

# **Review & Analysis**

## **A Review of Firefighter Physical Fitness/Wellness Programs: Options for the Military**

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20 November 1998

# REPORT DOCUMENTATION PAGE

*Form Approved*  
*OMB No. 074-0188*

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

<b>1. AGENCY USE ONLY (Leave blank)</b>	<b>2. REPORT DATE</b> 11/20/98	<b>3. REPORT TYPE AND DATES COVERED</b> Review & Analysis: Final Report
---	-----------------------------------	--

<b>4. TITLE AND SUBTITLE</b> A Review of Firefighter Physical Fitness/Wellness Programs: Options for the Military	<b>5. FUNDING NUMBERS</b> SPO700-98-D-4001
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<b>6. AUTHOR(S)</b> Barbara Palmer, Jon W. Carroll and Atia T. Mirza	
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<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b>  CSERIAC Program Office AFRL/HEC/CSERIAC Bldg. 196 2261 Monahan Way WPAFB, OH 45433-7022 Commercial: (937) 255-4842 DSN: 785-4842	<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b> RA-98-003
---	--

<b>9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b>  Force Enhancement and Fitness Division Department of Aerospace Physiology and Human Performance USAF School of Aerospace Medicine 311 <sup>th</sup> Human Systems Wing Brooks Air Force Base, TX 78235-5252	<b>10. SPONSORING / MONITORING AGENCY REPORT NUMBER</b>
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**11. SUPPLEMENTARY NOTES**  
This report contains information relevant to firefighter fitness and wellness issues. Proceedings for the workshop held at Wright-Patterson AFB on 5 & 6 August 1998 relating to firefighter fitness/wellness may be found in *Proceedings--Firefighter Physical Fitness Workshop* (CPR-98-001).

<b>12a. DISTRIBUTION / AVAILABILITY STATEMENT</b> DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.	<b>12b. DISTRIBUTION CODE</b> A
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**13. ABSTRACT (Maximum 200 Words)**  
The US Air Force is the Executive Agent for the firefighter fitness programs for all military components. This *Review & Analysis* examines four suggested candidate firefighter physical fitness programs and related research in support of the ongoing Air Force/Department of Defense project to adopt a defensible and acceptable firefighter fitness training and testing program.

The four programs that are compared and contrasted are the Interim Air Force/Department of Defense Fire Protection Program's Fire Fighter Physical Fitness Program, the Canadian Forces/Department of National Defence's new Fire Fighter Physical Fitness Maintenance Program, the emerging International Association of Fire Fighters/International Association of Fire Chiefs Fire Service Joint Labor Management Wellness/Fitness Initiative (IAFF/FC Initiative), and the National Fire Protection Association's work-in-progress, NFPA 1583.

<b>14. SUBJECT TERMS</b> Physical Fitness; Health; Air Force; Military Medicine; Physiology; Military Standards; Fire Fire Suppression; Aircraft Fires	<b>15. NUMBER OF PAGES</b> 56
	<b>16. PRICE CODE</b>

<b>17. SECURITY CLASSIFICATION OF REPORT</b> UNCLASSIFIED	<b>18. SECURITY CLASSIFICATION OF THIS PAGE</b> UNCLASSIFIED	<b>19. SECURITY CLASSIFICATION OF ABSTRACT</b> UNCLASSIFIED	<b>20. LIMITATION OF ABSTRACT</b> UNLIMITED
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NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)  
Prescribed by ANSI Std. Z39-18  
298-102

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## FOREWORD

The report documents a *Review & Analysis* of firefighter fitness/wellness issues relevant to the military. This report was performed by the Crew System Ergonomics Information Analysis Center (CSERIAC) for the Air Force's School of Aerospace Medicine, Department of Aerospace Physiology and Human Performance. It was conducted under Department of Defense Contract Number SPO700-98-D-4001. A companion publication, *Firefighter Physical Fitness/Wellness Workshop* (CSERIAC-PR-98-001), documents the workshop proceedings of subject-matter experts who gathered at Wright-Patterson AFB in August, 1998 to reach consensus on these issues.

The CSERIAC director during this period was Mr. Mathias Kolleck. The program manager and primary human factors analyst was Ms. Barbara Palmer, who was assisted by Mr. Jon Carroll and Ms. Atia Mirza. This project benefited greatly from the project suggestions and editorial comments from CSERIAC Chief Scientist Dr. Michael Fineberg.

## EXECUTIVE SUMMARY

The US Air Force is the Executive Agent for the firefighter fitness programs for all military components. This *Review & Analysis* examines four suggested candidate firefighter physical fitness programs and related research in support of the ongoing Air Force/Department of Defense project to adopt a defensible and acceptable firefighter fitness training and testing program.

The four programs that are compared and contrasted are the Interim Air Force/Department of Defense Fire Protection Program's Fire Fighter Physical Fitness Program, the Canadian Forces/Department of National Defence's new Fire Fighter Physical Fitness Maintenance Program, the emerging International Association of Fire Fighters/International Association of Fire Chiefs Fire Service Joint Labor Management Wellness/Fitness Initiative (IAFF/FC Initiative), and the National Fire Protection Association's work-in-progress, NFPA 1583. Table 1 details these programs; a summary of program comparisons shows these differences:

**Fitness Testing:** Programs diverge widely here. The Canadian Forces/Department of National Defence program consists of simulated firefighting tasks, endowing it with content validity but possibly making it more resource-intensive to administer. In contrast, the Department of Defense program consists of standard physical fitness tests that may be safer and easier to administer. This test is supported by research incorporating a criterion validity approach. The IAFF/FC program calls for testing of aerobic capacity, and muscle strength and endurance, but does not call for a specific test battery. Similar generic fitness tests are called for in NFPA 1583, but at this point, the test is even less well-defined than the IAFF/FC program's. The level of test program validity is a point for further discussion.

**Fitness Training:** All programs mandate prescriptive fitness training based on test performance. The Interim Air Force/Department of Defense program describes quantitatively this training and how personnel must progress; the other programs' fitness specialists will fill this need, probably in a manner equally quantitative but not as standardized.

**Standards:** The two military tests have associated standards. The Air Force requires a passing score on the cycle ergometry test and the Canadian Forces/Department of National Defence program mandates a maximum time to complete the job-task simulation. The NFPA and the IAFF/FC Initiative do not mandate a specific test program, so there are no cut-off scores.

**Contingencies of Testing:** The Interim Air Force/Department of Defense program does not have the option of administrative action if satisfactory training progress is not being made. At this point, the Canadian Forces/Department of National Defence program does not have any job action for failure to meet their standard. In 1999, they will be able to remove personnel from the Fire Service for unsatisfactory training progress. The NFPA and IAFF/FC Initiative emphasize the non-punitive aspects of their fitness program.

**Wellness/Lifestyle:** The Canadian Forces/Department of National Defence, IAFF/FC Initiative, and NFPA 1583 programs all contain a wellness/lifestyle component; the Department of Defense program does not offer a specific, firefighter-based wellness program. While the IAFF/FC program is comprehensive and well thought out, for the most part these programs appear to be an offering of educational and counseling services rather than a tight, cohesive, in-house package.

In addition to the information about the components of the candidate programs, this *Review & Analysis* presents concepts and data that are also needed to evaluate the appropriateness of the tests of each of the candidate programs. The Air Force/Department of Defense requires a firefighter fitness program that is job-relevant, so our first evaluation tool requires an understanding of the concepts of test validity. To apply this tool, we document critical firefighter tasks and underlying physical capacities, to ensure that a candidate program evaluates the necessary firefighter functions. The second tool to help us evaluate the candidate program tests is awareness of the advantages and disadvantages of each of the two test types, physical fitness vs job-task simulation. Table 2 combines the information extracted from Table 1 and applies our analysis tools to the test programs of each of the candidates. Table 2 presents an overview of how the programs break down according to these avenues of analysis:

- validity (type of validity established, if any)
- use of task analysis; use of military tasks (e.g., aircraft/aircrew) in task analysis
- test type (generic physical fitness test, specific physical fitness test or job-task simulation), does it have an associated standard
- does test evaluate the underlying physical characteristics derived from the literature
- science base (original research, references to others' studies, or none)
- overall strengths and weaknesses

This *Review & Analysis* suggests that the Air Force/Department of Defense consider these points in their firefighter fitness program decision-making:

- Neither of the civilian programs is adequately developed or standardized enough to serve as a good model for a proposed Air Force/Department of Defense program.
- The two clear candidates for a proposed Air Force/Department of Defense's program are its extant program and that of the Canadian Forces/Department of National Defence. The latter incorporated aircrew/aircraft tasks in the initial task analysis.
- The Interim Air Force/Department of Defense program is a physical fitness test and the Canadian Forces/Department of Defence program is a job-task simulation. The advantages and disadvantages of each test type need to be rank-ordered in importance by the Air Force/ Department of Defense so that an appropriate decision can be made between these two test types. There are several studies that suggest a relationship between physical fitness and job-task simulation performance in the firefighting arena.
- The Canadian Forces/Department of National Defence program may be the most job-relevant of the programs surveyed, but the generalizability of this validity to the Air Force/Department of Defense program would need to be addressed if the Air Force/Department of Defense were to consider adopting this program. Also to be evaluated would be potential additional safety risks and possible increased administration costs.
- Several research and civilian programs that might also be considered by the Air Force/

Department of Defense are documented here. Although used as job-entry tests, the methodological approaches of Gledhill and Jamnik (1992a, b) and Brownlie et al. (1985) may be of interest for future developmental efforts.

- Neither the NFPA 1583 nor IAFF/FC Initiative testing program is based on any unique scientific basis that would make their adoption by the Air Force/Department of Defense desirable.
- Should the Air Force/Department of Defense decide to acquire a wellness/lifestyle program, it would have to be created from the ground up. That is, the other organizations' programs might serve as a model or framework, but their offerings of counseling and education services do not exist in an off-the-shelf format that could be plugged into the Air Force/Department of Defense program. The IAFF/FC Initiative projects sincere, holistic concern for firefighters, which could serve as the basis for a Department of Defense Fire Fighter Physical Fitness Program wellness/lifestyle component.
- Additional insight into the technical and scientific bases of the candidate programs is expected from the subject-matter experts who will convene at the Firefighter Fitness Workshop in August, 1998.
- A further approach could be to extract those components from the candidate programs which best meet the current Air Force/Department of Defense needs. The most robust components might be the:
  - job-task simulation test from the Canadian Forces/Department of National Defence program
  - Air Force/Department of Defense aerobic fitness test (already a requirement for military firefighters)
  - Air Force/Department of Defense exercise prescription, which is less resource-intensive than other programs
  - IAFF/FC's wellness component, although this would need development to ensure that it was specific enough to meet the requirements of the military firefighting community.

**Table 1. Comparisons of Major Candidate Firefighter Fitness Programs**

<b>Program</b>	<b>Focus/Purpose</b>	<b>Wellness/Lifestyle</b>	<b>Fitness Training</b>	<b>Fitness Testing</b>	<b>Testing Contingency</b>
Interim Air Force/Department of Defense Fire Fighter Fitness Program	To ensure that covered fire and emergency services personnel are at a level of physical conditioning that allows them to perform their assigned tasks safely and successfully	No specific firefighter-focused program	A sixteen-week training prescription is mandatory, and based on cycle ergometer performance. A minimum of 3 workouts per week is standard, with 5 to 7 preferred. Stationary cycle, rowing machines and treadmills are acceptable aerobic workout equipment. Strength training is also prescribed based on test performance	Testing consists of Air Force Cycle Ergometer Program--fitness level III is standard. Strength testing consists of one-time maximal lift for bench press, leg press, curl and upright rowing as well as a repetitive lift with an 80 lb barbell at 30 lifts per minute until fatigued. There are no standards associated with the strength tests	Current interim program requires only that personnel participate in the fitness program. There is no administrative action at this time
International Association of Fire Fighters/International Association of Fire Chiefs	This program addresses the needs of the individual--physical, mental, emotional--in a "holistic, positive, rehabilitating, and educational manner."	The Behavioral Health component is based on IAFF/FC's belief that behavioral health of firefighter personnel is as important as physical health, but has been largely ignored. Program uses internal and external sources to provide professional and coordinated assistance; marketing of behavioral health services; education regarding smoking cessation, stress and substance abuse; counseling and Critical Incident Stress Management services as well as chaplains' services.	1. Training is mandatory 2. On-duty training time provided (60 to 90 minutes per shift)	Annual fitness testing battery suggested to include: aerobic capacity, muscular strength, muscular endurance, flexibility evaluation	Non punitive program. No adverse consequences for failure
National Fire Protection Association	NFPA 1583 is a work in progress. The purpose of the NFPA's fitness program is to promote the ability of fire personnel to "perform occupational activities with vigor, and demonstrate traits and capacities that are normally associated with low risk of premature development of injury, morbidity, and mortality."	The health promotion component of the NFPA covers preventive health activities that uncover both actual and potential health risks in the work environment as well as activities that inform and motivate the adoption of healthy lifestyles. Educational materials and counseling services are provided.	Program should consist of aerobic exercise program, muscular strength and endurance, flexibility exercises, injury prevention and a healthy back program	Annual fitness testing battery suggested to include: aerobic capacity, muscular endurance, flexibility evaluation and composition body testing	Non punitive program. No adverse consequences for failure
Canadian Forces/Department of National Defence Fire Fighter Physical Maintenance Program	The program's goal is to "provide the tools and training to ensure all fire fighters are physically fit to do the required tasks of their job."	The health-related fitness component provides information about physical activity, weight management, nutrition; sex, alcohol, smoking, drugs; stress management and suicide prevention	1. Training is mandatory 2. On-duty training time provided 3. Individual fitness prescription is created to improve individual performance, using diagnostic circuit test as a baseline	Annual fitness testing consisting of: 1. One Arm Hose Carry 2. 3.6 m (12 ft) Ladder Raise 3. Charged Hose Drag 4. First Ladder Climb 5. High Volume Hose Pull 6. Forcible Entry 7. Victim Drag 8. Second Ladder Climb 9. Ladder Lower 10. Spreader Tool Carry *Tasks must be completed in 8 minutes or less	In the event of failure, individual is retested in 3 months. In the current start-up phase of this program, there is no threatened job action. By 1999, an individual who is not making sufficient training progress can be removed from the Fire Service

