsored by the Naval Air Systems Command (NAVAIR) and the US Air Force Engineering and Services Center (AFESC). Mr Joseph L. Walker, Mr Wade Grimm (AFESC), and Ms Phyllis Campbell (NAVAIR) were the Government technical program managers. This report summarizes work accomplished between 4 January 1983 and 30 June 1984.

This report has been reviewed by the Public Affairs Office and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

WADE H. GRIMM
Project Manager, Fire Research Branch

STEVEN E. HAWN, Lt Col, USAF
Chief, Engineering Research Division

JOSEPH L. WALKER
Chief, Fire Research Branch

JAMES R. VAN ORMAN
Deputy Director, Engineering and Services Laboratory

(The reverse of this page is blank.)

TABLE OF CONTENTS

LIST OF TABLES

SECTION I

INTRODUCTION

A. OBJECTIVE

The objective of this effort was to select and test an adequate sample population to provide valid data describing the physical fitness status of DOD firefighters.

B. BACKGROUND

Field studies to determine the metabolic costs of performing selected USAF firefighting activities were conducted at Grand Forks AFB in 1980 and again in 1983 (Reference 1) to (1) collect data representative of the workloads imposed on USAF firefighters and (2) develop valid laboratory protocols to simulate the physical stresses of firefighting activities. These protocols could then be used to evaluate firefighter protective equipment, eg., self-contained breathing apparatus and the entire firefighter protective ensemble, under simulated field conditions. The results of these studies confirmed earlier subjective observations that firefighting activities, particularly search and rescue operations, may impose severe physical workloads. It was also found that an alarmingly high percentage of professional USAF firefighters lacked the physical strength and/or stamina, to successfully perform these critical tasks. Many of the search and rescue personnel studied were unable to complete this exercise, even in the absence of the stresses imposed by blinding smoke and life-threatening flames. This raised serious concerns about their real-life emergency capabilities.

C. SCOPE

Experience gained in the study of USAF firefighter workloads (Reference 1) made a subsequent study of firefighter fitness imperative. At that time, the Fire Chief at Grand Forks AFB was particularly concerned about the preparedness of his firefighters. He was the first to volunteer his department's cooperation in developing a test base for evaluating the status of physical fitness in USAF firefighters. The results of this preliminary study were presented at the annual meeting of the Strategic Air Command Base Civil Engineers at Offutt AFB in October 1983 and the concern for USAF firefighter fitness was evident. To preclude the possibility that the low degree of physical fitness demonstrated by personnel of the Grand Forks AFB Fire Department was unique, this study was expanded to include a larger number of USAF firefighters. The Fire Chiefs from Ellsworth, Randolph, and Plattsburgh AFBs volunteered for this effort. This report summarizes these studies.

SECTION II

METHODS AND PROCEDURES

A. METHOD

Among the many components comprising "physical fitness," the most important for predicting one's ability to perform strenuous total body exercise for a prolonged period of time is a measure of aerobic capicity ($\dot{V}O_2$ max). The determination of a given individual's $\dot{V}O_2$ max is technically demanding and not without considerable risk to the subject since it requires continuous exercise to the point of total exhaustion. On the other hand, this important physiological parameter may be validly predicted from cardiovascular responses to standard, submaximal exercise, eg., the Åstrand-Rhyming nomogram for the cycle ergometer (Reference 2). Thus, following the procedures and the precautions outlined by Åstrand and Rodahl (Reference 3), this method was used to obtain measures of $\dot{V}O_2$ max in USAF firefighters. Following the 1983 Grand Forks Study, a more comprehensive study of firefighter fitness was initiated to include measures of strength and body composition (body fat). The Grand Forks Fire Department was reevaluated in January 1984 and the Fire Departments of Ellsworth, Randolph, and Plattsburgh AFB Fire Departments were studied shortly thereafter.

B. PROCEDURE AND TEST CONDITIONS

All tests were performed in duplicate, i.e., on separate days, and always in the early morning (0530-0930) on subjects who had arrived at the station laboratory without breakfast, following a good night's sleep. Male subjects wore shorts and shoes, and female subjects wore blouses or halter tops. Room temperature was maintained at a comfortable level for exercise (65-75^{o} F), while relatively free from noise and other distractions.

