The development and validation of job-related muscular fitness tests

David William Wilson
The University of Montana

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THE DEVELOPMENT AND VALIDATION OF JOB-RELATED
MUSCULAR FITNESS TESTS

By

David W. Wilson
B.S., Valparaiso University, 1972

Presented in partial fulfillment of
the requirements for the degree of

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UNIVERSITY OF MONTANA
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Chairman, Board of Examiners

Dean, Graduate School

Date 3-15-78
The Development and Validation of Job-Related Muscular Fitness Tests (89 pp.)

Director: Brian J. Sharkey

This study describes some of the steps in the development and validation of a battery of simple and inexpensive strength and endurance tests designed to predict work capacity of fireline personnel. Following an analysis of the tasks involved in forest fire suppression, a series of tests was selected to provide information regarding fitness of the muscle groups involved. The proposed battery and muscle groups include:

- Arm and shoulder flexion strength - Chin-up
- Extensor muscle endurance - Push-up
- Abdominal muscle endurance - Sit-up
- Back strength - Back lift
- Leg strength - Pack test

Thirty female and 29 male subjects (18 to 24 years) were tested on the battery, which included tests of arm, back and leg strength, and a step test designed to predict aerobic fitness. The relationships among all tests were calculated along with the mean differences and the percentage of males and females passing the items in the proposed test battery. The results indicated that most men were able to pass all items of the battery while a low percentage of the women passed the chin-up (13%), push-up (13%), pack test (47%), or step test (67%). All men and women passed the sit-up and back lift items. Correlations among test items, the strength tests and the fitness test were higher among the women. The findings suggest that many women lack the strength, muscular endurance and aerobic fitness believed to be required for arduous fireline duties. The proposed test battery provides information regarding the work capacity of young women but does not provide additional information beyond that indicated by the aerobic fitness test, regarding the work capacity of young men.
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The understanding and active role in this study by my wife Carol is deeply appreciated.

D.W.W.
CHAPTER I

THE PROBLEM

Introduction

Prompted by a concern for worker safety, health, production, and efficiency, numerous municipal, state, and federal agencies have recently undertaken work capacity testing programs. One of the agencies most active in the study of job-related work capacity is the U.S. Forest Service. Their interest was spurred by the fire season of 1961. Many "pick-up" firefighters were used because of the number and severity of forest fires. Many of these "pick-up" firefighters exhibited low fitness for fireline work, thereby threatening their safety as well as that of their co-workers. Also, an increase in the number of heart attacks was recorded (17, 34).

The concern of the Forest Service led to an agreement in 1963 between the (then) Montana State University Department of Health and Physical Education Human Performance Laboratory and the Forest Service to work together on problems related to physical fitness and work capacity (25). Various projects were initiated to assess the energy expenditure and work levels of fireline tasks and to screen individuals for those tasks (17). Contact was also made with other physiologists
working in industry, such as Dr. Lucien Brouha (at that time of the Haskel Laboratory of Dupont Industries), who advised the Forest Service on procedures to determine cardiac cost of physical work (34).

In 1965, the Forest Service and Dr. Brian J. Sharkey, exercise physiologist at the University of Montana, conducted a number of tests on fireline workers to obtain the energy costs of the various tasks involved in fireline work. Procedures such as pulse counting, cardiac telemetry, metabolic measures, rectal temperatures, and laboratory treadmill tests were used. Analysis of the data indicated that an individual's ability to take in, transport, and utilize oxygen (aerobic fitness) was the major limiting factor in work capacity (24). The data collection and analysis led to the development of the step test, a simple and easy-to-administer prediction of aerobic fitness.

A minimum standard of 45 ml/kg/min. was selected because it represented twice the energy cost of fireline tasks. The results of the energy cost experiments showed that fireline tasks averaged approximately 22.5 ml/kg/min. in energy expenditure. A physically fit individual demonstrating 45 ml/kg/min. or higher can sustain a work intensity of 50 percent of his or her maximum aerobic capacity for long periods of time (e.g., eight hours). Should a less fit individual (below 45 ml/kg/min.) be able to sustain 50 percent of capacity that level will be below the energy required for
fireline tasks. On the basis of the results from the fireline task analysis, 45 ml/kg/min. was selected as the minimum level of aerobic fitness for prolonged physical work on the fireline (24).

The step test was initially developed for men. Women expressed an interest in being able to measure their fitness and in 1968 the step test was adapted for their use.

The step test was included in the Forest Service manual but was not required as a part of the employment procedure. Revisions were made as further research brought about more accurate computation and scoring methods (17, 34).

In 1973, Region 5 (California) of the Forest Service began a program called "Safety Sensing." This program was geared toward improving safety and performance on the fireline. Injuries to fireline personnel in previous years had caused concern for the safety and health of the fireline and supervisory personnel. The step test was instituted for fireline and supervisory personnel as part of the program to improve safety and performance (17).

Following approval by the U.S. Civil Service Commission in 1975, the Forest Service adopted the test as a national standard for the selection of firefighters (17, 34). This was an important action because it went beyond the medical examination and written tests which had formed the basic criteria for determining the qualifications for employment.

At meetings subsequent to the service-wide initiation
of the step test, the Fire Chiefs (Heads of Fire Management) from each region questioned the need for additional tests. These questions provided the basis for continued investigation on the requirements of fireline tasks and test measures which would reveal the ability of individuals to meet the task demands.

Muscular Fitness

Work capacity is the composite result of a wide range of factors influencing individual performance. Heredity, intelligence, aerobic fitness, muscular fitness, skill, experience, coordination, and motivation are all factors which influence work capacity. The Forest Service Fire Chiefs were concerned with the need for minimal levels of muscular fitness for fireline tasks. This investigation will concentrate on this component of work capacity.

Muscular Fitness

Muscular fitness investigations range from single and multiple tests for strength and muscular endurance to factorial designs which show independent muscular strength and endurance components.

Early work by Sargent (29) and Kellogg (18) concentrated on the "strongest" individual and development of a dynamometer to determine "Total Strength."

Martins (21, 22) constructed strength norms for children and adults by relating body weight to strength. In the
1920s, Rogers developed the Strength Index using performance on the chin-up and dip, as well as other variables to assess an individual's strength (28).

Larson (19) used weighted strength variables in attempting to determine the components of commonly used strength tests. He found two factors of strength--dynamic, represented by an arm strength cluster, and static, represented by a leg strength cluster. He concluded that dynamic measures described composite motor ability better than static.

Another method of determining strength was developed in the early 1950s. Clarke (6) adapted aircraft cable tension testing equipment for use in measurements of static strength. This permitted an alternative to the dynamometer and other strength testing methods. Cable tension results agreed with the other methods (7).

In the 1960s, Berger (3) adapted the chin-up to a single performance (1-RM) by adding weight to the individual in proportion to his or her Total Dynamic Strength (from certain strength measures). He went on to attempt to predict 1-RM from a maximum number of chin-ups (4). However, his results were confounded by the effects of muscular endurance.

In the early 1960s, Fleishman (9) conducted a study to identify the components of physical proficiency and provide recommendations of appropriate test procedures to measure these components. Fleishman hypothesized three general types of muscular strength--explosive, static, and dynamic.
He also hypothesized an additional dynamic measure, trunk strength, which loaded secondarily on the general dynamic grouping.

Factor analysis identified three types of strength. Explosive strength was found to involve the ability to expend a maximum of energy in one act (running tests, projecting objects). Static strength incorporated those activities in which "maximum" force was applied for a brief period of time "where the force is exerted continuously up to this maximum" (dynamometer tests, weights) (9). Dynamic strength involved the ability to perform repeated or continuous movements or support the body (best measures were tests of the arms). Fleishman also found this factor to have a common basis with "endurance" and "time limit" tests (9).

Jackson (11) attempted to further clarify the three factor structure developed by Fleishman. Jackson hypothesized factors of muscular strength (static and dynamic), projecting the body, and projecting objects. Jackson's results did not support the findings of Fleishman. Dynamic strength appeared to be more dependent upon individual differences in body weight than on the type of movement. Individual differences in muscular strength were a function of arms and legs, and with a constant and heavy enough weight, static and dynamic tests performed to exhaustion measured the same ability as tests of maximum force performed for a short time. Explosive strength was found to be multidimensional.
Jackson and Frankiewicz (12) developed a theoretical paradigm involving three parts: type of contraction--static, explosive, and dynamic; biomechanical quality--force, power, and work; and body segments--arms and legs. The findings confirmed four of the six cells in the paradigm. Arm involvement suggested that force, work, and power were independent, possibly the result of the function of task specificity. Leg involvement indicated that these factors were not as clearly defined and may be due to differences in height and weight.

The above findings suggest that various types and measures of strength and muscular endurance exist. Over the years researchers have developed what they consider accurate and definitive measures of strength and muscular endurance. Most of these early tests were not developed as job-related muscular fitness tests, rather their development was limited to determinations of strength and muscular endurance levels.

More recent work has shifted emphasis to the type of strength involved in task performance. The findings of Fleishman and Jackson are particularly important because they provide a framework for developing tests in relation to muscle groups involved in various dynamic activities and work tasks.

**Development of Job-Related Muscular Fitness Tests**

Is there a way of testing prospective employees to determine if they have adequate muscular fitness levels to perform safely and efficiently on the job? Job-related physical test development and studies on work requirements are
demonstrating that muscular fitness tests can be developed.