**Table 2. Analysis Table of Firefighter Fitness Tests**

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8
Name of Program	Validity of Test	Task Analysis Includes Climbing, Entry, Rescue, Ladder Use, Hose Use	Task Analysis Includes Aircrew/ Aircraft Task	Type of Test/Standard	Aerobic and Strength/Endurance Capacities and Body Composition	Science Base	Overall Program Strength /Weakness
Interim Air Force/Department of Defense	Content validity established through initial task analysis; criterion-related validity established through correlation with simulation battery	Undocumented task analysis	Undocumented task analysis	Specific physical fitness battery  Standard: Aerobic only	Yes	Original research – undocumented task analysis; 1997 tech report on relationship of test measures to simulation battery performance	S: Precision of exercise prescription, appropriateness of task analysis for AF tasks  W: No strength test standard
IAFF/FC Initiative	Content validity established, citing task analysis of Gledhill and Jamnik (1992a)	Yes	No	Generic physical fitness  Standard: None	Yes, but body composition test optional	Cites others’ research on task analysis and critical firefighter characteristics	S: Sincere concern for well-being of firefighter personnel  W: No specific test battery
NFPA 1583	None established	Undocumented task analysis	No	Generic physical fitness  Standard: None	Yes	None documented	W: No specific test battery
Canadian Forces/DND	Content validity through task analysis; criterion-related validity through correlation with physiological measures	Yes	Yes	Job-task simulation  Standard: Yes, completion time	Yes	Extensive original research and literature review	S: Degree of research, focus on content validity  W: Resource-intensive test

# **1. OVERVIEW AND METHODOLOGY**

## **1.1 INTRODUCTION**

The Department of Defense Fire Protection Program is governed by Department of Defense Instruction 6055.6. This Instruction establishes the US Air Force as the Executive Agent for the administration of the Department of Defense Fire Fighter Certification System, the Fire School at Goodfellow AFB, and the Department of Defense Fire Fighter Physical Fitness Program. Within the US Air Force, these programs are under the auspices of the Office of Civil Engineering. This Office requires a fitness and wellness program that is legally defensible, valid, reliable, and practical to administer, and requested that the consultants to the Air Force Surgeon General's Office acquire a plan and assist in fielding a program.

## **1.2 HISTORY OF DEPARTMENT OF DEFENSE FIRE DEFENSE PROGRAM**

The formal history of the Fire Fighter Physical Fitness Program began in the 1980s, with a program designed by what was then known as the Air Force's School of Aerospace Medicine. Publication of AFP 92-3 FFFP, in March 1989, documented this program. AFP 92-3 was replaced by AFM 32-2002, as the Air Force changed from a pamphlet to a manual system of policy documentation. During the re-coordination process in 1995, the Environmental and Occupational Medicine Division of the Office of the Air Force Surgeon General's Office raised some concerns that the Fire Fighter Physical Fitness Program was not performance-based, which limited its defensibility. The program's scientific merit and the amount of data that was used as its foundation were questioned. As an interim solution, it was decided, in August 1996, to continue AFP-92-3, with no administrative contingencies. This continuation has been in effect until the present day.

## **1.3 STATEMENT OF ISSUES**

The Air Force requires a fitness and wellness program with associated goals or performance standards. A program that includes physical fitness parameters, a wellness component, and testing with associated standards will be implied by our use of the term Fire Fighter Physical Fitness Program. Considerations for program adoption or adaptation include appropriateness of each of the program components (testing, training, lifestyle/wellness), validity of program (content, criterion-related, aircraft/aircrew tasks included in task analysis), and assessment of the science base of the program. Also discussed are standards development, gender and age differences, practicality and safety of administration, and compatibility with existing information systems.

## **1.4 ORGANIZATION OF *REVIEW & ANALYSIS***

In the quest to establish the requirements for an Air Force/Department of Defense Fire Fighter Physical Fitness Program, this *Review & Analysis* will explore several topics. The second chapter of this document compares and contrasts the current Air Force Fitness Program and three other major candidate firefighter fitness programs. Additional firefighter fitness test programs found in the literature are discussed here as well. Tools to help in the evaluation of these candidate programs are presented in Chapter 3. To ensure that any candidate program will evaluate the right capabilities, Chapter 3 gives us a basic understanding of what firefighters must be able to do on a daily basis and the working conditions and tasks of firefighters in general, and military firefighters specifically. This chapter includes a review of scientific investigations into physical characteristics that underlie successful performance of firefighter tasks. Chapter 3 also presents advantages and disadvantages of each test type (physical fitness vs job-task simulation) and other practicalities of test development.

The fourth chapter uses information about the candidate programs' components and applies the analysis tools to evaluate their test programs. This chapter summarizes the findings regarding the training and wellness/lifestyle components of the programs. Finally, this *Review & Analysis* suggests approaches for the consideration of the Air Force/Department of Defense Fire Fighter Fitness Program.

It is important to note here that the many pieces of research on firefighter fitness cited in this *Review & Analysis* apply to more than one of the topics addressed here. Rather than repeat their information, each study was placed in the area of discussion to which it seemed most relevant (Section 3.1.1.1's discussion of Critical Firefighter Tasks; Section 3.2's discussion of the degree of relationship between physical fitness measures and job-task simulation tests; or Section 2.2's description of Other Programs).

## **1.5 INFORMATION SOURCES**

Information for this *Review & Analysis* was gathered from several sources. The bulk of information was derived from published literature, including books, technical reports, and journals from the fields of fitness, sports medicine, physiology, medicine, and others. Relevant literature was identified subsequent to a comprehensive computerized search of the literature. Literature searches were performed on several databases, including:

Defense Technical Information Center (DTIC) Technical Reports (TR)  
Advisory Group for Aerospace Research & Development AGARD  
Dissertation Abstracts On-line  
National Aviation & Space Administration - Remote Control (NASA Recon)  
SPORTDiscus

Relevant and recent literature and researchers were identified and this information was used to access other sources. Over 150 journal articles, technical reports, and book chapters were obtained, reviewed, and analyzed for this report. In addition to databases of literature, additional information was obtained through World Wide Web newsgroups, subject matter experts, and electronic documents.

## **2. THE CANDIDATE PROGRAMS AND OTHER RESEARCH**

### **2.1 MAJOR FIREFIGHTER FITNESS PROGRAMS COMPARED AND CONTRASTED**

Major Firefighter Fitness Programs Compared and Contrasted documents the contents of each of four major candidate firefighter programs, Interim Air Force/Department of Defense, IAFF/FC Initiative, NFPA 1583, and the Canadian Forces/Department of National Defense programs. All programs implement medical screening so this is not discussed further. Components discussed in this chapter of the *Review & Analysis* are program goals or purpose; scientific basis behind program development, if any; fitness testing (mandatory or recommended, type of test); standards, contingencies of testing (prescribed fitness training, job action); fitness training (mandatory or recommended, frequency, sanctioned activities), and wellness/lifestyle programs.

Due to differences in available documentation, it is sometimes difficult to evaluate these programs fully. For instance, the Canadian Forces/DND publications describe the experimental program they conducted that forms the basis of their current battery in a very comprehensive manner. In contrast, early work by the Air Force that generated a task analysis of military firefighter tasks is not documented.

#### **2.1.1 Interim Air Force/Department of Defense Fire Protection Program**

Air Force Pamphlet 92-3 FFFP is the current guidance for the physical fitness program covering the firefighters of all Department of Defense components. It is in conformance with the National Fire Protection Association's (NFPA) physical fitness requirements, as outlined in the proposed NFPA 1500 series. The program's purpose is to ensure that the covered fire and emergency service personnel be at a level of physical conditioning that allows them to perform their assigned tasks safely and successfully.

The history of the Air Force program began in the late 1970s and early 1980s. A task analysis was performed after interviewing fire chiefs from several Strategic Air Commands regarding their most common firefighting tasks. Subsequent research (Myhre et al., 1997) mentions this task analysis and describes the relationship between the physical fitness measures used in the Interim Air Force/Department of Defense firefighter fitness program and performance on a standardized, strenuous simulated fire fighting task.

In the Myhre et al. (1997) study, two firefighting tasks were described that arose from the earlier task analysis by Strategic Air Command fire chiefs, to "simulate emergency activities that they considered representative of the most critical performance requirements for their fire fighters" (p. 2). The two tasks were a B-52 "crash" aircrew rescue and a structural search and rescue mission that took place in either a multi-story smokehouse or in a standard air base dormitory. The structural task was selected for use in the 1997 study because it lent itself to standardization of conditions. Myhre et al. (1997) describe the task:

Structure: Three-story dormitory. Main entry leads to both the first floor hallway and the stairwell.

Two flights of 16 stairs each lead to the third floor where a fire door separates the dormitory hallway from the third floor landing. The hallway floors in the Air Force dormitories were covered with a short-pile carpet; in the Army dormitory the floor was covered with vinyl tile. The longest distance from the stairwell door to the end of the hall was just over 40 yards. (In one series of experiments involving 16 firefighters the structure was limited to an exterior hallway which precluded maneuvering the "victim" from the hallway through a fire door and into a stairway landing.)

“Victim”: Fire fighters volunteered to alternate as simulated victims for these exercises. A turnout coat was worn over their normal day uniform, additional weight was added when necessary to bring their clothed weight as near as possible (+/- 2kg) to the selected standard of 77 kg.

“Fire fighter”: Fire fighters wore their standard protective ensemble which included a 30-min pressure-demand self-contained breathing apparatus (SCBA) over their normal day uniform. In addition, they carried two lengths of hoseline and a water thief which they deposited on the third floor landing during the first phase of the performance task.

Rescue scenario: Wearing the full protective ensemble and packing the equipment burden described above, the fire fighter stands “ready” 10 yds from the dormitory main entry. The fire fighter advances on command as quickly as would be prudent for safety through the opened doorway, on to the stairwell and stepping on each stair to the third floor landing. Upon reaching the landing, the fire fighter drops the equipment carried, activates the SCBA and enters the hallway through the opened fire door. Once in the hallway, the fire fighter crawls directly to the “victim” who is lying on his back, his head exactly 38.5 yards from the fire door and with his feet toward the other end of the hall. Upon reaching the victim, the fire fighter grasps the belt or rope positioned under the victim’s arms and around his chest, and begins to tow the victim toward the stairwell door. (The fire fighter must keep at least one knee on the floor at all times, and the victim’s head must stay in contact with the floor during the entire exercise.) The fire fighter continues to drag the victim until he is outside the hallway and resting on the third floor landing. (pp. 2-3)

The performance criterion was the time required to complete the task, and heart and respiration rate were also measured during the task. Data were gathered for each subject on absolute and relative VO<sub>2</sub> max, bench press (lbs), leg press (lbs), curl (lbs), row (lbs), and number of repetitions of the 80-lb bench press. Descriptive statistics were used to characterize these physical characteristics of the sample population (218 male and four female career firefighters). Pearson product-moment correlations were used to evaluate the relationship between several measures of fitness and time to complete the above task.

It was originally intended that after the victim was moved to safety, the firefighter would return to the hallway and complete the rescue for a second victim. Since the majority of firefighters were not able to complete the task in an acceptable time (10 minutes), the scenario was revised and limited to the rescue of one victim. When a firefighter was not able to complete the single-victim task, performance time was assigned using time until the point of failure, an addition of 60 seconds representing a needed rest, and an addition of estimated time to complete the task based on work rate prior to the point of failure.

Average time to complete the task was 6 minutes and 17 seconds, with mean values for ventilation and peak heart rate suggesting a near maximal effort. Fitness and performance scores showed considerable variability. All fitness variables and age correlated significantly and in the expected direction with rescue time, with no one variable being able to predict performance capability alone. The “most efficient formula for predicting performance time could be achieved utilizing the following three variables: body composition, aerobic capacity in total ml min<sup>-1</sup>, and arm strength for the forearm curl” (pg. 9). Myhre et al. (1997) conclude:

Fire protection specialists should review the results of this study to determine whether or not the performance task validly represents at least some of the

emergency duties expected of firefighters. If that is agreed, it is recommended that they reach agreement as to the slowest acceptable performance time for this task and then apply a regression formula. . . as a guide for determining minimal acceptable levels of cardiovascular fitness, muscular strength, and lean body mass for fire fighters who may be called upon to perform these tasks. It is recommended that applicants be held to a higher standard because of an abundance of evidence that (1) fitness decreases with age; and (2) higher levels of fitness translate to better performance, at reduced risk. (p. 12)

**2.1.1.1 Interim Air Force/Department of Defense Fire Protection Program Fitness Testing/Standards/Contingencies**

The framework for this Department of Defense program includes an earlier version of the Air Force Cycle Ergometry Fitness test, which is used to determine fitness status and to offer information for a prescriptive training program. Cycle ergometry is used because it is a reliable and safe estimate of cardiovascular fitness. It is a submaximal test, based on the physiological principle that heart rate increases as work intensity and oxygen consumption increase. The individual’s heart rate response is used to estimate VO<sub>2</sub>max. As an adaptation to physical training, heart rate is expected to decrease for a given level of workload. This test has demonstrated its correlation with the graded treadmill test (Pollock et al., 1994). Basically, the testing procedure assesses heart rate at the end of a six-minute steady-state cycling period. Minimum passing heart rates are established by sex and age. The standards for the male fitness levels based on the cycle ergometry test range from 27.6 to 34.0 (VO<sub>2</sub>max ml kg<sup>-1</sup> min<sup>-1</sup>) depending on age. The standards for women range from 23.0 to 27.0 (VO<sub>2</sub>max ml kg<sup>-1</sup> min<sup>-1</sup>), based on age. With VO<sub>2</sub>max ml kg<sup>-1</sup> min<sup>-1</sup> as the unit of measurement, these are the standards for men and women by age:

	<b>&lt;29 years</b>	<b>30-39 years</b>	<b>40-49 years</b>	<b>&gt;50 years</b>
<b>Males</b>	34.0-41.9	32.0-38.9	29.6-35.5	27.6-31.5
<b>Females</b>	27.0-35.9	26.0-33.9	26.0-30.9	23.0-25.9

Body composition measurements are taken and strength tests are administered at the beginning of training and every 16 weeks during training. The first strength test is a one-time maximal lift for bench press, leg press, curl, and upright rowing. The second strength test requires a repetitive lift with an 80 pound barbell at 30 lifts/min until fatigued. There are no standards associated with this program’s strength test; results are used to prescribe a training program. Total body fat is assessed by taking height and selected circumference measurements (abdomen and neck for men; abdomen, neck, and hips for women). While there is no current standard for body fat in the interim program, it should be noted that the Office of the Secretary of Defense is in the process of developing a Tri-Service body composition standard that could serve as a baseline.