The subject was fitted with a chest-lead cardiotachometer (Exersentry) and, after adjusting the cycle's saddle to the appropriate height for efficient pedaling, rested for 2 to 5 minutes in the seated position. The subject's "resting" heart rate (HR) was recorded and the exercise test was initiated with the subject pedaling the cycle ergometer (Monark #868) to the rhythm of a metronome (50 rpm). Minutes 1-3 were used to adjust the workload to a level which would result in a steady-state HR of between 130 and 155 beats per minute (bpm) during the 4th-6th minutes at that load. Thus, if the load needed no adjustment from the onset. the test would last 6 minutes; if a change was made at the end of the 3rd minute, the test would continue for a total of 9 minutes. No changes in the workload were made after the 3rd minute of exercise. In the relatively few incidents

where the workload was found to be inappropriate, i.e., not meeting the HR criteria during exercise at that load, the test was terminated and repeated on another day, using a more correct load for that subject. Heart rates were recorded between 45-60 seconds of each minute and the average of minutes 4-6 at the final load was used to predict $\dot{V}O_2$ max from the Åstrand-Rhyming nomogram with appropriate age corrections (Reference 2).

With subjects postabsorptive and either nude or wearing a tank suit, body density was determined by hydrostatic weighing in a quiet swimming pool according to Myhre and Kessler (Reference 3) and, on another occasion, by measures of body volume according to Allen (Reference 4). All measures were corrected for residual volume determined by the nitrogen dilution technique (Reference 5) and body fat was calculated from body density according to Brozek et al. (Reference 6) using the formula:

$$\%Fat = (4.570/Body\ Density) - 4.142.$$

SECTION III

RESULTS AND OBSERVATIONS

The physical characteristics of USAF firefighters at Grand Forks AFB in 1983 are presented in Table 1. The values for $\dot{V}O_2$ max as a function of age for the firefighters may be compared with measured values for normal sedentary men in Table 2 and for trained athletes in Table 3.

TABLE 1. PHYSICAL CHARACTERISTICS OF USAF FIREFIGHTERS AT GRAND FORKS AFB. (MEAN VALUES)

AGE (Years) Group	Mean	No.	HEIGHT (inches)	WEIGHT (pounds)	$\dot{V}O_2$ MAX* ($ml/kg \cdot min^{-1}$)
18-19	18.6	9	70.2	165.1	40.7
20-29	22.9	25	70.2	183.4	33.8
30-39	32.6	10	70.2	193.1	31.8
40-49	42.0	1	70.0	197.0	20.1

*Åstrand-Rhyming Nomogram; cycle ergometer

TABLE 2. MAXIMAL CARDIAC FUNCTION IN SEDENTARY NORMAL MEN AND WOMEN (Reference 9) (VALUES ARE MEAN ± S.E.)

AGE GROUP	$\dot{V}O_2$ Max ($ml/kg \cdot min^{-1}$)				HEART RATE MAX	
(Years)	No.	Men	No.	Women	Men	Women
20-29	6	45.4 ±4.2	9	37.9 ±4.2	196	198
30-39	7	41.8 ±5.7	33	28.3 ±3.4	189	184
40-49	35	37.7 ±5.6	39	25.9 ±3.3	181	179
50-59	28	34.8 ±6.1	22	24.7 ±2.8	172	177
60-75	22	28.0 ±6.9	1	18.7 ----	160	160

TABLE 3. COMPARISON OF MEASURES OF AEROBIC CAPACITY FOR YOUNG AND MASTER ATHLETES AND IN TRAINED AND UNTRAINED AVERAGE MEN (Reference 10) (VALUES ARE MEAN ± S.E.).