Johnson (13) provides an outline for the construction of physical performance tests in physical education. This methodology has been adapted to the development of job-related physical performance and muscular fitness tests.

Hubbard, Hunt, and Krause presented methodology for identification and construction of job-related muscular fitness and agility tests. The methodology consisted of task identification, rating of tasks for strength and agility factors, review of possible tests to be recommended, preliminary try-out and choice of the battery of tests, and preparation of a job relatedness analysis of the recommended tests (10). This outline is similar to that proposed by Johnson.

Misner and Considine (27) carried the basic idea of job-related muscular fitness tests one step further. Using task and factor analysis of traditional physical fitness and job-related tests for urban firefighting they developed a test which measured the ability to perform tasks of urban firefighting regardless of sex or racial group.

Independent investigations into job requirements have been conducted as well as those of job-related test development. For work in the stooped position, Jorgensen found that 41 percent of the 29 subjects with less than 50 kg back strength complained of pain and/or fatigue during a work day (15). Those with greater than 50 kg back strength rarely complained of pain and/or fatigue. Studies of this nature
indicate that minimum levels of strength are necessary for certain jobs.

Investigations of work rate and load in shoveling on the fireline have provided some theoretical considerations on task requirements for fireline work. At ten contractions per minute with a load of ten pounds, a worker should be able to work at 20 percent of his maximum strength for long periods of time. On this basis a worker should possess fifty pounds of arm strength to perform this particular task (31). Investigations such as these provide the theoretical and practical basis for establishing job-related tests and test standards.

A major reason for the attention given to the development of job-related muscular fitness tests is the sharp rise in the number of women applying for positions involving arduous physical labor. Wilmore has found that females are 43 to 63 percent weaker than males in upper body strength (40). Since a minimum level of strength is necessary to perform work tasks over long periods of time, weaker individuals could prove to be a hazard. Can sexually unbiased, job-related tests for wildland firefighters be designed? According to Johnson (13) or Hubbard et al. (10), tests which are formulated from task analysis can be objective measures for all who apply for the positions.
The Problem

Statement of the Problem

The problem of this investigation was to develop and validate a battery of job-related muscular fitness tests designed to aid in the prediction of an individual's ability to perform strenuous fireline work. Specifically this involved:

1. Determining the tasks involved in fireline work.
2. Analyzing the specific energy requirements and muscle groups involved.
3. Selecting appropriate tests.
4. Establishing test validity.
5. Preparing specific instructions for test administration.
6. Conducting field trips.
7. Evaluating results and making adjustments.
8. Recommending tests for service-wide adoption.

Steps one through three above have been accomplished through pilot studies conducted jointly by the Forest Service and the University of Montana Human Performance Laboratory. This investigation will concentrate on steps four through eight.

Several questions were considered in this investigation. Will the percentage of males and females passing the
muscular fitness tests be similar? Will the muscular fitness
tests be independent? Will the muscular fitness tests be
related to specific strength tests? Will changes be needed
in the minimum standards established for each muscular fit­
ness test? Will all tests contribute to the evaluation of
muscular fitness?

Scope

This investigation was specifically related to Forest
Service fireline tasks. It was limited to tests of arm flexor
strength, arm extensor endurance, abdominal strength and en­
durance, back strength, and leg strength. The age range for
subjects was 18 to 25 years since most applicants for fire­
line positions fall within this range. The sample was composed
of volunteers from the University of Montana campus community.
The majority of subjects were drawn from lower division physi­
cal education activity classes. Because of this, activity
levels and motivation may have been different than that of the
typical job applicant.

Definition of Terms

Muscular Endurance—The ability to repeat a movement
until exhaustion or until a predetermined number of repetitions
or length of time has been achieved.

Muscular Fitness—The level of muscular strength and
endurance needed to meet minimum standards for performing fire­
line tasks.
Muscular Fitness Tests--Muscular strength and endurance tests designed to determine an individual's ability to perform work tasks.

Strength--The ability to move a maximum amount of weight through the range of motion one time (one repetition maximum).

Strength Tests--Tests selected to determine the strength of the arm and shoulder flexors, leg extensors, and back muscles. These tests include the "arm curl" (arm flexion), leg press (leg extension), and back strength items and are performed according to the definition of strength given above.

Test Battery--Muscular fitness tests selected to determine the ability to perform arduous physical work (e.g., fireline tasks). The battery included the chin-up, sit-up, push-up, back lift, and pack test.

Work Capacity--The result of natural endowment, intelligence, aerobic fitness, muscular strength and endurance, skill, experience, coordination, and motivation, functioning together and forming an individual's ability to carry out the tasks required of the job without undue fatigue and with the greatest amount of efficiency, productivity, and safety for themselves and co-workers (34).
CHAPTER II

PROCEDURE

The basic format for test development is given in Table 1.

**TABLE 1**

<table>
<thead>
<tr>
<th>STEPS IN TEST CONSTRUCTION</th>
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<tbody>
<tr>
<td>1. Task identification</td>
</tr>
<tr>
<td>2. Determination of muscle groups involved</td>
</tr>
<tr>
<td>3. Selection of tests for identified muscle groups</td>
</tr>
<tr>
<td>4. Establishment of procedures for administration</td>
</tr>
<tr>
<td>5. Determination of: a) validity</td>
</tr>
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</tr>
<tr>
<td></td>
</tr>
<tr>
<td>6. Conduct field trips</td>
</tr>
<tr>
<td>7. Revision of test in light of findings</td>
</tr>
<tr>
<td>8. Construction of norms</td>
</tr>
</tbody>
</table>

Johnson and Nelson (13); Hubbard, Hunt, and Krause (10)

Fireline tasks have been identified through a survey by Sharkey and Jukkala (17, 34). Building fireline with hand-tools and chainsaws, packing water and/or hose and other heavy loads were all primary tasks. The muscle groups involved were identified as well as the extent and duration of involvement (e.g., strength and endurance). The analysis of tasks and muscle groups and a review of literature led to the development of a muscular fitness model for the muscle groups.
involved. The model was based on dynamic muscular strength and endurance requirements. Table 2 presents the muscular fitness model.

### TABLE 2

MUSCULAR FITNESS MODEL

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Requirements</th>
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<tbody>
<tr>
<td>Arm and Shoulder</td>
<td>Flexor Strength</td>
</tr>
<tr>
<td></td>
<td>Extensor Endurance</td>
</tr>
<tr>
<td>Trunk</td>
<td>Abdominal Strength and Endurance</td>
</tr>
<tr>
<td></td>
<td>Back Strength</td>
</tr>
<tr>
<td>Leg</td>
<td>Strength</td>
</tr>
<tr>
<td></td>
<td>Endurance</td>
</tr>
</tbody>
</table>

Specific muscular fitness tests were then selected. The tests had to be simple, easy to administer, safe, job-related, inexpensive, valid, reliable, and objective (35). Several of the tests had been accepted as valid, reliable, and objective by the International Committee for the Standardization of Physical Fitness Tests (20). Finally, field and laboratory tests were conducted with an extensive review of the literature to provide the practical and theoretical foundation for minimum levels of strength and endurance (appendix A, page 63). Table 3, summarizes the tasks, muscle groups, tests, and minimum standards.
TABLE 3

MUSCLE GROUPS, REQUIREMENTS, TASKS, TESTS, AND MINIMUM STANDARDS FOR MUSCULAR FITNESS TESTS

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Requirement</th>
<th>Task</th>
<th>Field Test</th>
<th>Minimum Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm and shoulder</td>
<td>Flexion strength</td>
<td>Lifting loads</td>
<td>Chin-up*</td>
<td>Under 110</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>111-135</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>136-175</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>over 175</td>
</tr>
<tr>
<td>Arm and shoulder</td>
<td>Extension endurance</td>
<td>Chopping with hand tools</td>
<td>Push-up</td>
<td>20 in</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60 sec.</td>
</tr>
<tr>
<td>Trunk</td>
<td>Back strength</td>
<td>Packing heavy loads</td>
<td>Back lift</td>
<td>10 repetitions</td>
</tr>
<tr>
<td>Trunk</td>
<td>Abdominal strength and endurance</td>
<td>Packing heavy loads</td>
<td>Sit-up</td>
<td>15 in</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30 sec.</td>
</tr>
<tr>
<td>Leg</td>
<td>Strength</td>
<td>Packing heavy loads</td>
<td>Pack test</td>
<td>5 min.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>with 50 lb. water pack 'on 13'' bench at 22.5 steps per min.</td>
</tr>
<tr>
<td>Leg</td>
<td>Endurance</td>
<td>Packing heavy loads</td>
<td>Step test</td>
<td>45 ml/kg/ min.</td>
</tr>
</tbody>
</table>

*Underhand grasp

Sharkey (30)
Subjects

The subjects were volunteers enrolled in courses at the University of Montana during the fall quarter of 1975. Thirty females and thirty males made up the total sample. However, only 29 males were used in the final analysis due to incomplete information on one subject.

The age of the subjects ranged from 18 to 25 years, similar to that of fireline personnel. A wide range of fitness levels was evident. Fitness was determined by the initial step test given each subject.

Each potential subject was informed about the investigation. The test battery and strength tests were explained in detail and questions were answered. The subjects volunteered to participate in the study.