There are no contingencies associated with this interim program; previously, personnel who fell below standard on the aerobic test (cycle ergometry) were retested in 90 days and had to show an improvement of 25% of the difference between their present score and the standard. The fitness monitor oversaw this training. If the firefighter did not show satisfactory progress after six months of rehabilitation training, the Fire Chief determined if administration action was warranted.

### **2.1.1.2 Interim Air Force/Department of Defense Fire Protection Program Fitness Training**

A 16-week computer-generated training prescription is provided based on performance on the cycle ergometry test. Three workouts a week is the minimum, and five to seven workouts a week is recommended. Stationary cycle, rowing machine, and treadmills are acceptable aerobic workout equipment. The strength prescription requires that personnel exercise large muscle groups of the upper and lower body, such as through bench press, leg press, upright curl, and upright rowing. Two sets of eight repetitions should be conducted with a 30 sec break between sets. Repetitions are increased by one at the end of the second week, and after each succeeding week, until two sets of 12 repetitions are completed. Then, additional weights are added. Weight training is to be limited to every other day to a maximum of three days a week. Also, curls (sit-ups performed without reaching the knees) should be performed on the same schedule.

### **2.1.1.3 Interim Air Force/Department of Defense Fire Protection Program Wellness**

The various military services provide health education and wellness programs to their active-duty members, but there is currently no official wellness component geared specifically toward the Air Force/Department of Defense firefighters.

## **2.1.2 The International Association of Firefighters/Fire Chiefs Initiative Program**

A landmark program due to extensive cooperation among labor and management, the Fire Service Joint Labor Management Wellness/Fitness Initiative (hereafter called the IAFF/FC Initiative) was a joint project of the International Association of Fire Fighters and the International Association of Fire Chiefs. These unions have considerable membership in most American and Canadian fire departments. The goal of the IAFF/FC Initiative was to address the needs of the total individual—physical, mental, and emotional—in a “holistic, positive, rehabilitating, and educational” (p. iii) manner. Moving beyond punitive, negatively timed, task-based testing to progressive wellness development, fire chiefs and IAFF local union presidents agreed to a set of fitness and wellness recommendations and pathways for achieving these recommendations. This program consists of medical evaluation (which includes body composition analysis), a rehabilitation component, and a holistic wellness emphasis, in addition to its fitness program. The program’s fitness recommendations were based in a general sense on a task analysis (Hyland & Peltin, as cited in IAFF/IAFC, 1997) and the work of Gledhill and Jamnik (1992a) which characterized physical demands of firefighting.

### **2.1.2.1 The International Association of Firefighters/Fire Chiefs Initiative Fitness Testing/Standards/Contingencies**

The recommended fitness evaluation has four components: aerobic capacity, flexibility, muscular strength, and muscular endurance. Aerobic capacity can be tested by treadmill, stair machine, stationary cycle, or step test. Flexibility is assessed with the sit and reach test. Muscular strength is evaluated with the hand grip dynamometer, leg dynamometer, and the arm dynamometer. Muscular endurance is assessed by sit-ups and push-ups. There are no specific standards. The Initiative recommends fitness testing that will be used to provide feedback to the firefighter and the department physician regarding physical capacity pertaining to his or her job-related wellness, level of improvement, and a suggested exercise program.

### **2.1.2.2 The International Association of Firefighters/Fire Chiefs Initiative Fitness Training**

The IAFF/FC Initiative mandates duty time for exercise, and recommends that 60-90 minutes every shift be spent on aerobic, strength, and flexibility activities, with the support of an exercise specialist and a peer trainer. A variety of activities is suggested.

### **2.1.2.3 The International Association of Firefighters/Fire Chiefs Initiative Wellness Activities**

The Behavioral Health component of the Initiative is based on the belief that an emotionally and mentally fit firefighter is essential to the fire service's foundation. Features of this component are professional and coordinated assistance; marketing of behavioral health services; education regarding nutrition, smoking cessation, stress, and substance abuse; counseling services; Critical Incident Stress Management and chaplains' services.

The IAFF/FC Initiative publication states the organization's commitment to behavioral health this way:

A wellness program is not complete without addressing the behavioral well being of those involved. The behavioral health of our uniformed personnel is every bit as important as their physical health. Yet, historically it has been largely ignored or taken for granted. Little attention has been paid to the behavioral health of members of the fire service until the last decade with the advent of Employee Assistance Programs and more recently, Critical Incident Stress Debriefing Teams. In general, few departments have comprehensive behavioral health programs. A mentally and emotionally fit fire fighter and EMS provider is an important building block in the fire service's foundation. The behavioral health component of this Initiative provides important tools to assist all uniformed personnel in achieving total wellness. The services available through behavioral health must insure the confidentiality and privacy of the uniformed personnel both in writing and in practice.

To maintain a high level of job performance, our uniformed personnel must be able to cope effectively with the emotional, physical, and mental stresses of work and personal life. If the ability to cope becomes compromised, these stresses may act to unbalance his or her mental and emotional health. Alcoholism, drug addiction, the death of a co-worker, financial distress, marital and family problems, and occupational stress may be affecting the individual both on and off the job. These stresses can further affect the individual's overall wellness. (p. 72)

### **2.1.3 National Fire Protection Association**

This international, nonprofit organization publishes the National Fire Codes and advocates the use of their scientifically based consensus codes and standards, research, and education for fire and related safety issues. Their 275 codes cover all areas of fire safety and are used throughout the world. A series of standards documents governs the National Fire Protection Association's medical and wellness programs.

- NFPA 1500 Fire Service Occupational Safety and Health Program—mandates development of physical performance requirements and establishment of physical fitness program

- NFPA 1581 Fire Department Infection Control Program –governs processes to control both airborne and blood-borne diseases
- NFPA 1582 Standard on Medical Requirements for Fire Fighters—covers professional qualifications and medical requirements
- NFPA 1583 Standard on Health Related Fitness Programs for Firefighters—being developed currently to cover a health-based fitness program, expected to be acted on by the NFPA in 1999. It will include fitness assessment, fitness training, and education and counseling regarding wellness and fitness.
- NFPA 1584 A future document may deal specifically with physical performance measures.

This program was developed on the basis of consensus reached by firefighters and fire management personnel regarding critical firefighter tasks.

### **2.1.3.1 National Fire Protection Association Fitness Testing/Standards/Contingencies**

NFPA will recommend that a fitness assessment will be conducted at least annually, to consist of aerobic capacity, muscular strength, muscular endurance, and flexibility evaluation, and body composition testing.

### **2.1.3.2 National Fire Protection Association Fitness Training**

The fire departments' exercise and fitness training program should consist of educational wellness and fitness programs, exercise guidelines, an aerobic exercise program, a muscular strength and endurance exercise program, a flexibility exercise program, a healthy back exercise program, and an injury prevention program.

### **2.1.3.3 National Fire Protection Association Wellness Activities**

The Health Promotion component of the NFPA 1583 covers preventive health activities focusing on actual and potential health risks in the work environment as well as activities that inform and motivate the adoption of healthy lifestyles. Educational materials are available on many health issues (self-breast exam, diabetes, mental health, recreational drug use) and workplace risks (back health, cardiac risks, and hazardous material exposure). Department members have access to counseling services through a contracting arrangement.

### **2.1.4 The Canadian Forces/Department of National Defence Program**

The Canadian National Defence's ADM (Per) 5595, *The Fire Fighter Physical Fitness Maintenance Program (FFPFMP) Implementation Period 1 April 1998-30 September 1999*, covers the phase-in of a new wellness/fitness program devised by DPERA and Queens University. The program's goal is to "provide the tools and training to ensure all fire fighters are physically fit to do the required tasks of their job" (p. 3/4). The large body of research behind the development of the new circuit and associated standards speaks to a strong desire to have a valid and defensible fitness testing program.

The Canadian Forces program (Deakin et al., 1997) is backed by the most ambitious, thorough, and recent development effort of all the major programs assessed here. A brief history of the CF/DND program indicates that before 1980, fitness was assessed with a battery consisting of a 1.5 mile run, and sit-ups, push-ups, and chin-ups, using age and gender-based standards. The death and injury rate

led to the development of the Exercise Prescription Plan (EXPRES), based on the Canadian Standardized Test of Fitness (1981). It provided CF/DND personnel with a prescribed training program. The approved programs of the CF/DND also include the Minimum Fitness Standards (MPFS), based on five common military tasks whose completion might be required of any member of the military. MPFS is the minimum level of fitness required by personnel to meet the physical demands of these five tasks (Stevenson, Andrew, Bryant, Thompson, Lee, & Swan, 1988). However, this requirement did not meet the mandate for specific occupational requirements (Singh, Lee, Wheeler, Chahal, Oseen, & Courture, 1991; Lee, 1991). Fire fighters are a special group, and until recently, their fitness was assessed twice a year. The Spring assessment consisted of the EXPRES and MPFS protocols. In the Fall, firefighters completed a trade-specific test consisting of a 1.5 mile run, sit-ups, push-ups, chin-ups, victim carry, and a balance task, scored on age and gender under CFAO 50-12. Objections to this program surfaced in 1991, with the CF Fire Marshall, who noted the existence of differential standards for CF and DND firefighters, even though their job requirements were identical, the lack of scientific validation, and questioned whether the test accurately predicted operational capacity.

The CF Fire Marshall requested that the current fitness standards for firefighters be replaced with an assessment tool that meets the bona fide occupational requirements (BFOR) of the Canadian Human Rights Act of 1985. A BFOR has three characteristics: it must quantify the essential components of the job, it must identify the capabilities needed to complete the components safely, efficiently, and reliably, and it must assess the individual's capabilities (Government of Canada, 1988).

The Ergonomics Research Group at Queen's University performed a task analysis and literature review of firefighter literature. Subject-matter experts from the Canadian Forces Fire Academy and the CF Fire Marshall's Office selected the most demanding and representative tasks for CF/DND firefighters. The task analysis, titled *Most Common and Demanding Tasks for CF Firefighters*, lists these twelve functions (Deakin et al., 1997, p. 109-110).

1. Perform tasks in hazardous environments wearing self-contained breathing apparatus (SCBA):  
oxygen-generating breathing apparatus;  
positive-pressure breathing apparatus;  
negotiating the smoke maze wearing breathing apparatus.
2. Use and maintain fire department ladders:  
correctly carrying and raising a 7 m ladder;  
correctly carrying and raising a 12 m ladder as a member of a team;  
correctly climbing a 12 m ladder and applying a leg-lock at a height of at least 8 m
3. Perform forcible entry practices:  
demonstrate the proper procedure for gaining access through doors, locked windows, walls, ceilings, roofs, and floors.
4. Participate in rescue operations during emergencies by operating the following equipment:  
portable rescue saw;  
chain saw;  
engine generator set;  
hydraulic rescue kit; and  
power rescue tool.
5. Perform fire apparatus practices:

operate a structural fire fighting vehicle connected to water sources;  
correctly perform a hydrant-to-fire lay of hose;  
open hydrants; and  
tighten couplings

6. Perform the following search operations:  
room search;  
above ground search; and  
search and rescue in a smoke maze while wearing an SCBA.

7. Conduct rescues from buildings using the following methods:  
helping a victim to walk; and  
carrying a victim by seat carry, chair carry, lone rescuer lift and carry, bunker coat or blanket drag,  
and stretcher carry.

8. Perform rescues using:  
breathing apparatus;  
cordage;  
ladders; and  
rescue equipment.

9. Perform ventilation, salvage, and overhaul operations:  
use smoke ejector/exhauster;  
fold, throw, and roll savage cover;  
use mop-up kit; and  
use clean-up kit; and  
apply water fog to expel gas and smoke.

10. Perform vehicle extrication:  
remove trapped casualty from a vehicle;  
gain access to vehicle through windows, doors, tops, and floors.

11. Perform aircraft fighting and rescue operations:  
apply foam, dry chemical, and halon using handlien techniques; and  
casualty evacuation.

12. Fight structural fires:  
carry dry hoses and advance charged hoses;  
carry, raise, use, and lower fire fighting equipment;  
carry, raise, climb, and lower ladders;  
perform duties of hoseman, nozzleman, rescue man, and salvage man;  
direct water streams;  
conduct search and rescue operations;  
conduct ventilation operations; and  
perform forcible entry.

These tasks were field tested, and modified slightly into a ten-task battery. During the study which established the ten-task circuit's reliability, the physiological demands of the circuit were characterized, which significantly correlated with on-the-job measures of heart rate and VO<sub>2</sub>.

#### **2.1.4.1 Canadian Forces/Department of National Defence Fitness Testing/ Standards/ Contingencies**

Firefighters are tested annually on this circuit, with testing preceded by a health appraisal questionnaire and medical pre-screening. The circuit test requires that personnel perform these firefighting tasks consecutively on a concrete slab floor, with very brief rest intervals (walking a specified distance) between tasks:

1. One-arm hose carry
2. 3.5 m ladder raise
3. 30.48m hose drag
4. 10-rung ladder climb – three times
5. High-volume hose pull
6. “Forcible entry,” moving a rubber tire by hitting it with a sledge hammer
7. Victim drag
8. 10-rung ladder climb—two times
9. 3.5 m ladder lower
10. Spreader tool carry which replaced a mannequin lift-and-carry task

This program is currently being implemented. When it is fully in place, the circuit must be completed within 8 minutes. Initially, as this program is implemented, there is no job sanction associated with not being able to compete the circuit in the required time allotment. Personnel who do not meet the standard are required to participate in mandatory physical fitness training, and to be retested in three months. By 1999, an individual who is not making sufficient training progress can be removed from the Fire Service. Body composition testing is optional.

#### **2.1.4.2 Canadian Forces/Department of National Defence Fitness Training**

Physical fitness training is performance-related, based on circuit performance. A diagnostic trial or practice test on the circuit course is used as a baseline. Mandatory on-duty training for CF/DND firefighters consists of an individual exercise prescription tailored for the firefighter. Individual fitness trainers in each fire department are responsible for designing and overseeing the training programs. The specifics of the prescribed exercise include time and type of activities, and frequency and intensity parameters.

