# Ergonomics Research Group

*Selection and Maintenance Standards Division*

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# ABSTRACT

The goal of this research was to develop and validate a bona fide occupational physical maintenance standard for Search and Rescue Technicians (SARTechs) in the Canadian Forces (CF). Essential components associated with the SARTech job were identified using job analysis, SARTech mission and training reports, and an expert advisory panel. Work samples were used to assess the physiological demands of the job. Participants in this phase of the work were 37 male operational SARTechs ranging in age from 28 to 48 years (mean age was 36). Following identification of the most demanding tasks, standardized, simulated victim extrication tasks were developed for the Stokes stretcher and the toboggan. Construct validation was carried out on 164 civilians (88 male and 76 female) and 49 operational SARTechs (48 male and 1 female). A set of four fitness measures were found jointly to be significant predictors of performance time on the Stokes stretcher task: maximal oxygen consumption ($VO_2$ max), push-ups, sit-ups, and combined handgrip strength. Analysis of the toboggan task revealed the same four predictor variables. A compensatory model was developed for the implementation of standards based on a minimum composite score for the four predictor variables (the curl-ups test was replaced by a sit-ups test for this purpose). With the exception of $VO_2$ max, no minimum scores were set for individual predictor variables. Although the model allows for “trade-offs” in performance, the minimum composite score requires that participants demonstrate competence for a majority of the predictor variables.

## ACKNOWLEDGEMENTS

The development of a physical maintenance standard for Canadian Forces Search and Rescue Technicians (SARTechs) was, in every way, an exceptional project to be involved in. The individuals with whom we had the opportunity to work with were helpful, and accommodating of all our requests. The combination of their willingness to contribute to and participate in the various phases of our work while allowing us to participate in their work has resulted in the development of a unique model for the attainment of physical performance objectives.

During the two years of contact that we have had with the search and rescue trade, we have seen, first-hand, how SARTechs risk their lives as a matter of course in this highly demanding occupation. Their dedication to humanity, and the preservation of life has had a profound effect on all of us. We are eternally grateful for the work the SARTechs undertake, and we feel privileged to have had this opportunity to do this work.

In a multi-disciplinary, multi-site research endeavour, there are a large number of people who are responsible for the successful completion of a project. Most of the data collection occurred at CFB Trenton, CFB Comox, and at additional sites with members of the Canadian Forces School of Search and Rescue (CFSSAR). To those SARTechs who gave so willingly of their time and effort in their role as participants in our work samples, we are most grateful. MWO Charlie Fleming was the SARTech Leader, and our contact at Squadron 424 - CFB Trenton. In addition to facilitating our work on the base, his proximity to Queen's resulted in additional trips to Kingston to evaluate our simulations. MWO Bob Verret , the SARTech leader at Squadron 442 - CFB Comox, coordinated the efforts of his staff, and supplied personnel for assessment during our multiple visits to the West Coast. The commandant of CFSSAR, CWO Fred Ritchie, not only supplied his staff for many testing scenarios, but he also facilitated our inclusion on the Hinton phase of the recruit training program, and the 6A course in the fall of 1998. Inclusion on these courses enhanced the authenticity of our work sample data beyond imagination.

CWO Arnie MacAuley's long time interest in the area of physical fitness testing for SARTechs is well known among his peers. In his role as A3- SAR 3, of First Canadian Air Division - Winnipeg, he has been instrumental in gaining approval and access for our team to interact freely, and be part of training programs while on base. His efforts on behalf of the research team facilitated all aspects of our data collection.

The Research and Development (R&D) cell of the Canadian Forces Personnel Support Agency (CF-PSA) has, once again, provided outstanding support to the ERG during this project. I have had the pleasure of working with Sue Jaenen, the National Fitness Co-ordinator for CF-PSA on a number of projects, and it is no exaggeration to say that she is the point person who makes sure all the pieces fall into place. Finding testing facilities, rations & quarters for testing teams, space on aircraft and doing all the paper work that allowed us to fly with the SARTechs were only a few of the tasks that she undertook on our behalf. Support from the top is essential to the successful completion of any project, and once again, the director of the R & D cell, Dr. Wayne Lee filled that role for us.

All members of the Selection and Maintenance Standards Division of the Ergonomics Research Group (ERG) deserve to be thanked and congratulated for their efforts on this project. Lara Callaghan, Chris Fortier, Thana Hodge and Jamie Kuhnke all contributed through their exemplar work in data collection and analyses. Lucie Fortier was an outstanding project manager. Her ability to conceptualize, organize, and standardize increased the efficiency of all operations related to the project. A special thank you to Brenda Rice, who, after Lucie and her husband responded to the "call of the west", became our new laboratory manager, and learned more about the SARTech project than she thought possible in 3 short months!