Testing

Two days of testing were necessary for each subject. The first day included the initial step test and all of the muscular fitness tests except the pack test. Prior to the testing period the subjects were required not to eat, drink, smoke, or exercise for two hours. When the subject arrived, name, age, height, weight (in gym outfit), telephone number, time of last food or drink, last exercise, last smoke (if a smoker), and number of hours of sleep were recorded for each individual. Date, time, barometric pressure, and room temperature were also recorded. On the second day the
subjects were tested for strength and were given the final job-related test (pack test).

The subjects were generally tested in pairs. However, on occasion subjects would not show up at the scheduled time or an extra subject would arrive, resulting in having one or three subjects being tested during a test period. The time required for each test session was approximately one-half hour.

The tests were spaced to minimize fatigue during the testing period. For example, on the first day the tests were given in the following order: step test, chin-up, sit-up, push-up, and back lift. On the second day the order of tests was: arm strength, leg strength, back strength, and pack test. This permitted a short rest period for each subject and minimized carry-over from one test to another. Each test was thoroughly explained to the subjects. Demonstrations were given for those unfamiliar with the tests.

**Muscular Fitness Tests**

Each of the tests in the muscular fitness battery and rationale for each test is listed below. A picture of each test and further rationale can be found in appendix A, page 63.

**Chin-up**

The chin-up is the only test in the battery requiring the use of special equipment, namely a horizontal bar.
However, the materials necessary for making a horizontal bar are easy to obtain and relatively inexpensive (33).

The Test

The bar should be approximately 1.5 inches in diameter and high enough to prevent any subject from touching the floor while grasping the bar with arms completely extended above the head. It is a good idea to place a mat or rug under the bar for safety.

The subject grasped the bar with palms toward the face. Beginning from a straight arm hang, the subject then pulled upward until the chin was above the bar. The subject then returned to the straight arm hang position and continued in this cycle until a maximum number of repetitions was accomplished. If the subject remained in the straight arm position for more than three seconds after a repetition, the number of repetitions completed to that point was considered the maximum. Kicking or swinging was prevented by the test administrator holding his arms in such a manner that the subject could not move the legs forward or backwards but was unrestricted to move up and down. Only completed repetitions were counted.

Rationale

The arm and shoulder flexor muscle groups play a large part in fireline tasks. Lifting, carrying, pulling, and shoveling are examples of some of the movements
performed by this muscle group during forest firefighting. In performing the chin-up the individual moves a mass through space. Lifting or carrying objects such as trees or shovels involves the same muscles performing a similar task.

The standards established for the chin-up came from a small pilot study conducted by Sharkey in the summer of 1975 on active and inactive female subjects (34). The line of best fit for the data indicated a relationship existed between 600 footpounds of work (chin-ups x weight) and arm strength. From these results the following tentative standards were proposed:

<table>
<thead>
<tr>
<th>Weight Range</th>
<th>Chin-ups</th>
</tr>
</thead>
<tbody>
<tr>
<td>under 110 pounds</td>
<td>6</td>
</tr>
<tr>
<td>111 - 135</td>
<td>5</td>
</tr>
<tr>
<td>136 - 175</td>
<td>4</td>
</tr>
<tr>
<td>176 and above</td>
<td>3</td>
</tr>
</tbody>
</table>

This allowed an evaluation of total work, not just the number of chin-ups.

Sit-up

The Test

Each subject began the test by lying on a mat with fingers interlocked behind the neck. The legs were positioned at a 90-degree angle as measured with a goniometer. The subject's feet were held down by the test administrator or an assistant. Each subject was then instructed to curl up, twisting and touching the elbow to the opposite knee,
and then return to the starting position, making sure the back of the hands touched the mat before beginning the next repetition. The subject was instructed to do as many sit-ups as possible in the time limit of 30 seconds. Partial repetitions were not counted. A clock with a sweep second hand was used to time the test.

Correlations between maximal sit-up tests and the number of sit-ups performed in 30 seconds are very high. The use of the timed test provides quicker and easier administration (20).

Rationale

Abdominal muscular fitness has an indirect relationship to work capacity (31). The abdominal muscles are effective in controlling body posture and aid in controlling the position of the body when performing various actions. Also, lack of abdominal muscle tonus contributes to low back problems. Due to the tasks performed on the fireline, low back pain is a common complaint. Lack of abdominal muscle tone could be a major factor in the individual's ability to perform without injury. The test of minimal abdominal muscle fitness is included for this reason, and to encourage attention to abdominal fitness in training programs.

Push-up

The Test

The subject began the test in the up position on the
mat (e.g., the body supported in a nearly horizontal position with arms straight and hands palm down on the mat directly beneath the shoulders). The subject lowered the body until the chest touched the mat and then returned to the up position. The subject was not permitted to hold the up position for more than three seconds. Partial repetitions, those in which the chest did not touch the mat or could not return to the up position, were not counted in the total. The maximum number of push-ups the subject could perform was then recorded.

Rationale

The push-up is used to test the extensor muscle groups of the arm and shoulder. Various fireline tasks require repetitions involving this muscle group. Working with the ax, brush hook, adze hoe, pulaski, and throwing dirt with a shovel are a few examples of these submaximal tasks. The repetitions using these tools require a low percentage of the strength of this muscle group (approximately 15 percent or less) (31). The push-up tests the endurance of the extensor muscle group which is necessary for fireline task performance.

Back Lift

The Test

The subject was instructed to lay face down on a mat, fingers interlocked behind the neck. The subject then lifted
the torso off the mat until the lower ribs cleared the surface or until the chin reached a height of 10 inches. The subject returned to the starting position and continued to repeat the movement for as many repetitions as possible up to a maximum of 20. No resting was allowed between repetitions and the subject was instructed to lift smoothly and avoid a jerking motion. The test administrator or an assistant held the subject's feet down while the test was being performed.

Rationale

Because fireline tasks necessitate that an individual constantly bend over, perform tasks in these positions, and repeatedly lift loads of varying weight, minimal levels of back strength are necessary. Control of the trunk not only involves the abdominal muscles but also the back muscles, and very often weak back muscles are the cause of poor job performance. Fireline tasks can produce serious consequences relating to safety and performance if the individual possesses inadequate back strength.

There is great difficulty in measuring the strength of the back muscles. Tests for back strength generally require expensive equipment which was not suitable for this test battery. This test was proposed as a simple, safe method of testing minimal back strength levels (31).
Pack Test

The Test

Five minutes carrying a 50-pound water pack (the actual pack used by Forest Service fireline workers) was set as the minimum standard for passing the pack test. For this project a maximum time of ten minutes was established to allow correlations with other tests.

The test is similar to the step test. The bench height was 13 inches and the metronome rate was the same (90 beats/minute). The subject carried the water pack while stepping up and down on the bench in cadence to the metronome. The lead leg was changed after two minutes to determine if any problems (e.g., strength, structural, injury) existed in either of the lower limbs. The subject was also told that the lead leg could be changed throughout the test after two minutes of leading with each leg. Each subject was tested individually due to the possibility that some individuals could be injured because they could not control the extra weight.

Rationale

Earlier studies established that pack tests could be used as a measure of work capacity (7, 37). After experimenting with various loads, rates, and bench heights, the Forest Service Equipment Development Center devised a pack test which exhibited face validity for the task requirements.
The test was designed to determine the muscular fitness of the legs.

An individual should be capable of adequately handling a load equal to one-third the body weight without undue fatigue. Because individuals differ in size and the load is a constant, a test of this nature will differentiate between those capable of performing this task and those who cannot. Safety and elimination of possible hazards can be enhanced with the knowledge provided by the pack test.

Carrying a load also involves balance and agility. The load will be different for each individual and fatigue will occur more rapidly if energy is expended to maintain balance and control.

**Strength Tests**

This section describes the strength tests used in this investigation. Strength test figures can be found in appendix B, page 72.

**Arm Strength** (figure 3)

The Test

Arm strength was measured on a Universal Gym (Gladiator 70 model) located in the fieldhouse of the University of Montana. All subjects were tested on the same machine.

The subject faced the machine and gripped the bar with the palms facing away from the body. The subject flexed the
arms at the elbow and movement was made through the range of flexion motion and returned to the starting point. Most individuals identify this motion by the term "arm curl."

Arm strength was recorded as the maximum amount of weight the subject moved through the range of arm flexion during one repetition (1 RM). The weight was measured to the nearest 2.5 pounds (e.g., 60, 62, 65, etc.).

Back Strength (figure 4)

The back strength test was a modification of a method used by the Danish National Association for Infantile Paralysis (1).

The Test

A strap with an attached metal hook was placed around the shoulders and arms of the subject across the lower portion of the chest. The subject then lay face down upon a table with a small section cut out. This section was arranged to permit the hook attached to the strap to hang freely through the table. A cable was attached to the hook and fastened directly below in the floorboard of the table. A calibrated cable tensiometer (model T5, Pacific Scientific Company) was placed on the cable (figure 4, appendix B, page 72). The subject was instructed to exert as much tension as possible on the cable by attempting to lift the torso off the table in the motion described for the back lift.

Back strength was measured in pounds and a single maximal
trial was recorded for each subject. All subjects were instructed not to use a jerking motion in performance of this test to reduce the possibility of injury. An assistant was required to hold the subject's legs during the test.