#### **2.1.4.3 Canadian Forces/Department of National Defence Wellness**

The health-related fitness component of the Fire Fighter Physical Fitness Maintenance Program ensures that firefighters are provided with information on physical activity, safer sex, alcohol and other drugs, smoking prevention and cessation, stress management and suicide prevention, and nutrition and weight management.

#### **2.1.5 Programs Compared and Contrasted**

The development of the above programs represent significant human efforts and economic output. Each has some unique advantages, and these will be the focus of this section. An important distinction that makes our comparisons difficult is that the military organizations’ programs are centrally organized and enforceable in ways that are not available to unionized, civilian, and organizationally disparate fire departments. That is, the IAFF/FC Initiative can recommend and encourage their many member departments to adopt their plan, but there is apt to be wide variability among stations and departments in the specifics of their compliance.

### **2.1.5.1 Fitness Testing Comparisons**

The Canadian Forces/Department of National Defence studies (Deakin et al., 1997) represent the largest specific body of original research, relies appropriately on a comprehensive literature search, and features extensive task analysis procedures. The procedure that led to the development of the circuit components, documented in the Deakin et al. publication "*Development of a Bona Fide Physical Maintenance Standard for CF and DND Fire Fighters,*" consists of an outstanding literature review and a task analysis that took advantage of appropriate subject-matter experts, including the firefighter instructors at the Canadian Forces Fire Academy. In addition to its clear relation to on-the-job tasks, the demonstration of the relationship between simulation battery performance and physiological measures taken during actual fire fighting speaks to its validity. The Air Force/Department of Defense program, based on physical fitness tests, was produced with input from fire chiefs and other subject matter experts. A strength of the Air Force/Department of Defense program and the Canadian Forces/Department of National Defence program is that they employ tests derived from data taken from hundreds of fire fighters. The IAFF/FC Initiative and the NFPA use a traditional, balanced physical fitness testing program. The physical parameters that they have chosen to test seem to measure physical characteristics necessary to perform fire fighter tasks. The IAFF/FC Initiative and the NFPA do not cite any original research, but appear to rely on the same or similar studies of others.

### **2.1.5.2 Contingencies of Fitness Testing Comparisons**

All programs offer a prescriptive physical fitness training program based on test performance. The military-based programs have the potential to be more enforcement-oriented, but at this time, neither the Interim Air Force/Department of Defense nor the Canadian program uses administrative action in the event of unsatisfactory training progress. The Canadian program is in the start-up phase of their program, and in 1999 can remove an individual from the Fire Service for unsatisfactory training progress. Both military programs mandate required physical training and testing. The NFPA and IAFF/FC Initiative do not have any contingencies associated with their test program.

### **2.1.5.3 Fitness Training Comparisons**

All programs recommend or provide equipment that is available to firefighters for physical fitness activities. The Initiative recommends 60-90 minutes of activity per shift, and the Air Force mandates three workout periods per week, and recommends five or seven. In their documentation, both the Interim Air Force/Department of Defense and the Canadian Forces detail the variables included in their fitness training programs. The US Air Force offers particularly quantitative information about weight load, rate, repetitions per minute, and other specifics of the workout program in its exercise prescriptions, and offers feedback at specific intervals about the progress of the training program. The Initiative and the NFPA also encourage the use of on-site exercise physiologists who will be able to deliver similarly detailed exercise training plans, but there will certainly be greater variability in training generated by these programs compared to the Interim Air Force/Department of Defense and Canadian Forces/Department of National Defence programs, with the latter relying on resident military exercise specialists.

### **2.1.5.4 Wellness/Lifestyle Comparisons**

The wellness/lifestyle components of these four major programs differ widely. The NFPA program is thorough in its approach. The Canadian Forces/Department of National Defence program does have a firefighter-specific health and wellness program, but the Interim Air Force/Department of Defense

does not. The IAFF/FC makes a clear and convincing statement of its commitment to the overall well-being of its personnel, through its lucid documentation to the specifics of its offerings. While the IAFF/FC program is comprehensive and well thought out, for the most part these programs appear to be an offering of educational and counseling services rather than a tight, cohesive, in-house package.

## 2.2 OTHER PROGRAMS

This *Review & Analysis* describes research on firefighter tests and tasks in several places, in order to bolster discussion on the various points that are addressed in this document. First, in this section, we attempt to broaden the scope of possibilities for the Air Force/Department of Defense's decision-making by describing various other firefighter fitness programs and if applicable, the research studies that generated them. The next set of studies and firefighter fitness programs is discussed in Section 3.1.1.1, Critical Firefighter Tasks. A third set of test batteries is reviewed in Section 3.2, Test Type. While the batteries and studies in Chapter 3 are not repeated here, a review of them will help provide additional context that allows us to look for commonalties among these programs, and to evaluate more clearly the degree of quantitative development that is possible in the arena of firefighter fitness.

Gledhill and Jamnik (1992 a, b) created a job-screening battery based on a characterization study that documented and decomposed critical firefighter tasks. The battery was tested on a group of firefighters and then revised. The tasks were ladder climb, a claustrophobia test, ladder lift, rope pull, simulated hose advance, drag, hose carry/stair climb, and victim drag. Physical fitness and related measures included years of service, age, height, weight, body mass index, skinfold assessment, distribution of fat, absolute and relative  $VO_{2max}$ , sit and reach, and sit-ups. A cross-validation approach using a second group of firefighters provided criterion related validity and performance data. Associated standards were derived from performance of experienced firefighters. An overall fitness score was calculated with weighted scores so that a high score on one component could offset a low score on another component. Although this battery was designed as a fitness screening protocol, its attempts to establish validity recommend it as a model for test development.

A 1985 study by Brownlie et al. documents a firefighter selection test battery, based on requisite knowledge, skills, and abilities (including but extending beyond physical). The physical attributes used as a basis for the battery were taken from an earlier (Bownas & Heckman, 1976) comprehensive analysis of firefighting functions from 109 jurisdictions in the United States determined to have construct validity and reliability. Applicants completed three tests of gross physical measures. A Cooper 12-min run test for cardiovascular fitness had a minimum passing standard of 1.75 miles. Basic strength and endurance were assessed by requiring personnel to carry a 125 lb dummy 150 feet in 13 seconds. This standard was set by making the passing score two standard deviations from the mean of the annual test of the previous year. Using a cut-off score based on the height of fire truck dimensions, personnel were required to unhook, lower, and raise a 15 foot extension ladder from brackets set at a height of 91.5 inches. A second battery assessed height, weight, extent flexibility, sit and reach flexibility, hand grip strength, back strength, static balance with eyes closed, and dexterity. The third assessment consisted of an obstacle course in which subjects performed hose coupling, a tunnel crawl, ladder mount, dummy carry, window entry, and obstacle shuttle run. Maximum time to complete was set at 90 seconds. Test results were standardized with test category scores formed by summation of standard scores from component tests. Weightings were used to transform these category scores to final weighted scores. Knowledge tests were incorporated into this model as well. This test program serves as the basis for an employee selection process, which is not the focus of the Interim Air Force/Department of Defense question, but the front-end knowledge-skills-and-abilities methodology provides a good model for task analysis.

Another program stressing the development of face and content validity was developed for the Oklahoma City firefighters by researchers at the University of Oklahoma (Purswell, McCauley, & Merrick, 1991). The goal of this project was to develop a job related physical performance test to be used in firefighter selection. A questionnaire was administered to present firefighters regarding the perceived task duration, perceived frequency of performance, and perceived physical effort involved in nine characteristic firefighting tasks. This exercise established the tasks that were the basis of the field and laboratory testing protocols. Both short, explosive strength and heavy exertion for up to five minutes were indicated as essential by the questionnaire. Content validity was said to have been established through the development of the field tests (cycle ergometry, number of situps in three minutes, number of chinups in three minutes, trunk and limb flexibility, grip strength, number of pushups in three minutes) and laboratory tests (isokinetic strength of quadriceps, hamstrings, biceps, and triceps, anthropometric data, flexibility of back, hamstring muscles, hip flexor muscles, and anterior thigh muscles, grip strength, oxygen consumption while on the treadmill, and perceived difficulty of treadmill task). Based on the degree of relationship between several of these measures, the following was suggested to the Oklahoma City Fire Service:

- That strength be tested with a static dynamometer for grip, biceps, triceps, hamstring, and quadriceps.
- A submaximal cycle ergometry test should be conducted for 12 minutes.
- Pullups should be administered with palms facing inward or outward.
- Number of situps within three minutes should be a test measure.

A submaximal job-related test drill was developed by Louhevaara et al (1994) to assess work capacity in the fire station environment based on earlier analysis of the consumption of oxygen during firefighting tasks. The five tasks associated with smoke diving are performed in full personnel protective gear and SCBA with one air container. The tasks are to walk with and without two rolls of hose, stair climbing, hammering a truck tire, going under and over bars, and hose rolling. Fixed maximal working time is 14.5 minutes and minimal walking between stations is required. The authors report that the test efficiently sorts out subjects according to their  $VO_2$  max. Over two-thirds of a group of firefighters reported that they thought the drill was superior to a cycle ergometry test in assessing their work capacity. More than 90% reported that the drill motivated them to train.

An entry-level job test was modified by the researchers (Mostardi & Urycki, 1989) and the City of Akron, Ohio, to ensure that their current requirements accurately reflected critical elements of firefighting. Information was gathered from fire chiefs regarding duties and the specifics of accomplishing them, including ladder length, ladder weight, and how far ladders would need to be carried. The city determined that their old test contained items that are no longer frequently done (e.g., the buster bar is now seldom used) or are not critical (e.g., clean up of hose stack, performed after the fire). Firefighter tasks deemed frequent and critical were tower climb/hotel pack, ladder lift, hose pull, hydrant event, fan hang, use of fire axe, and search and rescue. A nine-item job-sample test was created from this list. It was administered to 30 firefighters to establish validity and a cutoff score.

The Phoenix Fire Department Wellness Center (J. Bledsoe, personal communication, April, 1998) developed the fitness circuit to function as a gym based fitness evaluation. A study was conducted to develop a risk profile. Work capacity evaluations were based on job tasks critical to an emergency scene and by the muscle groups and force required for its completion. The field test consisted of measures of heart rate in response to simulated fireground operation. Measures were recorded during a basic fast attack hoseline evolution and subjects wore full turnouts and SCBA facepieces. The fitness circuit makes use of the information acquired in the study, with the weight and number of

repetitions adjusted in an attempt measure absolute power as well as endurance. The heart rates in the circuit are reduced in order to serve as a sub-maximal measure and to reduce discomfort for the individual (a target heart rate response of 75-85% of the predicted maximum was used with the study producing a heart rate of 90-100% of predicted max HR). The circuit is designed to be reasonably completed in 15 minutes and limited to the 75-85% predicted maximum heart rate. It is not judged on a pass-fail basis.

The tasks evaluated are as follows:

#### Circuit Activity

- Resting H.R. (Standing)
- DB Curls @ 15 lbs, 24 reps
- Treadmill, 5 mph @ 15%, 1 minute
- One arm DB rows @ 30 lbs, 24 reps
- Treadmill, 3.5 mph @ 15%, 1 minute
- Seated DB Military press @ 20 lbs, 24 reps
- Treadmill 3.5 mph @15%, 1 minute
- DB Pickup @ 35 lbs, 10 reps, 6 feet
- Treadmill, 3.5 mph @ 15%, 1 minute
- Lat pulldowns @ 80 lbs , 24 reps
- Heart rate @ 1 minute of recovery
- Heart rate @ 2 minute of recovery
- Heart rate @ 3 minute of recovery
- Heart rate @ 4 minute of recovery
- Heart rate @ 5 minute of recovery

The Physical Performance Test consists of ladder extension; hydrant operation; hose pull; simulated roof ventilation; ladder handling; attic crawl; and rescue drag. These must be completed in 7 minutes and 20 seconds.

Firefit, a cost-effective injury reduction program for public safety personnel was developed for the Fairfax City Firefighting Department. Using a personal-trainer approach to encourage firefighters to work out, the goal of the effort was to implement a comprehensive fitness program and measure its effects on the number of incidents and the severity of injuries, workers' compensation claims and medical costs. Forty male firefighters were tracked for eight years (1982-1992). All subjects were retested after every six months of training. Records of subjects' on-duty injuries, medical costs, and lost work days were evaluated every year. Results showed a significant increased level of fitness from 1984 to 1992 and a significant decrease in lost work-time injuries and workers' compensation claims, especially muscular strains to the lower back. Evaluations are based on body measurements, lifting, and cardiovascular measures. Body measurements consist of the chest, biceps, waist, and neck. The lifting measures consist of bench press, sit ups, sit & reach, and lat pulls or pull ups. Cardiovascular measures are resting heart rate, 1.5 mile run or 3 mile walk, and blood pressure. These measures are taken both as a pretest and a posttest. The program has demonstrated its potential for decreasing costs; Fairfax City saved \$46,000 in two years (*The Washington Post: Virginia Weekly*, 1989) and increased the quality of life for its firefighters.

The Santa Ana College Fire Technology Department Wellness Program for Public Safety personnel was developed by the fire technology, exercise, science, and administration of justice departments (T. Wann, personal communication, April 1, 1998). The Rancho Santiago College Fire Technology department has administered the program since 1973. More than 10,000 public safety and general

population students have participated in the fitness evaluation. Fitness norms have been established by fire, police, and general populations and by age groups, gender, and occupation. The Wellness program taught as a college class consists of the following:

- Comprehensive fitness assessment and individualized fitness profile.
- Blood Chemistry Panel for general health and coronary risk screen.
- Nutritional analysis and individualized nutritional profile.
- Lecture series on health, nutrition, injury prevention, and exercise science topics.
- In addition, individualized fitness consultations and departmental consultations on physical fitness programs are also provided.