GROUP	AGE (Years)	$\dot{V}O_2$ Max ($ml/kg \cdot min^{-1}$)
Young Athletes	22 ± 2	69.0 ± 2.3
Master Athletes	59 ± 6	58.7 ± 4.3
Average Trained	52 ± 10	36.2 ± 4.2
Average Untrained	50 ± 6	30.4 ± 2.8

In reviewing these tables, one must keep in mind that firefighters are engaged in an occupation which imposes an emergency requirement for extremely hard physical work under unusually hazardous environmental stresses in the defense of life and property. Thus, it is paradoxical that the fitness levels ($\dot{V}O_2$ max) of the Grand Forks firefighters are consistently below that found to be merely average for sedentary men. For example, the 20-29 year-old firefighters at Grand Forks were found to have $\dot{V}O_2$ max values averaging only 33.8 $ml/kg \cdot min^{-1}$, considerably below the average of 45.4 for sedentary men of the same age given in Table 2. This relatively poor fitness level persisted throughout all age groups represented there and, combined with their disappointing performance in the standard search and rescue exercises (Reference 1), caused serious concern. A more comprehensive study of USAF firefighter fitness was deemed necessary and this effort was expanded to include all firefighters assigned to four selected USAF Base Fire Departments. The results of this study are presented in Tables 4 and 5; normal values for percent body fat are presented in Table 6.

TABLE 4. SUMMARY OF PHYSICAL FITNESS CHARACTERISTICS OF FIREFIGHTERS ASSIGNED TO FOUR USAF BASES IN 1984. (MEAN ± S.D.)

Base	No.	Age (Years) Average	$\dot{V}O_2$ Max ($ml/kg \cdot min^{-1}$) Average	Minimum-Maximum	
GF	39	28.7 ± 7.8	37.2 ± 7.5	22.5	58.6
RA	44	30.7 ± 10.4	40.4 ± 9.6	20.9	62.9
EL	52	29.4 ± 8.5	38.7 ± 8.2	21.9	54.9
PL	57	28.5 ± 9.5	40.1 ± 10.9	17.1	67.2
TOTAL GROUP	192	29.3 ± 9.1	39.2 ± 9.3	17.1	67.2

TABLE 5. SUMMARY OF PHYSICAL CHARACTERISTICS ACCORDING TO AGE FOR FIREFIGHTERS ASSIGNED TO FOUR USAF BASES IN 1984. (MEAN ± S.D.)*

No.	HEIGHT (inches)	WEIGHT (pounds)	$\dot{V}O_2$ MAX ($ml/kg \cdot min^{-1}$)	BODY FAT (per cent)
		18 - 29 years		
112	70.2 ± 2.4 (63.3 - 78.0)	172.1 ± 23.2 (118.0 - 237.0)	43.4 ± 8.4 (28.4 - 67.2)	18.1 ± 5.7 (4.2 - 29.9)
		30 - 39 Years		
55	70.0 ± 2.7 (65.0 - 76.0)	182.6 ± 26.8 (131.9 - 247.0)	34.9 ± 7.1 (22.0 - 52.6)	22.3 ± 5.5 (7.5 - 33.8)
		40 - 59 Years		
26	69.3 ± 2.5 (66.4 - 77.0)	189.0 ± 25.0 (134.4 - 244.0)	30.0 ± 6.1 (17.1 - 43.4)	26.7 ± 4.7 (19.0 - 34.8)

*Minimum-maximum values are in ( ) under means.

TABLE 6. AVERAGE VALUES FOR PERCENT BODY FAT IN NORMAL MEN AND WOMEN. (References 3 & 7).

AGE Yrs	% BODY FAT Men	Women
18-23	13	25
24-38	18	28
39-48	22	31
49-56	26	34

Table 1 shows that the average USAF firefighter represented in this study is 29.3 years of age, 5 feet 10 inches tall and weighs 177.4 pounds. He has a body fat content of 20.3 percent and a $\dot{V}O_2$ max of 39.2 $ml/kg \cdot min^{-1}$. Compared with average values for sedentary men in Tables 2 and 6, the firefighter is above average in fatness (20.3 percent vs 18 percent) and below average in $\dot{V}O_2$ max (39.2 vs 45.4 $ml/kg \cdot min^{-1}$). There were no significant differences between the fitness values observed at each of the bases studied. This suggests that these data are reasonably representative of USAF firefighters as a whole.