Leg Strength (figure 5)

The Test

Leg strength was measured on the Universal Gym (Gladiator 70 model) leg press. The subject was seated with the feet placed on the upper foot pedals of the device. The starting point for the test was a 90-degree angle measured at the knee with a goniometer. Leg strength was measured by the maximum amount of weight the subject could move one time in leg extension. All subjects were tested on the same machine. This method of testing was used because it provided a safe, simple, and easily administered test for leg strength. Other methods involve complex and expensive equipment and very dangerous motions which could easily result in injury (e.g., squat with barbell).

Chin-ups x Weight

Chin-ups x weight is a calculation using the number of chin-up repetitions and body weight to gain a measure of work performed. It is included to provide additional information on an individual's ability to work at strenuous tasks. It is not an actual test.
Aerobic Fitness Test

Step Test (figure 6)

The step test is now being used by the Forest Service as a condition of employment. If the muscular fitness tests are approved, passage of the step test will be a prerequisite for the additional tests.

The Test

The test was given as outlined on the physical fitness calculator, *Measuring Your Physical Fitness* (23). The subject was seated and told to relax for five minutes prior to taking the test. Performance involved stepping up and down on a bench (15 3/4 inches for males, 13 inches for females) to the beat of a metronome for five minutes. At the end of the test, a post-exercise pulse was taken for 15 seconds, starting 15 seconds after completion of the test. By utilizing the post-exercise pulse rate and the weight of the individual, a fitness score (aerobic fitness) in milliters of oxygen per kilogram of body weight per minute was obtained from the calculator.

Statistical Treatment

Means and Standard Deviations for both sexes were calculated for each muscular fitness, strength, and aerobic fitness test. The percentage of males and females passing each muscular fitness test was determined also.
All tests were intercorrelated to determine relationships. These relationships were organized into a correlation matrix, one for each sex.

Regression analysis was performed on specific relationships to provide further information about test battery standards.
CHAPTER III

RESULTS

Test Results

Differences in the average performance of males and females on the muscular fitness, strength, and aerobic fitness tests are presented in table 4.

Muscular Fitness Tests

The muscular fitness tests showed differences and similarities in males and females. Males averaged approximately ten chin-ups higher than females. Many females could not perform one chin-up (appendix D, page 78). Males and females were nearly equal in the number of sit-ups performed. The abdominal muscles get similar usage in both sexes and this may account for the closeness in results. The push-up results also showed a large disparity between the sexes. All subjects performed the required number of repetitions on the back lift regardless of back strength.

All but one male subject achieved the standard of 10 minutes on the pack test. The mean time for females was slightly over the minimum standard of five minutes. Fourteen females performed the test for more than five minutes. Of these, nine went the entire 10 minutes and one went 9 minutes.
TABLE 4
MEANS AND STANDARD DEVIATIONS FOR THE MUSCULAR
FITNESS TESTS, STRENGTH TESTS,
AND THE AEROBIC FITNESS TEST

<table>
<thead>
<tr>
<th>Muscular Fitness Tests</th>
<th>Mean Male</th>
<th>Mean Female</th>
<th>Standard Deviation Male</th>
<th>Standard Deviation Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chin-up</td>
<td>12.0</td>
<td>1.2</td>
<td>± 5.5</td>
<td>± 2.7</td>
</tr>
<tr>
<td>Sit-up</td>
<td>23.4</td>
<td>21.2</td>
<td>± 4.6</td>
<td>± 4.1</td>
</tr>
<tr>
<td>Push-up</td>
<td>34.1</td>
<td>9.6</td>
<td>± 11.2</td>
<td>± 8.3</td>
</tr>
<tr>
<td>Back lift</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pack test (min.)</td>
<td></td>
<td></td>
<td>5.73</td>
<td>± 3.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strength Tests</th>
<th>Mean Male</th>
<th>Mean Female</th>
<th>Standard Deviation Male</th>
<th>Standard Deviation Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm Strength (pounds)</td>
<td>75.6</td>
<td>33.8</td>
<td>± 13.8</td>
<td>± 10.8</td>
</tr>
<tr>
<td>Leg Strength (pounds)</td>
<td>557.6</td>
<td>319.0</td>
<td>± 96.1</td>
<td>± 63.8</td>
</tr>
<tr>
<td>Back Strength</td>
<td>188.0</td>
<td>109.4</td>
<td>± 37.2</td>
<td>± 26.4</td>
</tr>
<tr>
<td>Chin-ups x weight</td>
<td>1925.3</td>
<td>167.0</td>
<td>± 833.5</td>
<td>± 384.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aerobic Fitness Test</th>
<th>Mean Male</th>
<th>Mean Female</th>
<th>Standard Deviation Male</th>
<th>Standard Deviation Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step Test (ml/kg/min.)</td>
<td>54.6</td>
<td>48.1</td>
<td>± 11.0</td>
<td>± 10.5</td>
</tr>
</tbody>
</table>
The other times above five minutes were 6:30 or less (appendix D, page 78).

Strength Tests

The results of the strength tests demonstrated a large disparity between the male and female subjects. Males had higher average strength on all tests. In addition, males performed greater amounts of work as shown by the chin-ups x weight results.

Aerobic Fitness Test

Both males and females averaged above the minimum standard of 45 ml/kg/min.

Percent Pass

The percentage of males and females passing the muscular fitness and aerobic fitness tests differed on all but two items. Table 5 lists the tests and the percentages of males and females passing each test.

Muscular Fitness Tests

The percentage of those passing each test shows the difference found in each sex.

Chin-up. One of the greatest differences between males and females was found on the chin-up. Of the 30 female subjects, 22 could not perform one chin-up. The range for males was 3 to 22 chin-ups and for females, 0 to 10 (appendix D, page 78).
TABLE 5

PERCENTAGE OF MALE AND FEMALE SUBJECTS PASSING THE MUSCULAR FITNESS AND AEROBIC FITNESS TESTS

<table>
<thead>
<tr>
<th>Muscular Fitness Tests</th>
<th>Test</th>
<th>Percent Pass</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chin-up</td>
<td>93.1</td>
<td>13.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sit-up</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Push-up</td>
<td>96.6</td>
<td>13.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Back Lift</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pack Test</td>
<td>100</td>
<td>46.7</td>
<td></td>
</tr>
</tbody>
</table>

| Aerobic Fitness Test  | Step Test     | 82.8         | 66.7 |

Sit-up. All male and female subjects demonstrated minimum abdominal muscular fitness by performing 15 or more sit-ups in the time limit of 30 seconds. The range for males was 18 to 38 sit-ups and for females, 15 to 31 (appendix D, page 78).

Push-up. All but one male subject completed 20 or more push-ups while only four females could perform the minimum number of repetitions. The range for males was 19 to 56 push-ups and for females, 0 to 36 (appendix D, page 78).
Back lift. All subjects performed 20 repetitions of the back lift.

Pack test. Less than 50 percent of the females could carry the water pack for the minimum standard of five minutes. Only one male carried the pack less than ten minutes and this was due to a previous knee injury. The range of time for females was 1:10 to 10 minutes and for males 5 to 10 minutes (appendix D, page 78).

Aerobic Fitness Test

Fewer males passed the step test when compared to the muscular fitness tests. The percentage of females passing the step test was one of the higher percentages in relation to the muscular fitness tests. The range of scores for males was 35 to 75 ml/kg/min. and for females 30 to 70 ml/kg/min. (appendix D, page 78).

Test Relationships

The relationships among the muscular fitness, strength, and aerobic fitness tests illustrate several differences between males and females. These relationships will be covered in three sections: relationships among muscular fitness tests, relationships of muscular fitness tests and strength tests, and relationships of muscular fitness tests and the aerobic fitness test.
Relationships Among Muscular Fitness Tests

The relationships among the muscular fitness tests will be presented separately for males and females. Comparisons between males and females will also be made.

Males

The correlations and significance levels between the muscular fitness tests for males are presented in table 6.

The male data revealed a high degree of test independence. The only significant relationship existed between chin-ups and push-ups. Similar results were found in other research (9). The results indicated that for males the tests are specific for the muscle groups involved.

Females

The relationships and significance levels of the muscular fitness tests for females are presented in table 7.

Chin-up. Significant relationships were found between the chin-up and push-up and chin-up and sit-up. The relationship between chin-ups and push-ups agreed with earlier findings by Fleishman (9).

Sit-up. Significant relationships were found between the sit-up and three of the four other muscular fitness tests. Moderately high correlations (significance at .01) were found between the sit-up and push-up and sit-up and pack test.