Fitness Evaluation:

- 12 lead ECG printout with computer interpretation at rest
- Pulmonary function recording of lung capacity and flow rates
- Resting and exercise blood pressure measurement
- 12 lead ECG printout during graded exercise treadmill test
- Body composition evaluation
- Abdominal endurance crunch test
- Bench press or pushup upper body strength and endurance test
- Grip strength
- Trunk, legs, shoulder, and spinal flexibility tests
- Health appraisal and coronary risk questionnaire
- Individualized fitness profile which includes all of the above results

### **2.3 CHAPTER CONCLUSION**

Our analysis of the four major candidate programs reveals that the two civilian programs are not detailed or standardized enough in their prescriptions to serve as appropriate models for the Air Force/Department of Defense's Fire Fighter Physical Fitness Program. In addition, neither of these programs is based on any self-sponsored or new research.

The only viable candidates for the Air Force/Department of Defense are its extant program and the Canadian Forces/Department of National Defence program. Both of these programs included aircraft/aircrew tasks in their initial task analysis. The programs differ from one another in that the Canadian Forces/Department of National Defence program is a job-task simulation, while the Interim Air Force/Department of Defense program consists of physical fitness tests. The arguments on both sides of the physical fitness vs job-task simulation test will be discussed in Chapter 3; the Air Force/Department of Defense will have to ascertain the relative importance of these factors before a decision can be made regarding test type.

It is noteworthy that the Interim Air Force/Department of Defense program has only an aerobic standard, which is not age/gender neutral. Its training program also does not require an on-site exercise specialist.

The remaining firefighter fitness programs found in the literature or through points-of-contact show the wide variety and high standards of several programs. These programs are presented to provide some context and a wider scope for the Air Force/Department of Defense's decision-making process. Of these additional programs, while both are employee-selection batteries, the work of Gledhill and Jamnik (1992 a, b) and Brownlie (1985) offer good methodological models.



### 3. ANALYSIS TOOLS—VALIDITY AND CRITICAL TASKS, AND TEST TYPE

This chapter of the *Review & Analysis* presents concepts that we can use as tools in our analysis of candidate firefighter fitness programs, especially their test components. To ensure that any chosen test is job-relevant, we need to define and discuss the several concepts of test validity. So that we can apply this tool to our analysis, it is important to establish an understanding of the subject-matter area, in this case, knowing what firefighter tasks and underlying physical capabilities are most important for job performance. Our second tool will be an understanding of the advantages and disadvantages of the types of tests associated with each of the candidate programs.

This discussion of test development issues can serve as the foundation for evaluating existing programs or the development of a new program that is valid, reliable, and practical for Air Force/Department of Defense firefighters. It is hoped that this chapter provides tools for analysis and a context within which to view the Air Force/Department of Defense's central firefighter physical fitness issues.

#### 3.1 JOB-RELEVANCY – THE CONCEPT OF VALIDITY

In the search for an appropriate fitness program and test, the Air Force/Department of Defense must ask whether the fitness standards under consideration are job-related, and if the standards are consistent with job performance requirements. In today's civilian environment, basic standards for evaluating a test's validity are found in these governing documents: *Uniform Guidelines on Personnel Selection Procedures* (1978), *Principles for Validation of Personnel Selection Procedures* (1980), and the American Psychological Association's *Standards for Educational and Psychological Testing* (1985) (Dwyer, Prien, & Burke, 1987). Since these documents deal with issues relevant to personnel testing in general, they can serve as a model as well for military applications.

In the development of a test or test battery, we need to establish job-relevance. Job-relatedness can be established through **content, construct, or criterion validation**. A given measure is valid to the extent that it corresponds to, or predicts, the human behavior of interest. Does the test measure what we want it to measure, does it measure all of what we want it to measure, and does it measure nothing but what we want it to measure? There are three important aspects of validity: content validity, criterion-related validity, and construct validity:

- Content validation. Content validity is the degree to which a test samples the behaviors of job performance. Job-task simulations are considered to have content validity.
- Construct validation. Construct validity, more a theoretical concern, is the extent to which a measure assesses an underlying construct, such as an ability or behavior.
- Criterion validation. Criterion validity is the extent to which a test predicts performance. Physical fitness tests which predict a job-task simulation test score are considered to have criterion-related validity.

Content validation involves linking job and test domains. It is a process which strives to show a relationship between the test and important duties or job behaviors. Jackson (1994) states that "There is no index of content validity that is agreed upon, and professional judgment is usually the basis for estimating content validity. . . . A content validity study needs to present data showing that the content of the selection procedure represents important aspects of performance on the job for which the candidates are to be evaluated. . . . The job analysis gives the essential job content data" (p. 67).

A job analysis is specifying in words what people do as they accomplish their work; its objective is to find measures of work behavior that are used in doing the job, and to determine the extent to which they represent critical work duties, behaviors, or outcomes (Jackson, 1994). Jackson also specifies the several methods available for conducting a job analysis: observing work, recording work activities, interviewing workers or supervisors, using questionnaires to collect data, or some combination of these.

Construct validation tests empirical and theoretical relationships. Jackson (1994) states that construct validity is more complete, and establishes linkages between the important constructs and multiple indicators of job performance; it will be sufficient for the purposes of this *Review & Analysis* to limit our discussion to content and criterion-related validity.

Criterion-related validity indicates how well a test predicts a specific future outcome; the specific future outcome that an optimal test would predict is the performance of the firefighter under actual working conditions. In general, statistical procedures enable us to calculate validity coefficients based on correlational and regression analysis. These statistics express the degree of relationship (i.e., the ability to predict firefighter performance) between a predictive test and the criterion; the more difficult question arises as we move beyond this relative standard and attempt to establish an absolute one. How high must our validity coefficient be so that we can say that our predictive test is useful? The practicalities of implementing these measures is a separate issue. Having said this, there are no consistently reported methods of evaluation of on-the-job performance of firefighters. Importantly, criterion-related validity is seen in some of the work to be presented as an assessment of the relationship between physical fitness tests and job-task simulation tests, rather than the more typical on-the-job performance criterion. This approach (using task samples as the criterion side of the equation rather than as predictors) was featured as a “dramatic twist” when it was used by the Job Performance Measurement/Enlistment Standards (JPM) Project (Committee on the Performance of Military Personnel, 1991).

Researchers have followed several paths to determine characteristics needed for successful firefighter performance. They have generally sought to establish both content and criterion-related validity. The paradigms used provide answers that are not quite parallel, yet their outcomes will still be useful in our search for a test instrument that incorporates what we hope will be some common and recurring themes. Some studies have made direct physiological measures during actual firefighting, while others decompose crucial firefighting tasks. A third group’s approach focuses on the relationship between simulated firefighting tasks and more basic physical fitness measurements as a way to characterize vital human characteristics. Collingwood, Hoffman and Sammann (1995) present this table illustrating how job-task simulations and physical fitness tests are often validated:

**Table 3. Validation of Job-Task Simulation vs Physical Fitness Tests (Collingwood et al., 1995)**

**Job-task simulation tests are validated through a four-step process that provides content validation proof of job job-relatedness:**

- Essential job tasks are defined, either through task analysis or by subject matter experts' (often supervisors) descriptions.
- The number of tasks is narrowed to those thought to be most critical, usually by the subject matter experts.
- Test scenarios are developed that simulate the most critical job tasks, again by the subject matter experts.
- A cutpoint score is defined in one of two ways:
  - The experts set a minimum criterion for performance based on opinion.
  - A sample of incumbents takes the test and the score is defined based on that sample's norms.

**Physical fitness tests are validated through a seven-step process that provides criterion proof of job-relatedness:**

- Essential job tasks are defined, either through task analysis or by subject matter experts' (often supervisors) descriptions.
- The number of tasks is narrowed to those thought to be most critical, usually by the subject matter experts.
- Test scenarios are developed that simulate the most critical job tasks, again by the subject matter experts.
- A fitness battery is developed of tests that measure the underlying fitness factors that should predict performance on the test scenarios.
- A sample of incumbents takes the fitness test battery and the test scenarios for critical job tasks.
- The task and fitness tests are analyzed to determine which fitness tests are underlying and predictive tests for job task test performance.
- A cutpoint score is defined in one of two ways:
  - If the relationship between the fitness test battery and the critical job tasks is strong enough, the experts set an absolute cutoff score. This score defines the level of fitness that best discriminates between who can and who can't perform the job tasks.
  - If the relationship between the fitness test battery and the critical job tasks is not strong enough, the experts choose a norm-referenced standard that may or may not reflect age or gender differences. [Note: Norm reference standards are derived from tests of large numbers of people who are representative of groups who will be tested in the future, whereas criterion-referenced scores are based on scientific evidence that has established a relationship to the test in question.]

To summarize this section on validity, an appropriate firefighter fitness test must be relevant to tasks performed on the job. Two types of validity are discussed in detail. Content validity, often associated with job-task simulations, requires that the test incorporate tasks representative of job performance tasks. Criterion-related validity implies some predictive relationship between test item performance and some specific future outcome, either on-the-job performance, or more likely in this context, simulation battery performance. This type of validity is often associated with physical fitness tests.

### **3.1.1 Critical Firefighter Tasks and Capacities**

In order to analyze the validity of the candidate fitness tests, we need to establish an understanding of the subject matter of firefighter tasks—specifically the requisite tasks and underlying capabilities necessary to perform the job. A fitness program needs to accurately reflect the job tasks of the personnel involved, in its training, wellness, and testing programs. A very important consideration today is that a test battery used in an employment arena must robustly represent the actual job tasks required of the worker. Several efforts have focused on identifying the tasks most important in

firefighting, or the most frequently performed tasks. By assessing the commonality of these lists, some of which were used to form simulation test batteries, we can establish critical job tasks and identify underlying physical capabilities that can form the basis for a predictive test or test battery.

### **3.1.1.1 Critical Firefighter Tasks**

Many studies over the past two decades have compiled documentation on tasks crucial to firefighting performance. These data were gathered by various means, via surveys of professional firefighters, by formal task analysis, and by empirical studies with firefighters. In some cases, the findings led to the construction of simulation test batteries or circuits that are being used today. In other cases, the lists were derived solely for experimental purposes.

Table 4 contains lists of crucial firefighting tasks and lists of simulated tasks used in some batteries, either applied or experimental. The purpose of this table is to illustrate the commonalties among tasks thought to be most important to firefighting, so that we can consider development of a training program and battery that tests for physical characteristics necessary to complete tasks like these.

Of all the work cited in the table below, three seminal programs, the Canadian Forces/Department of National Defence program (Deakin et al., 1997), the work of Dotson, Davis, and Santa Maria (1982), and the studies of Lusa (1994) need mention due to their extensive research. The Canadian Forces circuit is being implemented currently, while the batteries developed by Dotson serve as the basis of the firefighter Combat Challenge Test, performed worldwide by competing firefighter teams.

The Canadian Forces/Department of National Defence effort began with a review of the literature, and a task analysis, followed by meetings with subject-matter experts from the Canadian Forces Fire Academy and the Canadian Forces Fire Marshall to determine the most demanding and representative tasks specific to Canadian Forces fire fighters. The ten occupational tasks chosen were tested for reliability, physiological demands were quantified, and correlations between circuit performance and physiological measures were identified.

The firefighter Combat Challenge Test is a well-known competition for military and civilian firefighters worldwide. The work of Davis, Dotson, and Santa Maria (1982) began with a pool of potential criteria measures of fire fighting ability derived from task analysis surveys, screening tests, and tasks nominated by firefighter officers. Tasks were those frequently required and/or critical in a fire-suppression operation. The five tasks chosen were the most reliable and amenable to a logical sequential performance. The tasks were a ladder extension, standpipe hose carry, hose pull, simulated rescue, and simulated forcible entry.

An extensive study by Lusa (1994) assessed by questionnaire 234 professional firefighters across all of Finland. Firefighters were asked to rate firefighting and rescue tasks according to aerobic demand, muscular performance, and motor coordination, and to estimate the average frequency with which they performed these tasks over the last three years. Smoke diving (entry into a smoke-filled room) was documented as the more aerobically demanding of the tasks, while clearing debris with heavy tools was the most demanding on muscular performance. Motor coordination was most necessary in roof work.