Although the lack of even average fitness in the USAF firefighter is enough cause for concern, the extremely low levels exhibited by some members of each group are causes for alarm. The minimum and maximum values given in Table 5 suggest that some "professional" firefighters, could not even attempt to complete a search and rescue exercise. What then could be expected of them in an all-out emergency? For example, every USAF Fire Department studied had active firefighters who were found to have VO_2 max values below 25 $ml/kg \cdot min^{-1}$; the low values observed for the 18-29 and the 30-39 year-old age groups were 28.0 and 22.0 $ml/kg \cdot min^{-1}$, respectively. These values are particularly disconcerting when compared with the average of 28.0 $ml/kg \cdot min^{-1}$ found for normal sedentary men of 60-75 years (see Table 2).

Looking at the problem another way, Figure 1 illustrates the general decline in VO_2 max with age; USAF firefighters follow this trend but they remain consistently below the average at every age. The mean values tend to shield the poorest performers from view, but it takes little imagination to project the fitness future of a firefighter who, in his twenties, is already only as fit as an average 70-year-old man.

Standards for body fat in normal American men and women remain controversial and are still being studied. However, for health reasons alone, limits of 20 and 30 percent are reasonable for men and women, respectively. Indeed, the USAF permits an upper limit of only 26 and 32 percent body fat for men and women in uniform. Thus, from Table 5 the maximum values of 30, 34, and 35 percent body fat for USAF firefighters in the respective age groups of 18-29, 30-39, and 40-59 years are worrisome. Since the USAF Fire Departments combine civilian and military firefighters, it becomes important to obtain a physical portrait of each of these classifications. These data are presented in Tables 7 and 8.

TABLE 7. SUMMARY OF PHYSICAL CHARACTERISTICS ACCORDING TO SERVICE CLASSIFICATION GROUPS OF FIREFIGHTERS ASSIGNED TO FOUR USAF BASES (MEAN ± S.D.)

	No.	Age (Years)	Height (Inches)	Weight (Pounds)	$\dot{V}O_2$ Max ($ml.kg^{-1}.min^{-1}$)	Body Fat percent
Civilian	70	37.6 ± 8.2	69.9 ± 2.6	185.8 ± 27.0	34.2 ± 7.6	23.2 ± 6.0
Military	123	24.6 ± 5.6	70.1 ± 2.4	172.5 ± 22.3	42.0 ± 9.0	18.8 ± 5.9

TABLE 8. SUMMARY OF PHYSICAL CHARACTERISTICS ACCORDING TO AGE AND SERVICE CLASSIFICATION GROUPS OF FIREFIGHTERS ASSIGNED TO FOUR USAF BASES IN 1984. (MEAN ± S.D.)

Age Group		18 - 19	20 - 39	40 - 54
Height (in)	Civ	71.0 ± 2.3 (10)	70.0 ± 2.7 (36)	69.3 ± 2.5 (24)
	Mil	70.1 ± 2.4 (102)	69.9 ± 2.6 (19)	69.2 ± 3.7 (2)
Weight (lbs)	Civ	190.7 ± 27.6 (10)	181.8 ± 28.2 (36)	189.8 ± 25.1 (24)
	Mil	170.3 ± 22.1 (102)	184.3 ± 24.4 (18)	179.0 ± 18.4 (2)
$\dot{V}O_2$ Max ($ml.kg^{-1}.min^{-1}$)	Civ	38.3 ± 7.3 (10)	35.9 ± 7.4 (36)	30.0 ± 6.3 (24)
	Mil	43.9 ± 8.3 (102)	33.0 ± 6.1 (18)	29.2 ± 0.8 (2)
Body Fat (%)	Civ	19.5 ± 4.2 (8)	21.7 ± 6.1 (29)	26.9 ± 4.7 (19)
	Mil	17.9 ± 5.9 (88)	23.4 ± 4.1 (16)	22.4 ± 0 (1)

Table 7 shows that, of the 193 firefighters studied, 123 were military and 70 were civilian. The military firefighters were younger, about the same height, lighter, more fit, and less fat than their civilian counterparts. Upon further inspection, when the fitness levels of these classifications of firefighters were compared according to age (Table 8), military man demonstrating relatively better physical fitness were limited to those who were less than 20 years of age; from 20 through 54 years of age the military firefighters were slightly less fit than were the civilians, although these differences were not statistically significant. One is tempted to conclude that, although the young man entering the military at age 18-19 tends to be significantly more fit than firefighters of that age, he quickly falls into an occupational lifestyle that results in a rapid deterioration of physical fitness. Indeed, after 20 years of age, the military firefighter is slightly less fit than his civilian counterpart.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSION

The above data show that, on the average, the young man entering the USAF firefighter career field is below average in physical fitness and above average in fatness. Already starting at a low level of physical preparedness, his fitness level deteriorates with age and he soon becomes ill-prepared for strenuous physical tasks. To be sure, several firefighters in every age group tested were not only above average in fitness, but some were at levels comparable with highly competitive athletes. Although the Fire Chief would be well-advised to select these highly fit men for the most critical and the most dangerous search and rescue tasks, there is an obvious injustice in routinely assigning the same firefighters to the most life-threatening tasks just because the others are not fit enough to participate.

To this observer, the firefighter's lifestyle contributes heavily to his low and progressively declining fitness level. Although engaged in an occupation which, in times of emergency, demands extraordinary levels of physical effort under extreme stress, he is seldom called upon to perform at that level; to do so often would be akin to physical training leading to respectable levels of fitness in the participants. The efficiency of fire protection in the USAF is outstanding, consequently, there are relatively few major fires on any given base during the course of a typical year. Therefore, the typical workday of the USAF firefighter is one of remaining on standby for possible engagement in very serious aircraft and structural fires. However, since the serious threat of a major disaster associated with aircraft fires is always present, and indeed expected in wartime, the firefighters must maintain a high state of physical and mental preparedness. All normal healthy men and women can develop and maintain physical fitness, therefore, the goal is achievable.

B. RECOMMENDATION

In all Fire Departments included in this study, the firefighters are on duty for a 24-hour day and off for the next day. Activities during the duty day are varied and some are unpredictable, but it should not be difficult to find an hour during every shift that could be devoted to a systematic physical conditioning program. Such a commitment in both time and effort would be unequivocally effective and, if the firefighter's fitness to perform physical tasks is considered important, such a conditioning program should not be left to chance.

REFERENCES

1. Myhre, L. G., L. Redman, and D. Knowles. "Physiological Stresses Imposed on USAF Firefighters." Preprints of the Scientific Program, Aerospace Medical Association, pp. 273-274, 1979.

2. Åstrand, P.O., and K. Rodahl. Textbook of Work Physiology. McGraw-Hill Book Co., New York, 1970.

3. Myhre, L.G., and W.V. Kessler. "Body Density and Potassium 40 Measurements of Body Composition as Related to Age." J. Appl. Physiol. 21:1251-1255, 1966.

4. Allen, T. H. "Measurement of Human Body Fat: A Quantative Method Suited for Use by Aviation Medical Officers." Aerospace Med. 34:907-909, 1963

5. Rahn, H., W.O. Fenn, an A.B. Otis. "Daily Variations of Vital Capacity, Residual Air, and Expiratory Reserve Including a Study of Residual Air Methods." J. Appl. Physiol. 1:725-743, 1949.

6. Brozek, J., F. Grande, J.T. Anderson, and A. Keys. "Densitometric Analysis of Body Composition: Revision of Some Quantative Assumptions." Annals of the New York Academy of Science 110:113-140, 1963.

7. Kramer, H.-J and H.-V Ulmer. Reference Values for Body Fat Content as A Measure for Desirable Body Fat Content. Zeitschrift fur Ernahrungswissenshaft 23:1-11, 1984.

8. Åstrand, I. "Aerobic Capacity in Men and Women with Special Reference to Age." Acta Physiol. Scand., 49 (Suppl. 169), 1960.

9. Hossach, K.F. and R.A. Bruce. "Maximal Cardiac Function in Sedentary Normal Men and Women: Comparison of Age-related Changes." J. Appl. Physiol. 53:799-804, 1982.

10. Heath, G.W., J.M. Haberg, A.A. Ehsani, and J.O. Holloszy. "A Physiological Comparison of Young and Older Endurance Athletes." J. Appl. Physiol. 51:634-640, 1981.