Push-up. Push-ups had significant relationships to all the tests in the battery. All correlations between the
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chin-up</td>
<td>1.0</td>
<td>.193</td>
<td>.668(^b)</td>
<td></td>
<td></td>
<td>.194</td>
<td>.134</td>
<td>.149</td>
<td>.963(^b)</td>
<td>.411(^a)</td>
</tr>
<tr>
<td>Sit-up</td>
<td></td>
<td>1.0</td>
<td>.141</td>
<td></td>
<td></td>
<td>.188</td>
<td>-.112</td>
<td>-.124</td>
<td>.171</td>
<td>.212</td>
</tr>
<tr>
<td>Push-up</td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
<td>.569(^b)</td>
<td>.279</td>
<td>.471(^b)</td>
<td>.755(^b)</td>
<td>.225</td>
</tr>
<tr>
<td>Back lift</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pack test</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm str.</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.227</td>
<td>.291</td>
<td>.386(^a)</td>
<td></td>
<td>.139</td>
</tr>
<tr>
<td>Back str.</td>
<td></td>
<td>1.0</td>
<td>.156</td>
<td>.191</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-.154</td>
</tr>
<tr>
<td>Leg str.</td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
<td>.293</td>
<td></td>
<td></td>
<td></td>
<td>.176</td>
</tr>
<tr>
<td>Chin-ups x wt.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.368(^a)</td>
</tr>
<tr>
<td>Step test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

\(^a\) significant at .05  
\(^b\) significant at .01
<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chin-up</td>
<td>1.0</td>
<td></td>
<td>.361(^a)</td>
<td>.719(^b)</td>
<td>.28</td>
<td>.72(^b)</td>
<td>.338(^a)</td>
<td>.572(^b)</td>
<td>.988(^b)</td>
<td>.408(^a)</td>
</tr>
<tr>
<td>Sit-up</td>
<td>1.0</td>
<td>.699(^b)</td>
<td></td>
<td>.613(^b)</td>
<td></td>
<td>.456(^b)</td>
<td>.683(^b)</td>
<td>.374(^a)</td>
<td>.367(^a)</td>
<td>.529(^b)</td>
</tr>
<tr>
<td>Push-up</td>
<td>1.0</td>
<td></td>
<td>.581(^b)</td>
<td></td>
<td></td>
<td>.567(^b)</td>
<td>.594(^b)</td>
<td>.567(^b)</td>
<td>.702(^b)</td>
<td>.612(^b)</td>
</tr>
<tr>
<td>Back lift</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>.36(^a)</td>
<td>.596(^b)</td>
<td>.307(^a)</td>
<td>.319(^a)</td>
<td>.639(^b)</td>
</tr>
<tr>
<td>Pack test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm str.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>.506(^b)</td>
<td>.545(^b)</td>
<td>.777(^b)</td>
<td>.257</td>
</tr>
<tr>
<td>Back str.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>.315(^a)</td>
<td>.383(^a)</td>
<td></td>
<td>.547(^b)</td>
</tr>
<tr>
<td>Leg str.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>.583(^b)</td>
<td></td>
<td></td>
<td>.377(^a)</td>
</tr>
<tr>
<td>Chin-ups x wt.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>.393(^a)</td>
</tr>
<tr>
<td>Step test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

\(^a\) significant at .05
\(^b\) significant at .01
push-ups and other muscular fitness tests were significant at .01.

**Back lift.** No relationship was found between the back lift and other muscular fitness tests for females.

**Pack test.** The pack test had significant relationships to all but one of the test battery items. The relationships between the pack test and push-ups and pack test and sit-ups were significant at .01. A nonsignificant relationship was found between the pack test and chin-up.

The female results are quite the opposite of males. The test battery items are more closely related for females. The results indicate that at lower levels of strength and muscular endurance a higher degree of relationships between muscle groups exists.

**Relationships of Muscular Fitness and Strength Tests**

Many interesting relationships developed between the muscular fitness and strength tests.

**Males**

Relationships and significance levels for the muscular fitness and strength tests for males are given in table 6.

Very few significant relationships were found between the muscular fitness and strength tests in males. The lack of a relationship between the chin-up and arm strength was surprising. The chin-up has been used as a measure of arm
strength, however it did not emerge as a test of arm strength in males.

Chin-ups and chin-ups x weight produced a high correlation \((r = .963)\) demonstrating the usefulness of the chin-up as a measure of work.

Interesting relationships were found between push-ups and arm strength and push-ups and chin-ups x weight. Push-ups and arm flexion strength correlated moderately high \((r = .569)\) and push-ups and chin-ups x weight correlated highly \((r = .755)\). These results were interesting because the push-up was a measure of arm extensor muscle endurance and chin-ups x weight was a measure of arm flexion strength.

Push-ups also produced a significant relationship with leg strength in males.

Females

The relationships of the muscular fitness and strength tests provided significant results in all but one case. These results are presented in table 7.

Chin-up. Chin-ups correlated highly with all strength tests except back strength. Both results, number of chin-up repetitions and maximum weight lifted, were low (on the average) for the female subjects.

Chin-ups and chin-ups x weight resulted in a very high correlation. Arm strength and chin-ups x weight was also high. The results show the interrelatedness of the three measures for the female subjects in this investigation.
Sit-up. Sit-ups produced significant relationships to all the strength tests and chin-ups x weight. Of particular interest was the moderately high correlation of sit-ups and back strength ($r = .683$). This would tend to support the idea that abdominal strength and endurance may help reduce the incidence of low back problems.

Push-up. Moderately high relationships were found between push-ups and all the strength tests. A high relationship was found between push-ups and chin-ups x weight. Again, these results are interesting in light of the muscle groups and requirements being measured.

Pack test. The pack test resulted in low, but significant relationships with arm strength, leg strength, and chin-ups x weight for females. A moderately high correlation between the pack test and back strength was found, indicating that back strength and leg strength are related to this one test.

Muscular Fitness and Strength

The results of the data for males indicate that males easily possess the strength and muscular endurance needed to perform arduous work. At higher muscular fitness levels the relationship to strength is very low. One possible reason for the lack of relationship between muscular fitness and strength is the specificity of training found in many males. This specific muscular development may have influenced the relationships between tests for males.
The results of the data for females suggest that at lower muscular fitness levels a definite relationship between muscular fitness and strength exists. For example, chin-ups correlated highly with arm strength. This would indicate that chin-ups are a valid measure of arm strength for women.

Regression analysis of the relationship between arm strength and chin-ups x weight provided further information on male and female performance. From the data for females it was found that 600 footpounds of work (chin-ups x weight) predicted 50 pounds of arm strength (figure 1, page 41). The results show that chin-ups x weight can be used to estimate arm strength for females. Males, because of their higher muscular fitness and greater strength development, scored well above the female results.

Relationship of Muscular Fitness Tests and the Aerobic Fitness Test

The relationship and significance levels for the muscular fitness tests and aerobic fitness test for males and females are presented in tables 6 and 7, pages 35 and 36, respectively.

Males

Only one significant relationship was found between the step test and the muscular fitness test for males. The relationship between the step test and chin-ups was moderately
Figure 1. Relationship of Arm Strength and Chin-ups x Weight (Work Performed)
low (r = .411). All other correlations were not significant.

The results of the data for males support the assumption by Sharkey that aerobic fitness is the major limiting factor in work capacity for males (32). If a male possesses the minimum aerobic fitness level of 45 ml/kg/min., he has the muscular fitness required to perform fireline tasks.

Females

All the muscular fitness tests were significantly related to the aerobic fitness test (high of r = .639--pack test and step test, low of r = .408--chin-up and step test).

The results of the muscular fitness and strength tests show that females possess lower muscular fitness and strength when compared to males. The percentages for arm and leg strength are in approximate agreement with earlier investigations. On the average, women had 44.75 percent of the arm strength of males. This percentage is in close agreement with studies conducted by Wilmore who found that females were approximately 43 to 63 percent weaker than males in upper body strength (40).

Females were found to have 57.21 percent of the leg strength of males in this study. This percentage is lower than that reported by Wilmore who found women to be 27 percent weaker than males in lower body strength (40).

The relationships among the muscular fitness tests for males were very low, demonstrating the independence of each test. The data for females demonstrated higher
correlations between the various muscular fitness tests.

It was also found that muscular fitness test performance and strength were not highly related for males. The data for females showed that relationships between the muscular fitness tests and strength did exist. The specificity of training in males and lack of training in some females may have accounted for these results.

Comparing the correlations of male and female test battery and aerobic fitness test performance, it seems that the major limiting factor in performance of arduous tasks might be aerobic fitness for males. Both muscular fitness and aerobic fitness seem to be related to the female's ability to perform arduous tasks.
CHAPTER IV

DISCUSSION

The results of the muscular fitness tests revealed a large disparity between males and females in fitness for arduous work. It would seem that many females are not well suited for work on the fireline. Males, on the other hand, demonstrated more than adequate muscular fitness for the tasks required. Several factors may have accounted for these differences.

Social and Cultural Influences

Traditionally, females have ceased vigorous physical activity with the onset of menarche. Society encourages the female to remain at home where little muscular fitness is required to carry out daily tasks. Society has also labeled participation in physical activity by women as unfeminine.

Further evidence of social influences on female muscular fitness is found in the fact that the AAHPER Youth Fitness Test includes no arm flexion strength item for females. The flexed arm hang which was earlier described as a strength test for females (13), is now described as an endurance test (14). However, an unpublished electromyographic study by Miller has shown no MAP (muscle action
potential) activity in the principal arm and shoulder flexor muscle (biceps) during the flexed arm hang (26). It appears that the flexed arm hang measures neither strength nor endurance of the arm flexors.

**Activity Levels**

Those females who did pass the standards for the muscular fitness tests showed continued participation in physical activity. The high correlations found in the female results indicate that if a female did well on one muscular fitness test, she tended to perform well on the others.

Males easily passed the minimum standards. The general activity of daily living and the development of strength and muscular endurance through physical activity allow minimum muscular fitness levels to be maintained.

**Body Fat**

It is well known that women carry a higher percentage of their weight in fat as compared to men (25 vs. 12.5 percent). This weight is essentially nonfunctional and inhibits the ability of females to perform muscular fitness tests.