**Table 4. Lists of Firefighter Tasks**

<p>Davis, P. O., Dotson, C. O. &amp; Santa Maria, D. L. (1982b). Combat Challenge Test</p> <ol style="list-style-type: none"> <li>1. Ladder extension</li> <li>2. Standpipe hose carry</li> <li>3. Hose pull</li> <li>4. Simulated rescue</li> <li>5. Simulated forcible entry</li> </ol>	<p>Lemon, P. W. R. &amp; Hermiston, R. T. (1977a)</p> <ol style="list-style-type: none"> <li>1. Aerial ladder climb</li> <li>2. Victim rescue</li> <li>3. Hose drag</li> <li>4. Ladder raise</li> </ol>	<p>Myhre, L.G., et al., 1997</p> <ol style="list-style-type: none"> <li>1. B-52 “crash” aircrew rescue</li> <li>2. Structural search and rescue activities in smokehouse or dormitory               <ul style="list-style-type: none"> <li>• enters, climbs stair to third floor, activates SCBA</li> <li>• crawls to victim, tows victim</li> </ul> </li> </ol>
<p>Deakin, J. M.; Pelot, R.; Smith, J. T.; Stevenson, J. M.; Wolfe, L. A. (1997). Canadian Forces/DND Job analysis list</p> <ol style="list-style-type: none"> <li>1. Perform specified tasks in hazardous environments wearing self-contained breathing apparatus (SCUBA)</li> <li>2. Use and maintain fire department ladders</li> <li>3. Perform forcible entry practices</li> <li>4. Participate in rescue operations during emergencies by operating specified equipment</li> <li>5. Perform fire apparatus practices</li> <li>6. Perform search operations</li> <li>7. Conduct rescues from buildings</li> <li>8. Perform rescues with specified equipment</li> <li>9. Perform ventilation, salvage, and overhaul operations</li> <li>10. Perform vehicle extrication</li> <li>11. Perform aircraft fighting and rescue operations.</li> <li>12. Fight structural fires</li> </ol>	<p>Deakin, J. M.; Pelot, R.; Smith, J. T.; Stevenson, J. M.; Wolfe, L. A. (1997). Canadian Forces/DND Post-field test list</p> <ol style="list-style-type: none"> <li>1. One-arm hose carry</li> <li>2. 3.5 m ladder raise</li> <li>3. 30.48m hose drag</li> <li>4. 10-rung ladder climb (3 times)</li> <li>5. High-volume hose pull</li> <li>6. “forcible entry,” moving a rubber tire by hitting it with a sledge hammer</li> <li>7. Victim drag</li> <li>8. 10-rung ladder climb—two times</li> <li>9. 3.5 m ladder lower</li> <li>10. Spreader tool carry which replaced a mannequin lift-and-carry task</li> </ol>	<p>Misner, J. E., Boileau, R. A., &amp; Plowman, S. A. (1989). Misner, J. E., Plowman, S. A., Boileau, R. A. (1987)</p> <ol style="list-style-type: none"> <li>1. Stair climbing</li> <li>2. Hose coupling</li> <li>3. Flexed arm hang</li> <li>4. Lift and carry</li> <li>5. Modified stair climb</li> <li>6. Ladder lift</li> <li>7. Forcible entry</li> <li>8. Dummy drag</li> <li>9. Obstacle run</li> </ol>
<p>Schonfeld, B. R., Doerr, D. F. &amp; Convertino, V. A. (1990)</p> <ol style="list-style-type: none"> <li>1. Stair climbing</li> <li>2. Chopping</li> <li>3. Victim rescue</li> </ol>	<p>Windle, D. (1975) Albuquerque Fire Department Selection Test</p> <ol style="list-style-type: none"> <li>1. Ladder extension</li> <li>2. Standpipe hose carry</li> <li>3. Hose pull</li> <li>4. Simulated rescue</li> <li>5. Simulated forcible entry</li> <li>6. Pull-ups</li> <li>7. Aerial ladder climb</li> <li>8. Hose pull</li> <li>9. Charged hose drag</li> <li>10. Hose carry</li> <li>11. Wall scale</li> <li>12. Ladder lower and ladder raise</li> </ol>	<p>Lusa, S.; Louhevaara, V.; Kinnunen, K. (1994)</p> <ol style="list-style-type: none"> <li>1. Smoke diving</li> <li>2. Clearing debris with heavy tools</li> <li>3. Roof work</li> <li>4. Internal response to a fire</li> <li>5. Terrain fire</li> <li>6. SCUBA diving</li> <li>7. Using hydraulic tools</li> <li>8. Transferring a patient</li> <li>9. Using portable ladders</li> <li>10. Setting up ladders</li> </ol>
<p>Gledhill, N. &amp; Jamnik, V. K. (1992a). Task analysis list</p> <ol style="list-style-type: none"> <li>1. Carrying equipment up stairs in a high rise</li> <li>2. Advancing charged hoses</li> <li>3. Breaking down doors, walls, ceilings, and roofs</li> <li>4. Raising ladders</li> <li>5. Working overhead with a pike pole</li> <li>6. Rescuing victims</li> <li>7. Raising and lowering equipment or victims</li> <li>8. Auto extrications</li> <li>9. Carrying equipment long distances</li> </ol>	<p>Gledhill, N. &amp; Jamnik, V. K. (1992b). Job-related performance test list</p> <ol style="list-style-type: none"> <li>1. Ladder climb</li> <li>2. Claustrophobia test</li> <li>3. Ladder lift</li> <li>4. Rope pull</li> <li>5. Hose drag</li> <li>6. Hose carry/climb</li> <li>7. Victim rescue</li> </ol>	

Agreement as to what constitutes the most vital firefighter tasks allows us to devise a test that predicts performance of these tasks. There is considerable agreement among efforts cited as to what constitutes the most important and/or most frequent firefighter tasks. Climbing, entry, rescue, working with ladders, and hose manipulations are common to most circuits. It is important however, to focus on the military/aircraft nature of firefighters being trained by the Air Force/Department of Defense program. Air Force/Department of Defense firefighters face different challenges than their municipal counterparts. They are responsible for fire suppression and protection of high-cost military inventory, including aircraft. For instance, the Plan of Instruction for the Fire Protection Apprentice course indicates that the trainee be able to gain entry, simulate shutdown, securing the egress system, and rescue a victim from a fighter type aircraft and a helicopter, wearing full personal protective equipment. Only the work of Myhre (1997) and the work of Deakin et al. (1997) in the above table include aircraft-related tasks in their critical tasks lists. The Air Force/Department of Defense may also need to consider other military branch-specific firefighting tasks, such as the Navy and shipboard fires.

### **3.1.1.2 Physical Characteristics that Underlie Successful Firefighter Performance**

The section above documents crucial tasks that firefighters must be able to perform. Agreement on crucial tasks is the first step in establishing a fitness battery for firefighters. Our next task is to define the physical capacities that underlie the performance of these tasks. The following discussion of necessary physical characteristics is based on the demands placed on firefighters, including cardiovascular, strength, heat, noise, smoke, and several other stressors.

Fire fighting has been frequently characterized as one of the most demanding occupations, for both civilian and military firefighters (Bahrke, 1982; Brownlie et al 1985; Ben-Ezra & Verstraete, 1988; Davis, Dotson, & Santa Maria, 1982a; Schonfeld, Doerr, & Convertino, 1990; Faria & Faria, 1991; Gledhill & Jamnik, 1992a; Green & Crouse, 1991; Guidotti, 1992; Hilyer, Brown, Sirls, & Peoples, 1990; Lusa, 1994; Orris, Melius, & Duffy, 1995; Myhre, Tucker, Bauer, & Fischer, 1997). Stresses include physical, mental, and psychological workload, thermal demands, smoke and toxins exposure, and an irregular work schedule.

Firefighters must be able to perform a wide variety of physically demanding tasks, such as transporting equipment to a fire site or staging area, maneuvering hoses, raising and climbing ladders, venting roofs, forcibly entering a building, and dragging or carrying victims. To safely and efficiently fight fires, a combination of physical capabilities is necessary, including aerobic capacity, anaerobic power, muscular strength and endurance, and motor-related abilities such as total body speed, eye-hand coordination (Considine, Misner, Boileau, Pounian, Cole, Abbatiello, 1976), agility, dexterity, balance, and flexibility (Gledhill & Jamnik, 1992a). The physical demands of firefighter work is detailed here.

Researchers have found many ways to quantify the physical and physiological demands of fire fighting so that accurate fitness standards can be established. For example, recordings of heart rate during actual firefighting can set a standard for a laboratory-administered submaximal aerobic test.  $\text{VO}_2$  max can be measured in the laboratory or predicted via other variables during exercise, such as with the treadmill or cycle ergometry. Identifying relevant physical performance measures helps us achieve understanding of the human variables underlying successful firefighter performance.

#### **3.1.1.2.1 Oxygen Consumption**

Maximal oxygen utilization is the most important way to characterize work demands during firefighting (Gledhill & Jamnik, 1992a). Lemon and Hermiston (1977a) estimated that firefighting requires oxygen consumption of 60-80% of maximum. At a given level of absolute  $\text{VO}_2$  (l/min),

energetic strain, or relative  $\text{VO}_2$  (expressed as ml/kg min), varies, depending on body weight and cardiorespiratory work capacity (Ilmarienen, 1984). Davis and Dotson (1987) report a minimum  $\text{VO}_{2\text{max}}$  of 3.0 l/min and an optimum  $\text{VO}_{2\text{max}}$  of 3.5 l/min or above, in order to provide survival insurance during firefighting. Louhevaara et al (1985) reported  $\text{VO}_2$  (l/min) levels of 2.1-2.8, while similar work conditions employed by Sothmann et al. (1990) reported average  $\text{VO}_2$  (l/min) of 2.5. In an actual emergency, Sothmann, Saupe et al. (1992) found a predicted  $\text{VO}_2$  (l/min) of 2.28. Other reported levels are a  $\text{VO}_{2\text{max}}$  of 39.6 ml/kg min (Davis, Dotson, & Santa Maria, 1982) and 48.5 ml/kg min (O’Connell, Thomas, Cady, & Karwasky, 1986). Gledhill and Jamnik (1992b) report that the most demanding firefighter tasks required a mean  $\text{VO}_2$  of 41.5 ml/kg/min, and that 90% of firefighting tasks required a mean  $\text{VO}_2$  of 23 ml/kg/min. In addition to the demands of the fire and the environment, body fat over 120% of normal places a considerable load on the cardiorespiratory and musculoskeletal systems during firefighting simulations (Davis & Dotson, 1978; Davis et al., 1982B; and Schonfeld et al., 1990). Some studies and their associated recommended levels of  $\text{VO}_2$  are (adapted from Lusa, 1994):

**Table 5. Recommended Minimum  $\text{VO}_{2\text{max}}$  Standards from Various Sources**

Reference	l/min	ml/min/kg
Zylberstein*	2.8-3.0	-
Louhevaara et al. 1985	3.0	-
Sothmann et al. 1990	-	33.5
Sothmann, Saupe et al. 1992	-	33.5-42.0
O’Connell et al. 1986	2.7	39.0
Lemon & Hermiston 1977b	-	40.0
Davis et al., 1982		42.0
Gledhill & Jamnik 1992a	-	45.0
Horowitz & Montgomery 1993	-	-
Sykes 1991	-	-
Interim Air Force/DoD Males <29-->50		41.9—27.6
Females <29-->50		35.9—23.0
Canadian Forces/DND (corresponds to 8-min circuit completion time)		39.0

\*(as cited in Lusa, 1994)

Besides the actual work tasks, the heat, protective clothing and SCBA (self-contained breathing apparatus) gear needed in firefighting adds to the physical stress borne by firefighters. Gear and clothing increase weight and the temperature burden in the firefighter, which increases physical work stress. Lusa (1994) estimates that SCBA and fire-protective clothing weigh about 25 kg. Lusa, Louhevaara, and Kinnunen (1994) found oxygen consumption of 2.1 to 2.8 l/min during smoke diving in SCBA. O’Connell, Thomas, Cady, & Karwasky, (1986) studied firefighters who walked on a stair-treadmill. In fire-protective equipment, firefighters averaged 3.15 l/min and neared maximal working levels, while without the gear, l/min averaged 1.78. Skoldstrom (1987) reported that with 60 minutes of submaximal work (20-30% of  $\text{VO}_2$  max) conducted between 15 degrees C and 45 degrees C, using fire-protective equipment increased  $\text{VO}_2$  by 0.4 l/min. A similar increase was noted by Duncan (1979) at corresponding work levels.

#### **3.1.1.2.2 Heart Rate**

Actual firefighting tasks generate heart rate responses between 150-190 beats/min for extended periods of time (Barnard & Duncan, 1975). Barnard and Duncan also found that high heart rate is associated with the first three to five minutes of the fire (175-195 beats/min). Romet and Frim (1987) found a 10-15 beat/min increase in heart rate at the beginning of a simulated scenario. Victim rescue and evacuation leads to the greatest increase in heart rate (Lusa, 1994). A five-min stair climbing simulation resulted in mean heart rate of 95% of HRmax with fire protective equipment (O'Connell et al., 1986). Wearing protective gear elevates average HR by about 25 beats/min (Skoldstrom, 1987, Smolander, Louhevaara, Korhonen, & Jaakkola, 1984). Davis and Santa Maria (1975) found that the energy cost of moderate work while wearing firefighter clothing and protective equipment was 33% greater than the same work without that clothing and equipment.

#### **3.1.1.2.3 Strength and Endurance**

Gledhill and Jamnik (1992b) report that strength and endurance tasks require firefighters to carry objects up to 80 lbs, pull objects up to 135 pounds, and work with objects in front of the body up to 125 pounds. Doolittle (1979) recommends that firefighters be able to do a military press of 95 pounds as a minimum (desirable is 120 pounds) and a biceps curl of 100 pounds (desired is 120 pounds). Tonnes, Behm & Kilbom (as cited in Lusa 1994) indicate that firefighters carrying two hose rolls suffer most from tiredness of the finger flexor muscles. EMG showed that tiredness increased by 60% from the initial level at the start of the task. Carrying a victim without a stretcher produces torque that is greatest at the L5/S1 vertebral disk. Deakin et al. (1997) report that firefighters must "lift, carry, push, pull, hoist, and drag equipment" weighing up to about 50 kg and victims who weigh over 100 kg (p. 10). A comprehensive work by Lusa specifies the biomechanics of a simulated clearing task, and found that estimated static compressive forces varied from 1979N to 3835 N, a range which includes values (greater than 3400) at risk for back injury according to NIOSH guidelines. Related to strength and endurance is the issue of body fat; Misner et al. (1987) reports that obesity hampers performance when the body is moved horizontally or vertically, and that a large amount of active muscle mass improves performance when tasks require absolute force, such as lifting, carrying heavy loads, and striking with heavy tools. The Air Force is currently updating the strength standards for enlisted personnel entering the Fire Protection career field by observing how and how often tasks are undertaken, and by weighing pieces of firefighting equipment and measuring the forces it takes to move them.

#### **3.1.1.2.4 Temperature Extremes**

Firefighters are exposed to frigid outdoor temperatures and extremely high temperatures (232 degrees C, Gilman & Davis, 1993) inside a burning structure. Romet and Frim (1987) reported a 1.3 degree rise in core temperature during just 20 minutes of firefighting. Matticks, Westvater, Himel, Morgan, & Edlich (1992) explicate on the wide range of thermal conditions, which includes such variables as protective clothing, season and climate, geographic location, and heat intensity of the fire. Protective clothing worn by firefighters does offer protection from heat, but it also retards dissipation of body heat and evaporation of perspiration, and therefore increases general physiological stress (Skoldstrom, 1987). Davis and Dotson (1987) report that excessive sweating can lead to plasma volume loss, fatigue, heat exhaustion and heat stroke. In addition, the protective gear exacts other costs, increasing energy costs of work.

#### **3.1.1.2.5 Smoke and Pollutants**

Firefighters are often exposed to ambient smoke, which is a variable mixture of compounds whose toxicity depends on the heat of the fire, the type of fuel involved, and the amount of available oxygen (Guidotti & Clough, 1992). Smoke can include products of combustion of plastics, explosives, toxic gases, solvents, and dust (Hariene & Honkonen, 1980). Guidotti and Clough (1992) and Treitman et

al. (1980) report that firefighters are also exposed to carbon monoxide, hydrogen cyanide, nitrogen dioxide, sulfur dioxide, hydrogen chloride, aldehydes, and organic compounds such as benzene. While the self-contained breathing apparatus (SCBA) protects firefighters during its use, Davis and Dotson (1987) report that when the mask is removed, as perhaps during the cleanup portion of interior fires (Radford & Levine, 1976), firefighters are exposed to toxic levels of pollutants. Thomas (1993) reports carbon monoxide levels as high as 3000 ppm during firefighting, which could cause temporary or permanent paralysis, blindness, and muscular effects.