Although body fat measurements were not taken in this study, body fat remains a factor in the test results. In a study on male firefighters performing simulated urban firefighting tasks, Davis found that the individuals with higher percentages of body fat performed the tasks in the slowest
time (8). Davis considered body fat to be inversely related to work capacity.

Recent work by Wilmore has shown that females can reduce the percent of body fat during a 10-week strength training period (39). Lean weight increased by 1.9 percent and absolute fat decreased by 9.3 percent during the training program (39).

A higher percentage of body fat increases the amount of energy necessary to move the body. Additional burdens (hose, water pack, etc.) only serve to increase that energy demand further. The individual with a higher percentage of body fat is working at a level closer to his maximum performance ability and this decreases his ability to sustain performance.

Percent Pass

The percentages of subjects passing the muscular fitness standards show that males generally did not have difficulty passing the test requirements while females had greater difficulty achieving the established standards. This suggests that the tests could be unfair to females.

The tests were developed by careful analysis of the tasks performed in forest firefighting. The tasks were analyzed for energy expenditure and the level of muscular fitness required for prolonged performance. Standards were established according to these analyses as well as population norms on the tests, and the tests given to determine
whether they differentiated between individuals. Many females did not qualify on the basis of the standards. Similarly, females did not qualify for urban firefighting positions in Chicago. Of 9890 applicants, no females were found in the top 3000 (27).

Females do possess the ability to increase strength. Wilmore found gains in females of 29.5 percent in leg strength, 28.6 percent in bench press strength, and 10.6 percent in forearm flexion strength during a 10-week training program (39). Although these percentages are not remarkably high, they do indicate that females have the potential to increase strength and muscular endurance and possess the underlying physical qualities required for jobs which demand physical exertion.

If a 10.6 percent increase in forearm flexion strength was applied to the average strength level for females found in this investigation (33.8 pounds), it would mean an increase of 3.5 pounds in arm strength in ten weeks. The resultant figure of 37.3 pounds of arm strength may not result in many more females passing the minimum standard for the chin-up. However, the level of arm strength may permit females to perform one or two more chin-ups and shows that through training, females can develop the muscular fitness necessary for jobs requiring physical exertion.
Test Relationships

Relationships Among Muscular Fitness Tests

Further confirmation of the disparity between males and females is found in the relationships among the muscular fitness tests.

Males

The muscular fitness test relationships for males clearly show the tests to be independent of one another. At higher muscular fitness levels the tests were found to be specific for the muscle group being tested. The one exception was between chin-ups and push-ups where the relationship was moderately high. Earlier work by Fleishman (9) and Simri (36) has also found a high degree of relationship between these tests of the arm and shoulder muscles.

Females

The muscular fitness tests were found to be related in females. Females exhibited lower muscular fitness on all tests except the back lift. At lower muscular fitness levels, a higher degree of relationship between muscle groups was found.

Data from females also exhibited a high relationship between chin-ups and push-ups. This relationship did not seem to be affected by muscular fitness or strength levels.

The relationship found between chin-ups and push-ups in both sexes suggests that one test of upper body muscular
fitness may be sufficient. Both Simri (36) and Fleishman (9) have said that no new information is gained by having both chin-ups and push-ups in the same test battery.

However, the author feels that both tests should remain in the test battery. The nature of the tasks involved in forest fire suppression require the information provided by each test. Better analysis of an individual's muscular fitness for fireline tasks and further job selection (fitness for a particular task) can be made from the information of both tests. Moreover, the inclusion of both items insures attention to both muscle groups in pre- and in-season training programs.

Muscular Fitness and Strength Test Relationships

Several relationships between the test battery and strength tests demonstrate the differences found in male and female muscular fitness.

Males

Chin-ups x weight (work performed) yielded a higher correlation with arm strength than chin-ups alone (table 6). Push-ups showed a higher correlation with arm strength than chin-ups (table 6). This is surprising in light of the fact that push-ups were testing arm extensor muscle endurance and not strength. This correlation further reflects the close relationship between the arm and shoulder muscle groups.
Females

**Chin-up.** A moderately high correlation was found between arm strength and chin-ups in females. Chin-ups did not result in as high a relationship as chin-ups x weight and arm strength. Tornvall states that "... and in fact it is the work performed rather than the strength that is measured" (38). The relationship of chin-ups x weight and arm strength in both sexes indicates that Tornvall's assessment may be true. At low levels of strength the ability to perform work is most evident. The relationship of the three measures of arm flexion strength show that the simple chin-up provides a good estimate of arm strength.

**Push-up.** The push-up yielded a surprising relationship with arm strength in females as well as males. Results for both sexes were almost identical (tables 6 and 7).

**Sit-up.** The sit-up yielded a significantly high correlation with back strength. The problem of low back pain and the role of the abdominal muscles in control of this problem is suggested by this relationship. At lower back strength levels, where back pain is more commonly found (15), the abdominals may be one of the most important factors in the control and prevention of this problem.

**Pack test.** The pack test was found to be a dual measure in females. Not only did it give an indication of leg strength, it also yielded a moderately high correlation with back strength (table 7). This relationship is important because the pack test can provide a measure of back strength.
as well as leg strength.

Definite relationships between the muscular fitness and strength tests existed at lower strength levels. These relationships point out that lower activity levels and higher body fat affect maintenance and development of strength. The higher activity levels, specific training, and lower body fat help account for the lack of relationships between tests found in males.

Relationship of Muscular Fitness and Aerobic Fitness Tests

If the muscular fitness tests are approved for service-wide use by the Forest Service, passage of the aerobic fitness test will be required before an applicant will be permitted to take the muscular fitness tests. The relationship between the muscular fitness tests and aerobic fitness test suggest that for some, the aerobic test is all that is necessary.

Males

Males recorded nonsignificant relationships or no relationships between the muscular fitness tests and aerobic fitness except for one case (table 6). These correlations demonstrate that in males muscular fitness is independent of aerobic fitness. A lower percentage of males passed the aerobic fitness tests compared to the muscular fitness tests. The relationship between the aerobic fitness test and the muscular fitness tests, and the lower percentage of males passing the step test, support earlier work by Sharkey who
found aerobic fitness to be the greatest limiting factor affecting prolonged work performance in males (32). Further evidence that aerobic fitness is the major limiting factor in performance for males is shown in recent work by Davis who found high aerobic fitness to be of major importance in the individual's ability to perform simulated urban firefighting tasks (8). Total time was the criterion for task performance and the basis for comparison of subjects. Individuals who performed the tasks in the shortest time had the highest aerobic fitness (8).

Females

Females recorded significant relationships between the muscular fitness tests and the aerobic fitness test in all but one case (table 7). These relationships suggested that the aerobic fitness test may be all that is needed to determine ability to perform fireline tasks. Examination of the female results does not confirm this idea.

Many females demonstrated adequate aerobic fitness by passing the standard (45 ml/kg/min.) for the step test. Achieving this standard indicates that an individual possesses the basic fitness to perform arduous physical tasks. When the females were tested on the muscular fitness battery, they demonstrated low levels of muscular strength and endurance. Analysis of fireline tasks has shown that minimum levels of muscular strength and endurance are necessary for safe and efficient task performance. The additional muscular fitness tests
become very important because they give further information (at lower strength and muscular endurance levels) about an individual's ability to perform arduous work. The muscular fitness tests are justified on the basis of the female results found in this investigation.

Jorgensen and Poulsen have suggested that the differences in maximum lifting frequencies (work rate) of males and females is due to the aerobic fitness in each sex (16). Sharkey (30) adapted the findings of Jorgensen and Poulsen to fireline work and determined that differences in work rate are not strictly due to sex (figure 2, page 54). The relationships of the step test and muscular fitness tests demonstrate that the information gained from the muscular fitness tests gives further information on work performance. Lower levels of muscular fitness also influence work rate.

Minimum Standards

Establishment of Standards

The minimum standards for the muscular fitness tests were established on a theoretical and practical basis. For example, at a work rate of ten contractions per minute in shoveling, the load should not be greater than 20 percent of an individual's maximal strength. If the load weighs ten pounds, the individual must possess 50 pounds in arm strength to work at or below 20 percent of his maximal strength (31). Performing a certain number of chin-ups for a certain
Figure 2. Work Rate, Strength, and Aerobic Fitness as Determinants of Work Capacity

Jorgensen and Poulsen (16); Sharkey (30).
weight will yield a figure in footpounds (work performed). The figure arrived at after investigation was 600 footpounds of work for the arm and shoulder flexor muscle group. This study has shown that 600 footpounds of work predicts 50 pounds of arm strength (figure 1).

Each test item requires minimum muscular fitness. The minimum standards established for the muscular fitness tests were based on population norms for each test or field and theoretical determinations (e.g., chin-up). Since these are average test performance levels, the standards do not demand extraordinary levels of strength or muscular endurance.

Changes in the Minimum Standards

Chin-up

The chin-up standard demonstrates direct relationship to fireline task performance. Minimum arm strength of the flexor muscle group can be determined by chin-up performance. The chin-up not only determines the number of repetitions, but also determines the total amount of work accomplished. By combining the total number of repetitions and the individual's body weight, all individuals are assessed equally.

Sit-up

The indirect relationship of the abdominal muscles to fireline task performance requires only a minimal level of abdominal muscle strength and endurance. The sit-up was passed by all subjects. No change should be made in the
minimum standard established for the sit-up.

Push-up

Arm and shoulder extensor muscle endurance is adequately determined by the push-up. A time limit of one minute and a minimum number of 20 push-ups is a measure of minimal muscular fitness for related fireline tasks.

Back Lift

The back lift provided no relationship to back strength. It is recommended that this test be deleted from the test battery.

Pack Test

The pack test was developed directly from the task of carrying a water pack. This test provides information on leg strength and back strength, making this test a possible measure of back strength also.

Performance at a certain rate will level off in three to five minutes and be maintained at that level as long as the rate remains the same (2). The pack test standard of five minutes permits the individual to sustain a set work rate long enough to determine the ability to perform that task for a prolonged time.

Forest Service Test Criteria

The muscular fitness tests studied in this investigation illustrate that the testing criteria established by the
No subject reported injury or soreness during or after the brief (15 to 30 minutes) testing sessions. The tests were easy to administer due to the subject's familiarity with each test. The test battery was also inexpensive and required a minimum of equipment. Water packs are standard items of Forest Service equipment and the 13-inch bench is already used for the adopted step test.

Validity, reliability, and objectivity for these muscular fitness tests have been established by earlier investigations (9, 19, 28, 29). Validity (job-relatedness) of the muscular fitness tests for fireline tasks has been found in the results of this investigation.

Fireline workers must be able to perform their tasks safely, with a maximum of efficiency and productivity. The information obtained from performance on a muscular fitness test battery can help to meet the above requirements. Developing a test battery and minimum standards for muscular fitness based on task analysis is a means of meeting this critical need.

The Forest Service has utilized a careful task analysis procedure to determine fireline performance requirements. In keeping with the criteria of safe, easy to administer, inexpensive, brief, job-related, and valid, reliable and objective tests, the Forest Service has found a means of aiding the prediction of an individual's ability to perform
arduous work by assessing their muscular fitness.

Summary

This project set out to develop and validate a battery of job-related muscular fitness tests. Due to the type of work involved in fireline tasks, tests of muscular strength and endurance were found to meet the criteria for measurement. After assessing the tasks and muscle groups involved, tests were determined for each muscle group as follows:

- arm and shoulder flexion strength: chin-up
- arm and shoulder extensor endurance: push-up
- abdominal strength and endurance: sit-up
- back strength: back lift
- leg strength: pack test

The results show that females are physically weaker than males. Many do not now qualify for fireline positions. The results show that the test battery is useful in measuring the minimum muscular fitness of females. Men who pass the step test already exceed the minimum muscular fitness standards.

The test battery of chin-ups, sit-ups, push-ups, and pack test has demonstrated its usefulness as a predictive tool. The back lift is recommended for deletion from the test battery. All other items are recommended for inclusion and adoption of the test battery. The pack test has demonstrated that it measures back strength in addition to leg strength. The development of an additional back strength
test is not recommended. Further studies on the effects of body fat and lean body weight on work performance, development of muscular strength and endurance for qualification for fireline positions, and the relationship of the pack test to balance and agility measures are recommended.

Conclusions

The following conclusions are drawn from this study:

1. The muscular fitness tests provide a useful index of an individual's ability to perform strenuous physical work as indicated on the task analysis.

2. The established standards are adequate for the chin-up, sit-up, push-up, and pack test.

3. The back lift should be deleted from the test battery.

Recommendations

From the results of this investigation the following recommendations are indicated:

1. Further research is not necessary for developing a back strength measure. The relationship of the pack test and back strength show the pack test to be a measure of back strength.

2. The relationship of the pack test to other balance and agility measures should be considered for further study. The findings in this investigation indicate that an expanded
role for the pack test as a predictive measure is possible.

3. The muscular fitness tests should be given further field trials throughout all Forest Service Regions.

4. Study concerning the development of strength and muscular endurance to meet job performance standards is necessary to provide guidelines for those who do not now possess adequate levels of muscular fitness to qualify for fireline positions.

5. Additional research in the relation of body fat and lean body weight to physical performance could be helpful in determining the effect of body fat on work performance.
APPENDICES
APPENDIX A

ADDITIONAL RATIONALE AND PICTURES OF

THE MUSCULAR FITNESS TESTS
MUSCULAR FITNESS

Muscular fitness required for arduous physical work includes minimal levels of muscular strength, endurance, and flexibility. The components of muscular fitness and the tests used to measure them include:

<table>
<thead>
<tr>
<th>Component</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>arm and shoulder strength</td>
<td>chinup</td>
</tr>
<tr>
<td>abdominal endurance</td>
<td>situp</td>
</tr>
<tr>
<td>back strength</td>
<td>back lift</td>
</tr>
<tr>
<td>arm and shoulder endurance</td>
<td>pushup</td>
</tr>
<tr>
<td>leg strength and agility</td>
<td>pack test</td>
</tr>
</tbody>
</table>

Another important component of muscular fitness, leg endurance, is measured by an aerobic fitness test — either the step test or the 1½-mile run.

Flexibility, the range of motion through which the limbs are able to move, can be developed in preseason conditioning programs.

This section will describe each test, instructions for test administration, and the rationale behind each test. Those who fail any of these tests should be encouraged to train and retest.
Chinup – Arm and shoulder strength

The Test

The chinup is a valid test of muscular strength and endurance of the arms and shoulders. Traditionally, the test has been used with the palms-out grasp. There is no logical reason why this grasp should be used, other than it is more difficult than the palms-inward grasp. In fact, since the palms-inward grasp allows more repetitions, it may result in a better distribution of scores. The palms-inward grasp was chosen for this test, because it better involves the flexor muscles in the positions used on the job.

The palms-inward grasp will be employed in the new version of the national youth fitness test currently being revised by the American Alliance for Health, Physical Education and Recreation.

Equipment

Horizontal bar(s) 1½ inches in diameter, raised so the tallest subject cannot touch ground in the hanging position. Two or more bars may be necessary.

Directions

Subject hangs from bar using palms-inward grasp, pulls up till chin is over bar, and returns to hanging position. Repeat as many times as possible. Score is the total number of completed chinups.

Only one trial is allowed unless it is clear that subject misunderstood directions or hands slipped (use chalk). Do not allow flexed legs, kicking, swinging, and snap-up movements. If subject tends to swing, you may hold an outstretched arm in front of the subject's legs. Trial is complete when subject pauses for an appreciable period (3 seconds) or when subject fails to raise chin above bar on two successive attempts.

<table>
<thead>
<tr>
<th>Body Weight</th>
<th>No. of Chinups</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 110 lbs.</td>
<td>6</td>
</tr>
<tr>
<td>110-135</td>
<td>5</td>
</tr>
<tr>
<td>135-175</td>
<td>4</td>
</tr>
<tr>
<td>&gt; 175</td>
<td>3</td>
</tr>
</tbody>
</table>
Rationale

Strength and work capacity are related. A minimum amount of strength is necessary for fieldwork.

At a given work rate (for example, 10 contractions per min), the load should not exceed 20 percent (one-fifth) of employee's maximal strength. If the load weighs 10 pounds, a minimum strength of 50 lbs (10 x 5 = 50) is required if the work is to be sustained indefinitely.

Of the three types of strength identified by researchers (static, explosive, dynamic), dynamic strength is most related to fireline duties. The chinup is a valid, reliable, and objective measure of dynamic strength. The chinup is an inexpensive test of upper body flexion strength.

Minimum levels of upper body strength are required for various fireline tasks:

- Digging and throwing dirt with a shovel (load approximates 10 pounds/rate 10 per minute)
- Lifting and carrying loads (hoses, chain saw)
- Pulling (brush, hose, crosscut saw)

Standard

The chinup is a test of minimum muscular strength and predicts arm flexor strength and work capacity. Studies in the Human Performance Laboratory at the University of Montana indicate the relationship between dynamic strength and performance on the chinup test.

In the chinup each individual must lift his or her own weight. Thus, a lighter individual has an easier task. On the fireline the situation is reversed. Each individual uses the same tools, so the task is easier for the one with more weight (presuming of course that the extra weight is muscle and not fat). To achieve a fair and equitable test of dynamic strength and work capacity for individuals of varying body weight and to predict muscular strength, the chinup standard is based on the total work accomplished, not just the number of chinups.

Weight (100 lbs) x 6 (repetitions) = 600 ft lb work

- 120 x 5 = 600
- 150 x 4 = 600
- 200 x 3 = 600
Further support for weight related standards comes from laboratory studies that indicate a strong relationship between muscular strength and absolute muscular endurance. Absolute muscular endurance is the maximum number of repetitions possible when each subject must use the same load or tool, as in wildland firefighting.

Over 80 percent of the young adult male population should be able to achieve the minimum standards.

Since women average 50 percent less arm and shoulder strength and seldom take this test, little data exists regarding their potential for success. The California Physical Performance Test indicates that only 5 to 10 percent of the 18-year-old girls tested are able to pass (versus 80 to 90 percent of the 18-year-old boys). Studies at the University of Montana indicate similar findings for college-age women (10 to 15 percent). However, among those who have remained active (for example, college gymnasts), the standards are easily met.