#### **3.1.1.2.6 Other Stressors**

Kalimo, Lehtonen, Daleva, & Kuorinka (1980) reported that 42% of firefighters felt quite tired at the end of a work shift. This subjective strain was attributed to the pace of the work, physically heavy work, continuous alertness, intermittent sleep, and poor work posture.

Deakin, Pelot, Smith, Stevenson, & Wolfe, (1997) and Kalimo et al (1980) note that firefighters must be able to work at physical capacity on demanding tasks at irregular intervals separated by periods of less-demanding work or rest. Night work and shift work potentiates the effects of other environmental stressors, such as noise, lighting, and ambient temperatures (Akerstedt, 1988, 1990).

Stresses faced by firefighters include the stress inherent in the work situation as well as that implied by their role as a help provider (Fullerton, McCarroll, Ursano, & Wright, 1992), which requires that they be responsible for the safety of others. Rescuing helpless victims and being exposed to painful and emotional events take their psychological toll.

Firefighters are often exposed to high levels of noise (Matticks et al., 1992; Tubbs, 1985), often due to loud equipment that firefighters operate (Davis & Dotson, 1987), at levels that exceed US Occupational Safety and Health Administration standards (Reischl, Bair, & Reischl, 1979). Firefighters rarely wear hearing protection devices because they must be able to hear victims and communicate verbally with each other, and the resulting noise level can lead to hearing loss and cardiovascular effects (Reischl et al., 1979).

Summarizing the research in this area, we see great commonality among lists of critical firefighter tasks. Almost all studies and applied batteries include climbing, entry, hose manipulation, ladder use, and rescue in their lists. Several studies emphasize the importance of aerobic capacity in firefighting work. Of all the variables seen as important to the firefighting occupation, measures of  $VO_2$  are the most commonly studied. Any battery that assesses firefighter fitness should incorporate a measure of aerobic fitness. Studies have indicated that absolute values of between 2.1 and 3.0 l/min are necessary, and up to 45 ml/kg/min for relative  $VO_{2max}$ . Cardiorespiratory capacity, body fat, and muscle strength and endurance are all documented as important characteristics underlying the completion of crucial firefighting tasks.

The seriousness of stressors (psychological, fatigue, noise, shiftwork) has two implications for the Air Force/Department of Defense program—that healthier and more fit personnel will be better able to withstand the effects of these stressors, and that a firefighter-focused lifestyle/wellness program could help personnel deal better with some of the psychological factors.

### **3.2 TEST TYPE**

In addition to concerns over job relevancy, the Air Force must evaluate the candidate program tests on the basis of test type. Knowledge about the advantages and disadvantages of each of the two major types of test will be a valuable analysis tool for the Air Force. The two test types in question are the physical fitness test or a job sample test. A physical fitness test measures underlying fitness areas

such as cardiovascular endurance, anaerobic power, muscular strength, muscular endurance, flexibility, and body composition (Collingwood, Hoffman, & Sammann, 1995). Performance on these tests is often correlated with performance on a job sample test, indicating the degree of criterion-related validity. A job-task simulation test measures performance on activities that personnel are likely to perform in their work. Tests of these types are considered to have high content validity.

Jackson (1994) describes the history of pre-employment testing, citing the movement away from physical fitness testing toward more job-task simulation testing, due to the appeal of the latter's content validity to the courts. Jackson states, "...the use of motor ability and physical fitness tests is likely to increase the chance that a preemployment test will be challenged in the courts. A work-sample test represents observable job behaviors; it is more difficult to show that the capacity to do pull-ups or sit-ups, for example, is job related" (p. 68). Ayoub (1982) cites two disadvantages to job-task simulations. The first is that highly-motivated test-takers (applicants in his context) who are not physically fit may have an increased risk of injury. A second limitation is that tests of this type do not generate any quantitative information about the test taker's maximum work capacity. A work-sample test that is marked pass or fail will be completed easily by some and just barely by others. The lack of specific fitness information could give an erroneous estimate of fitness status, not providing enough information to rank-order workers or identify those who might be at greatest risk for on-the-job injury.

Lusa (1994) indicates that field tests can be done quickly and without complicated equipment, while a laboratory assessment might require a trained staff and computerized equipment. On the other hand, Lusa indicates that simulation batteries are often performed competitively or as timed tests, which would require the completion of tasks in a manner dissimilar to the way they are performed on the job. Lusa also cautions that skill and fitness may be confounded in a job-task simulation.

One view of the advantages and disadvantages of the two test types, that of Collingwood et al. (1995), is shown in Table 6.

**Table 6. Job-Task Simulation vs Physical Fitness Testing (Collingwood et al., 1995)**

	Advantages	Disadvantages
Job-task simulation	<ul style="list-style-type: none"> <li>▪ Is easily understood and explained</li> <li>▪ Perception of reduced probability of litigation due to the ADA and Civil Rights Act of 1991.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Does not discriminate well between who can and who can't do the job</li> <li>▪ Does not help reduce health risks</li> <li>▪ Does not measure or encourage fitness development</li> <li>▪ Has less predictability because of low standards and dependence on prior learning</li> <li>▪ May show adverse impact</li> <li>▪ Is less generalizable across agencies</li> <li>▪ Typically accounts for only 20% to 25% of performance on all physical tasks</li> </ul>
Physical fitness	<ul style="list-style-type: none"> <li>▪ Discriminates well between who can and can't do the job</li> <li>▪ Has good predictability, especially for trainability</li> <li>▪ Helps reduce health risks</li> <li>▪ Measures and encourages fitness development</li> <li>▪ Is not as dependent on prior learning</li> <li>▪ Reduces probability of adverse impact</li> <li>▪ Reduces probability of negligence litigation</li> <li>▪ Is more generalizable across different agencies</li> <li>▪ Typically accounts for 50% to 80% of performance on all physical tasks</li> </ul>	<ul style="list-style-type: none"> <li>▪ Requires more effort to document job-relatedness.</li> <li>▪ Perception of increased probability of litigation due to the ADA and Civil Rights Act of 1991</li> </ul>

Collingwood et al. document that experts do not agree on which test type is more appropriate. Collingwood et al. state, “Some suggest that fitness tests are best for selection purposes (as a measure of trainability) but that job-task simulation tests are best for academy completion and incumbent standards. Still others suggest the opposite. . . . This situation has led some agencies to design applicant, recruit and incumbent standards in. . . different ways” (pp. 45-46). Collingwood et al. conclude that in the case of law enforcement, physical fitness tests are to be recommended as fairer than job-task simulation and better at predicting officers’ physical capacities. They feel that fitness tests are defensible as job-related.

Another of the factors which will determine the outcome of the debate is the extent to which physical fitness tests show criterion-related validity when a simulated battery or job-sample test is the criterion. Several studies have assessed relationships between physical fitness (and physiological) measures and job-task simulation measures, showing considerable criterion-related validity. Summaries of these studies are described here.

A study performed by Williford, Duey, Olson, and Blessing (1996) for the Montgomery (AL) Fire Department evaluated the relationship between performance times on the firefighter Combat Challenge Test, a popular worldwide competition based on the work of Davis, Dotson, and Santa Maria (1982) and physical fitness test outcomes. The Combat Challenge Test consisted of the stair climb, hoist (hose pull), hammer (forcible entry), hose advance, and victim rescue; physical

measurements and fitness tests were height, weight, percent fat, resting heart rate, resting blood pressure, number of sit-ups, number of push-ups, number of pull-ups (each in 1min), total grip strength, time to run 1.5 miles, and the sit-and-reach test. Multiple regression analysis revealed that the best set of Combat Challenge Test performance time predictors was composed of fat free weight, run time, and pull-ups.

*An Occupational Performance Test Validation Program for Fire Fighters* at the Kennedy Space Center (Schonfeld et al., 1990) employed three tasks derived from the from the Combat Challenge Test, the seven-flight stair climb, the chopping simulation using a 3.6kg sledge hammer, and the 81kg victim drag, all performed without stopping, in standard fire fighter turnout gear including self-contained breathing apparatus (SCBA). Time to complete the tasks and heart rate data were gathered. Physical performance measures included assessments of aerobic capacity, power output, strength and endurance, and flexibility. Correlation analysis revealed that four variables significantly predicted task performance time. Treadmill time,  $VO_2$ max, peak torque knee flexion, and percent body fat were significantly related to total task performance. The authors conclude that laboratory testing in lieu of the task battery provides reasonable degrees of accuracy and economy.

As mentioned earlier, Air Force research (Myhre et al., 1997) has also sought to determine the relationships between simulated firefighting task performance and physical performance measures. The firefighting simulation required the firefighter to enter a dormitory, proceed to the third floor, and crawl to and carry a 170 lb victim. Performance time was the performance criterion. Several physiological and fitness variables correlated significantly with test time; regression analysis produced percent body fat, strength, and  $VO_2$ max as the best predictors.

Davis, Dotson, and Santa Maria (1982) composed a job-related test battery that formed the basis for the Fire Fighter Fitness Challenge, a population firefighter competition. These researchers also measured the relationships between simulated fire fighting tasks and physical performance measures. Ladder extension, standpipe carry, hose pull, simulated rescue, and simulated forcible entry were used as criteria measures for which time and heart rate data were determined. Twenty-six performance measures (anthropometric, neuromuscular, and physiological measures at rest and during work) were subjected to canonical correlation with time and fractionated heart rate measures from the sequentially performed firefighting tasks. Two factors accounted for time and heart rate data: physical work capacity and resistance to fatigue. Physical work capacity was predicted best by maximal heart rate, sit-ups, grip strength, age, and submaximal oxygen pulse. Resistance to fatigue was best predicted by lean body weight, maximal heart rate, final treadmill grade, age, and percent fat.

Part of the extensive research project performed by the Ergonomics Research Group of Queen's University for the Canadian Forces and DND firefighters focused on physical fitness correlates of performance time on a circuit that simulated several important firefighter tasks. They found that heart rates induced by the circuit were similar to those experienced during actual fire fighting. Other measures taken during circuit test which showed values similar to those during actual firefighting were ratings of perceived exertion and peak blood lactates.

Lusa (1994) reports similar findings between test drill physiological measures and actual firefighting physiological measures, for  $VO_2$ max and %HR max. Lusa also reports that the firefighters surveyed considered the drill a better method for assessing physical work than cycle ergometry, and felt that the drill motivated them to train. Lusa does point out, though, the specificity of each drill as a drawback and also the confounding of skill with fitness when timed performance is the measure.

While most of the studies summarized here found sufficient correlations, Misner et al. (1989) found generally low correlations between traditional physical performance tests and job-related tests. The job-related firefighting tasks were stair climb, flexed arm hang, hose coupling, obstacle course, body lift and carry, forced entry, and dummy drag. Traditional performance measures were grip strength, standing broad jump, vertical jump, agility run, 46-meter dash, flexed arm hang, and 804-meter run. Of the physical performance measures, the standing jump test had the highest correlation, indicating that leg power was important in successful job-related test performance. The authors concluded that job-related tests were more complex and demanding of skills than traditional fitness tests.

Laboratory tests are simpler and less resource-intensive to administer. Schonfeld et al. (1990) argue convincingly for laboratory tests to assess firefighter fitness at the Kennedy Space Center:

The use of laboratory fitness testing in lieu of the CTT [Combat Task Test] has several advantages. First, because performance of simulated fire-fighting tasks specific to the support of the space program activities at the Center can be predicted with reasonable accuracy using our regression models, the administration of these fitness tests should provide results comparable with those of actual CTT performance. This advantage can diminish the extensive need for and the costs associated with field testing, although field practice and simulations remain important. Second, simple physical ability tests can be utilized as screening tools for identification of fitness levels required to meet occupational performance standards as well as selection of potential firefighter candidates. Third, a fitness prescription can be developed to enhance or maintain a firefighter's physical abilities to meet the CTT standard. Finally, the fitness program and the firefighter's adherence to it can be monitored through periodic administration of simple physical ability tests.  
(p. 643)

There is no agreement about the superiority of one test type over the other. Making a decision about test type will depend on the importance for the Air Force of the various factors that are affected differentially by test type, including safety risk, cost of administration, legal defensibility, discriminability, and the degree to which physical fitness tests might correlate with job-task simulation performance.

### **3.3 OTHER PRACTICALITIES IN TEST DEVELOPMENT AND ADMINISTRATION**

#### **3.3.1 Standards**

Until it is determined what test battery will be adopted by the Department of Defense Fire Fighter Physical Fitness Program, any considerations of standards will be general in nature. General techniques found in the literature include the one used by Gledhill and Jamnik (1992), who state, "Because loss of life and damage to property are at stake, the speed of a firefighter's response is critical. It follows, therefore, that the job related performance tests should be accomplished within a reasonable period of time. Hence the performance times of candidates are judged against a mean time, an acceptable time (one standard deviation above the mean time), and a maximum time (two standard deviations above the mean time)" (p. 202). It could be noted here that this standard would equate to a failure rate of about 5%.

The Canadian Forces/Department of National Defence program recommends a time of 8 minutes for completion of its job-task simulation circuit; this performance objective falls within one standard deviation of the 7.46 min performance time for all the firefighters who were tested (N=226; both Canadian Forces and Department of National Defence firefighters were included). In the view of its

developers, this performance standard “will provide a moderate challenge for the young, aerobically fit firefighters, while representing an attainable objective for older, or less aerobically fit individuals” (p.95).

Regarding specific cut-off scores for firefighter fitness, the literature presents a significant degree of subjectivity and variability regarding acceptable levels for various measures; some of those will be presented here. Also of interest are the values expressed in the section on underlying physical characteristics, especially Table 5 which summarizes recommended VO<sub>2</sub> max standards from different studies.

The Finnish Institute of Occupational Health recommends these standards for firefighters:

**Table 7. Finnish Institute of Occupational Health Standards**

Physiological Test	Poor	Moderate	Good	Excellent
VO <sub>2</sub> max l/min	<2.4	2.5--2.9	3.0--3.9	>4.0
VO <sub>2</sub> max ml/min/kg	<29	30--35	36--39	>50
Bench Press (45 kg – reps/60 sec)	<9	10--17	18--29	>30
Sit-ups – reps/60 sec	<20	21--28	29--40	>41
Pullup (max reps)	<2	3--4	5--9	>10
Squatting (45 kg – reps/60 sec)	<9	10--17	18--26	>27

### 3.3.1.1 Age

How does age affect firefighting job performance? Saupe, Sothmann, and Jasenhof (1991) found that firefighters between the ages of 20 and 65 had levels of cardiorespiratory health and physical fitness similar to a sedentary population of the same age. The authors found particularly worrisome, “the low maximal aerobic capacity (31, 28, 26 ml/kg/min, high percent body fat (26, 29, 30), and high resting blood pressure (136/86, 140/90, 143/93mm Hg) observed in the 40-45, 50-55, and 60-65-year-old firefighters in these three age groups respectively. In fact, 66%, 83%, and 93% of the firefighters in these three age groups, respectively fell below the lowest published recommendations for maximal aerobic capacity in this profession” (p. 1192).

Buskirk and Hodgdon (1987) published an analysis of cross-sectional studies of VO<sub>2</sub> max and found that the rate of decline for men varies from 0.20 to 0.52 ml/min/kg per year. Longitudinal studies report a decline of 0.23 to 1.04 ml/min/kg per year. Sothmann et al. (1990) reported mean VO<sub>2</sub> max of 47.4 ml/min/kg and 27.4 ml/min/kg for youngest (20-25 years) and oldest (60-65 years) firefighters, respectively.

These age-related declines are not absolute. Individual differences and continued physical training must be considered as important variables in this discussion, as both influence the degree of fitness with aging. Sothmann et al. (1990) indicates that it is lifestyle and not aging itself that is responsible for this decline. While the reduction in VO<sub>2</sub> max is attributable to an age-related reduction in maximal heart rate, stroke volume and oxygen extraction (Sothmann, Landy, & Saupe, 1992), an additional factor that may contribute is the loss of muscle mass that can occur if muscles are not exercised as regularly as one ages. One of the factors that determines oxygen utilization is the amount of active muscle mass (Lusa, 1994). Lakatta and Gerstenblith (1992) and Buskirk and Hodgdon, (1987) indicate that cardiac output can be maintained at high levels in the aged, with adequate motivation.

Shephard (1987) reports that muscle strength is more likely to be preserved than aerobic power with age. Although many studies document that deterioration in muscle strength begins at about age 45, with a 1.5% reduction per year (Vanderboort & McComas, 1986), physical training can maintain and even increase muscle strength up to age 70 (Aniansson & Gustafsson, 1981; Frontera, Meredith, O'Reilly, Knuttgen, & Evans, 1988).

Schonfeld (1990) found age not to be a significant predictor for performance of three simulated firefighting tasks, with men from 27 to 60 years. Lusa (1994) quantified the biomechanical stressors associated with simulated clearing of passages using a power saw, and concluded that this task put a high load on the musculoskeletal system, and that load was not influenced by age.

It appears that while aging can affect our physical capacities, with training, physical capacities can be maintained at a level sufficient for firefighting tasks.

### **3.3.1.2 Gender**

There are about 4500 full time women firefighters in the United States, and between 200-300 in the rest of the world. Women comprise 5% of the membership of the International Association of Firefighters. There are between 40,000-60,000 women volunteer firefighters in the United States.

The North Atlantic Treaty Organization's publication, *Optimizing the Performance of Women in the Armed Forces of NATO*, provides a comprehensive discussion of gender-related physiological differences. Females have lower absolute lean body mass and a higher percent of body fat, which may account for lower performance levels on simulated firefighting tasks (Misner et al., 1987). Wilmore (1975), Wilmore and Brown (1974), Heyward, Johannes-Ellis, & Romer, 1986, and Clarke (1986) have shown that females have less absolute strength and cardiovascular endurance than men. Despite these differences, Misner et al. (1987) trained a group of women who were able to score at or above the men's average physical performance test values.

The NATO group recommends optimization of training to maximize the strength of women, and the implementation of true role-related physical selection tests.

The Canadian Forces/Department of National Defence program recommends a time of 8 minutes for completion of the circuit; this performance objective falls within one standard deviation of the 7:46 min mean of all subjects gathered during the main collection phase of this test development effort. The small number of women firefighters who were subjects in this phase were considered to be relatively unfit and completed this circuit in an average of 9:57 mins. A sub-study used more fit women who were not firefighters. These women averaged a circuit completion time of 6:56 mins with practice. It was considered that with practice, women with a good level of physical fitness would be able to meet the Canadian Forces/Department of National Defence standard.

While physical capacities of all women do not equal the physical capacities of all men, individual differences must be taken into account. The adoption of a truly valid test battery will contain standards that are sufficient to predict firefighting performance, regardless of gender.

### **3.3.2 Software/Hardware**

Any change in the Interim Air Force/Department of Defense program is not expected to make a big impact on current computer systems. It is not anticipated that a change in the way fitness data are collected will adversely affect the currently-used systems, including the existing cycle ergometry program and its associated equipment and database, and two other relevant databases which must

receive data in some compatible fashion. The software and operating systems of the USAF Medical (PHA) and Civil Engineering (ACES) information management and reporting systems will need to be taken into account. However, no matter what software is used, if any, to collect or analyze fitness data, data can be formatted appropriately for entry into the necessary databases.

### **3.4 CHAPTER CONCLUSION**

This section sought to provide tools that can be used to analyze the candidate firefighter programs. Knowledge about validity, and its appropriate application was established. Summarizing the research in this area, we see great commonality among lists of critical firefighter tasks. The underlying physical capabilities needed for successful firefighter performance are aerobic capacity, muscular strength and endurance, and body composition.

Firefighter fitness tests are primarily of two types—physical fitness or job-task simulations. Drawbacks and advantages to each were presented; this knowledge can serve as our second analysis tool in candidate program evaluation.

## 4. ANALYSIS AND CONCLUSIONS

Do the other major candidate programs discussed have advantages that the current Department of Defense program does not? Are there other candidate possibilities besides the four major ones? Does our discussion of the physical capacities of firefighters and the science behind firefighter fitness batteries offer alternatives to the Interim Air Force/Department of Defense program? presents a definitional breakdown of the candidate programs, while Table 2 provides the analysis that is the focus of this chapter.

This section attempts to apply the tools presented in Chapter 3 to the major candidate programs, so that the Air Force/Department of Defense can analyze the major candidate programs. This analysis allows us to synthesize the information presented so far, with the goal of stating factors for and against the major candidate programs' test, training, and wellness components and addressing other testing practicalities as well, such as the eventual task of establishing standards and hardware/software compatibility issues.

### 4.1 ANALYSIS AND SUMMARY

This section analyzes the test components of each of the major candidate programs, according to their job-relevance and test type, and summarizes their training and wellness components.

#### 4.1.1 Test Battery Analysis

An overall comparison among the four candidate programs reveals that there is one specific physical fitness test (Interim Air Force/Department of Defense), two generic physical fitness tests (IAFF/FC and NFPA 1583), and a job-task simulation test (Canadian Forces/Department of Defence). The Interim Air Force/Department of Defense has an aerobic capacity fitness standard and the Canadian Forces/Department of National Defence has a completion-time requirement for its simulation battery. Applying the analysis tools (knowledge about validity and test type differences) allows us to evaluate these test programs. All programs except the NFPA 1583 feature either content and/or criterion-related validity. To assess the appropriateness of that process, we can ask if the tasks used in the task analysis are like those seen most often in the literature. All programs that used a task analysis (all except the NFPA program) did indeed include these tasks in their task analysis. In addition, the Air Force/Department of Defense and the Canadian Forces/Department of National Defence included aircrew/aircraft tasks in their analysis. All the tests compared did evaluate the underlying physical characteristics that are thought to underlie successful performance of firefighting tasks. From this point of view, all programs except the NFPA have demonstrated appropriately-derived attempts to establish validity, albeit with varying degrees of success.

While all programs address the major physical fitness factors that underlie successful performance of firefighting tasks, they are not equal in other aspects. The lack of standardization and specificity behind NFPA 1583 does not recommend it to the Air Force's attention at this time. Similarly, the general nature of the IAFF/FC program, and the lack of consistent application or enforcement, does not make it an appropriate test model for the Air Force/Department of Defense.

The most obvious difference among the remaining candidates, the Interim Air Force/Department of Defense and Canadian programs, is the simulation based vs physical fitness based nature of their tests. As discussed earlier, job-task simulation tests have content validity but this validity is often considered to be task-specific, with the implication that it is not appropriate to assume that one organization's tasks, personnel, or environment will map well enough onto another organization to allow that second organization to employ the first's test battery. Lusa (1994) argues this point,

reporting that simulations have high reliability but are task-specific. (He also notes that they are usually performed as fast as possible, which is not consistent with actual firefighting operations.) However, this specificity may not be a problem in this particular instance, if the Air Force/Department of Defense were to consider the Canadian Forces/Department of National Defence program, because the Canadian program *did* include aircrew/aircraft issues in their task analysis. It is possible that further assessment of this transferability issue will reveal that the Canadian program would be an appropriate one for the Air Force/Department of Defense in the aspect of relevance or content validity.

To address in general the use of a simulation battery vs a laboratory fitness battery, we can recall the earlier discussion of Collingwood et al. (1995) who lists the advantages and disadvantages of both test types. There are strong arguments on both sides, and it will be important for the Air Force/Department of Defense to indicate the order of importance of these variables (for example, safety of administration, degree of discriminability among personnel, fairness challenges) to their organization. Especially of interest here is the appeal to the courts of the content validity of job-task simulation tests

Also affecting this question is the extent to which physical fitness tests show criterion-related validity when a simulated battery or job-sample test is the criterion. Several studies have assessed relationships between physical fitness (and physiological) measures and job-task simulation measures, showing considerable criterion-related validity. Summaries of these studies indicate for the most part that physical fitness tests have sufficient criterion-related validity.

#### **4.1.1.1 Testing Battery Analysis Summary**

The Interim Air Force/Department of Defense and the Canadian Forces/Department of National Defence programs are supported by original research. The other physical fitness based programs did not sponsor research of their own (the IAFF/FC Initiative cites eight studies in their chapter on fitness and apparently relied heavily on the work of Gledhill and Jamnik, studies which may also have been used in the development of the NFPA program.) Although the predictive validity regarding simulated test battery performance is not perfect, the Interim Air Force/Department of Defense test does incorporate those variables commonly associated with simulated test battery performance. Unfortunately, only their aerobic test has an associated standard, and as can be seen in Table 5, it is relatively low. In contrast, the Canadian Forces/Department of National Defence program may have more content validity, but may be more costly and less safe to administer, and the validity may need to be assessed for relevance to other organizations. Job-screening batteries developed by Gledhill and Jamnik (1992a, b) and Brownlie et al. (1985) provide suggestions for test development methodology.

#### **4.1.2 Fitness Training Summary**

There is no great difference among the programs in terms of their training recommendations, except that the military programs are more specifically described than the civilian programs. The Interim Air Force/Department of Defense's training program seems superior in its specificity of prescription and its milestones and feedback. Maintaining this segment of the Air Force/Department of Defense program would be economically attractive because it does not require an on-site military exercise specialist.

#### **4.1.3 Lifestyle/Wellness Summary**

In general, these programs seem to consist of offerings of counseling and educational services to firefighter populations. There is no off-the-shelf program that could be put in place by the Air

Force/Department of Defense program. The best that can be extracted from these components is a framework and an expression of commitment to firefighter well-being. The IAFF/FC Initiative provides a healthful emphasis that the Air Force might want to incorporate into a wellness/lifestyle program tailored to firefighters.

## 4.2 CHAPTER CONCLUSION

This *Review & Analysis* suggests that the Air Force/Department of Defense consider these points in their firefighter fitness program decision-making:

- Neither of the civilian programs is adequately developed or standardized enough to serve as a good model for a proposed Air Force/Department of Defense program.
- The two clear candidates for a proposed Air Force/Department of Defense's program are its extant program and that of the Canadian Forces/Department of National Defence. Both incorporated aircrew/aircraft tasks in their initial task analysis.
- The Interim Air Force/Department of Defense program is a physical fitness test and the Canadian Forces/Department of Defence program is a job-task simulation. The advantages and disadvantages of each test type need to be rank-ordered in importance by the Air Force/Department of Defense so that an appropriate decision can be made between these two test types. There are several studies that suggest a relationship between physical fitness and job-task simulation performance in the firefighting arena.
- The Canadian Forces/Department of National Defence program may be the most job-relevant of the programs surveyed, but the generalizability of this validity to the Air Force/Department of Defense program would need to be addressed if the Air Force/Department of Defense were to consider adopting this program. Also to be evaluated would be potential additional safety risks and possible increased administration costs.
- Several research and civilian programs that might also be considered by the Air Force/Department of Defense are documented here. Although used as job-entry tests, the methodological approaches of Gledhill and Jamnik (1992a, b) and Brownlie et al. (1985) may be of interest for future developmental efforts.
- Neither the NFPA 1583 nor IAFF/FC Initiative testing program is based on any unique scientific basis that would make their adoption by the Air Force/Department of Defense desirable.
- Should the Air Force/Department of Defense decide to acquire a wellness/lifestyle program, it would have to be created from the ground up. That is, the other organizations' programs might serve as a model or framework, but their offerings of counseling and education services do not exist in an off-the-shelf format that could be plugged into the Air Force/Department of Defense program. The IAFF/FC Initiative projects sincere, holistic concern for firefighters, which could serve as the basis for a Department of Defense Fire Fighter Physical Fitness Program wellness/lifestyle component.
- Additional insight into the technical and scientific bases of the candidate programs is expected from the subject-matter experts who will convene at the Firefighter Fitness Workshop in August, 1998.

- A further approach could be to extract those components from the candidate programs which best meet the current Air Force/Department of Defense needs. The most robust components might be the:
  - job-task simulation test from the Canadian Forces/Department of National Defence program
  - Air Force/Department of Defense aerobic fitness test (already a requirement for military firefighters)
  - Air Force/Department of Defense exercise prescription, which is less resource-intensive than other programs
  - IAFF/FC's wellness component, although this would need development to ensure that it was specific enough to meet the requirements of the military firefighting community.

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