Several weeks of specific training should yield success for a large segment of the population (see *Fitness and Work Capacity*).
Situp — Abdominal endurance

The Test

The bent knee situp is a valid, reliable test of abdominal muscular fitness. It is incorporated in most fitness test programs. We are using a 30-second test as recommended by the International Committee for the Standardization of Physical Fitness Tests (in the volume *Fitness, Health and Work Capacity: International Standards for Assessment*). The correlation between the 30-second test and longer tests is very high. Using the shortest test period saves time without losing reliability.

Equipment

Mat or rug and a stopwatch. Optional equipment includes padded board with strap for testing and training (used as a tilt board for training).

Directions

Subject lies on back with knees flexed at approximately 90-degree angle and fingers laced behind neck. An assistant should hold subject's ankles. On command subject *curls up* and touches right elbow to inside of left knee, returns to starting position, then repeats with left elbow touching right knee. Each situp counts as one repetition. The score is the *total number* of situps in 30 seconds (repetitions are not counted when fingertips do not maintain contact behind head, when knees are not touched, and when subject pushed off mat with elbow). The back of the hands should touch the mat before the next situp is performed.

Rationale

Abdominal muscular fitness is indirectly related to work capacity. Low back problems and injuries result when abdominal muscular tone is poor. Over 50 percent of those engaged in hand labor complain of back troubles. Thus, the bent knee situp is included as a test of minimal muscular fitness of the trunk, particularly the abdominal muscles. By including the test, it is hoped that subjects will emphasize preseason abdominal fitness training. Furthermore, the test should encourage fitness program directors to emphasize this important aspect of muscular fitness.

Standard

According to various sources, the standard for this test (15 situps in 30 seconds) represents a level attainable by the average young man or woman. Since the abdominal muscles seldom contribute directly to work capacity, average muscular fitness of the abdominal muscles seem sufficient. Those unable to meet the standard should succeed after several weeks of training.
Pushup — Arm and shoulder endurance

The Test

The pushup is among the tests most frequently used in fitness test programs. The procedures have been standardized throughout the world and the test procedure is both reliable and objective. While the test obviously measures the muscular endurance of arms and shoulder girdle, some investigators suggest that little additional information is obtained when both chinups and pushups are used. We have included the test because it is specific for endurance and for arm extensors (the chinup is a specific test of the flexor muscles of the arm and for muscular strength).

Equipment

Floor, mat, or rug.

Directions

Subject assumes front leaning rest position, arms straight, hands beneath shoulders. Subject lowers body until the chest touches, then pushes up to straight-arm position; repeated as many times as possible in 1 minute. Do not allow subject to stop and rest. Back must be kept straight throughout test; no sag or "pike." Do not count repetitions when: chest doesn't touch mat, body sags or pikes, arms are not fully extended.

Rationale

The pushup is included as a measure of the muscular endurance of the arms and shoulder girdle. More specifically, the test purports to measure the muscular fitness of the extensor muscles of the arms as well as the strength and endurance of muscles in the chest.

Many of the work capacity tasks involved in fireline construction require repetitious work with the arms. The extensor muscles often are used with tools such as the pulaski, ax, brush hook, adze hoe, and the hoe blade of the McLeod. Extensor muscles also are employed when dirt is thrown with a shovel. Most of these tasks do not require high levels of strength (less than 15 percent of maximal strength). Hence, continued contractions depend on muscular endurance.

Standard

Pushups have seldom been administered to females, so there is little data available to suggest how difficult the standard will be for women. Our studies indicate that the standard is attainable by many active young women. Most young men can easily achieve the minimum standard, 20 repetitions in 60 seconds.

Several weeks of training should allow all but the sedentary to achieve this minimum muscular fitness standard.
Back Lift — Back strength

The Test

The back lift is a test of minimum muscular fitness. Previous test programs have included static tests of back strength (back dynamometer, Kraus-Weber test, Poulsen). Since dynamic back strength is involved in work capacity, this test calls for 10 dynamic repetitions.

Equipment

Mat or rug. Optional equipment includes padded board with strap for testing and training (used as a tilt board for training).

Directions

Subject assumes prone position on mat, fingers laced behind neck. Assistant holds subject’s ankles. Subject arches up so chest clears mat and chin is at least 9 inches above floor, returns to starting position and repeats for a total of 10 successful repetitions.

Encourage subject to work rhythmically and continuously — not to jerk. Do not allow rests between repetitions.

Rationale

Repeated lifting of maximum loads is related to back strength. Those with greater back strength can tolerate higher loads in repeated lifts. A minimum level of back strength is necessary to carry out prolonged work tasks.

Endurance of the trunk musculature is important in sustained submaximal work tasks, especially when the body must be bent over while using handtools (shovel, pulaski).

Back strength is difficult to measure reliably. Most tests involve expensive equipment. Maximal back strength tests are unsuitable for this testing program because of the cost of equipment and because maximal tests carry the risk of injury to the back.

This test is included to insure minimum muscular fitness of the muscles of the trunk. The test should help to:

- Assess minimum muscular fitness.
- Screen back problems.
- Minimize the incidence of back injuries.
- Insure production.

Remember, over 50 percent of those involved in hard physical labor suffer from back problems.

Standard

The test standard (10 repetitions) constitutes a minimum test of dynamic back strength. Subjects should not be encouraged to do their maximal number of repetitions. Repetitions may be increased gradually in a training program that includes adequate training of the abdominal musculature. Failure to balance the training (abdominal and back) could create the excessive low back curve (swayback or lordosis) often associated with low back problems.
Pack Test — Leg strength and agility

The Test

The pack test was first suggested by researchers at the Harvard Fatigue Laboratory in 1942. The Forest Service pack test was the outgrowth of experiments conducted at the Equipment Development Center at Missoula and the Human Performance Laboratory at the University of Montana. Various rate, load, and bench height combinations were used in an attempt to provide a test of minimum muscular fitness. Validity was established by administering the test to a sample of men and women. Those acknowledged to be capable of packing heavy loads had to pass the test; those who lacked the necessary muscular fitness had to fail the 5-minute test. Field studies established the validity of the test.

Equipment

A 13-inch-high bench, metronome, watch, and 5-gallon backpack water pump, filled to a gross weight of 50 pounds (remove hose and nozzle).

Water Bag, FSN 4320–00–289–8912; Cost, $38.

Directions

Test only after subject scores 45 or better on the step test. Subject steps on and off bench in time with metronome set at 90 beats per minute. After 1 minute, change lead leg for at least 1 minute. Subject must complete 5 minutes to pass. Terminate test if subject cannot keep up with beat (allow two warnings), if subject cannot or will not stand erect on bench, or if one leg is incapable of lifting the body. Poor balance or lack of agility should lead to termination if subject is unable to maintain rate. Stop the test if the subject shows obvious physical distress.
Rationale

Line workers are expected to pack heavy loads over difficult terrain. Workers need the leg strength to carry loads up and down steep slopes, to pull and pack hose, to carry and use backpack water pumps.

Pack loads average between 40 and 50 pounds. These loads may be carried 3 or more miles. The larger, and, therefore, stronger worker, has an advantage in that a given load (for example, 50 pounds) represents a smaller percentage of body weight and maximal strength.

As a general rule, an individual should be able to handle one-third of his or her body weight without undue fatigue. When the job requires that all workers carry the same load, the lighter individual will feel that the work is more difficult. Generally the lighter worker will tire more quickly, will become less efficient, and could pose a safety hazard.

So it is important to assess leg strength and endurance for those jobs where load carrying is an important part of the task. Leg strength and endurance are difficult to measure directly. Strength tests require expensive equipment or dangerous maneuvers, like deep knee bends with a barbell. Endurance tests are difficult to standardize. This test is designed as a minimum test of leg strength and endurance.

In addition to testing strength and muscular endurance, the test also serves as a job-related measure of balance and agility. Problems of balance and agility are more evident in the fatigued worker. The 5-gallon backpack pump was used to increase the problems of balance and agility without further increasing the load.

The addition of the 50-pound load makes the pack test maximal for some individuals. Care should be taken during test administration to watch for loss of balance, excessive fatigue, and other symptoms of distress. Those with fitness scores below 45 should not take the test.

Standard

Subject must successfully complete the 5-minute pack test. The test is quite easy for those with adequate leg strength. Those with somewhat less strength but higher levels of aerobic fitness also do well. Individuals with marginal fitness and low strength are likely to fail the test.
APPENDIX B

STRENGTH TEST FIGURES
Figure 3. Arm Strength
Figure 4. Back Strength
Figure 5. Leg Strength
APPENDIX C

AEROBIC FITNESS FIGURE
Complete 5 minute test.

Figure 6. Step Test
APPENDIX D

MALE AND FEMALE INDIVIDUAL DATA
### TABLE 8

**INDIVIDUAL MALE DATA**

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APPENDIX E

SAMPLE DATA SHEET
## SAMPLE DATA SHEET

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### CHIN-SIT-UP

- **30 SEC.**

### PUSH-UP

### BACK LIFT

### LEG STR.

### ARM STR.

### BACK STR.

### PACK TEST TIME

### PACK TEST POST PULSE

### DATE STR. TEST:

### TIME STR. TEST:

### COMMENTS:
SELECTED BIBLIOGRAPHY
SELECTED BIBLIOGRAPHY


33. , Jukkala, A., and Herzberg, R. Fitness Trail - How to: build the trail, sign the trail, use the trail. Forest Service Equipment Development Center, Missoula, Montana, No. 7761 2512, 1977.