To my co-investigators Ron Pelot, Terry Smith and Caroline Weber, your collaborative effort and your willingness to spend countless hours questioning and challenging our emerging models have led to a truly unique model in the development of bona fide occupational requirements. I believe that the intellectually challenging, yet open environment that is the hallmark of our group meetings has served us well, and is reflected in the strength of the document that we now deliver.

Thank you and congratulations.

Janice M. Deakin, Ph.D.
Principal Investigator
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# EXECUTIVE SUMMARY

In 1996, the Canadian Forces Personnel Support Agency contracted the Ergonomics Research Group (ERG) of Queen's University to develop a *bona fide* physical maintenance standard specific to the CF SARTechs. This standard was to comply with the Canadian Human Rights Act (1985), and the *Bona Fide Occupational Requirements Guidelines*. The completion of this contract included several phases: 1) identification of essential SAR tasks, 2) quantification of the physical requirements associated with performance of these tasks, and 3) development of a bona fide physical maintenance standard.

## Identification of essential SAR tasks

Strategies for the identification of essential SAR tasks included job analysis, information gathering from mission and training reports, and consultation with an expert advisory panel. The outcome was a list of physically demanding and representative tasks which were subsequently modeled for assessment. Among these were casualty evacuations by toboggan and Stokes stretcher, hiking with SAR equipment, and mountain rescues.

## Quantification of Physical Requirements

The first phase of information gathering involved the collection of work samples. From January to September 1997, a total of 37 SARTechs performed a variety of work simulations from the list created by the expert panel. Where possible, oxygen consumption ($VO_2$) was measured throughout task performance using a portable oxygen analyser (Aerosport KB1-C). The resulting $VO_2$ measures ranged from 16 to 34 ml/kg/min for the various tasks. Work samples which required a $VO_2$ less than 20 ml/kg/min were regarded as having low physical demand and were not included in further analysis. The remaining physically demanding tasks elicited a mean $VO_2$ of approximately 29 ml/kg/min.

During the second phase of data collection, the ERG conducted a validation study to evaluate muscular strength and endurance requirements associated with common SAR tasks. Specifically, statistical relationships between performance on common physical fitness tests (curl-ups, push-ups, chin-ups, vertical jump and combined handgrip) and performance on three simulations of demanding SAR tasks (100 m stretcher carry, 100 m toboggan pull, and a 40 kg lift) were investigated. The subjects for this phase of data collection were 164 civilians stratified by age and gender, as well as 49 operational SARTechs (total n = 213).

Stepwise regression analysis of the results from this study identified curl-ups, push-ups, combined handgrip, and maximal oxygen consumption as significant predictor variables for the stretcher carry and toboggan pull tasks. It was therefore concluded that these tasks should form the basis of strength and endurance testing for the physical maintenance standard.

## Bona Fide Physical Maintenance Standard

### (a) VO2 max

Based on $VO_2$ data obtained from the work samples, the ERG determined a minimum $VO_2$ max necessary for SARTechs to sustain prolonged work (1 to 2 hours) without undue fatigue. It was concluded that the minimum $VO_2$ max for operational SARTechs should be 44.6 ml/kg/min. This level of aerobic fitness is equivalent to the completion of stage 8 on the 20 Metre Shuttle Run (20-MSR) test.

**(b) Muscular Strength (Compensatory Model)**

The validation study provided the ERG with the information necessary to determine the relationships between the essential SAR tasks (toboggan and stretcher) and the physical fitness test variables. Since the observed scores for curl-ups (or sit-ups; see section 5.3.7) , push-ups, combined hand grip and $VO_2$ max were significant predictors of performance on the simulated toboggan and stretcher tasks, these tests were incorporated into a compensatory model. The model was designed to require individuals to achieve a composite score on the predictor variables based on their performance relative to the mean performance of a SARTech comparison group (n=86). A composite test score is derived from the results on the three strength tests mentioned above, as well as $VO_2$ max using supplied scoring charts constructed for this purpose. On a possible scale from 0 to near 100, an overall score of 30 or greater is considered a passing score for this component of the maintenance standard.

**(c) Lifting Task**

Heavy lifting was identified as an essential component of SAR work and therefore the ERG concluded that it should form one of the components of the SARTech physical maintenance standard. Since lifting is an easy test to administer without the need for specialized equipment, it was determined that a simulation would not be necessary. The test should entail lifting an extrication kit weighing 40 kg onto the back of a Hercules air craft or a table 1.5 m in height. It is suggested that a time criterion not be imposed.

**(d) Surface Swim**

Although the ERG did not include the 1000 m SAR swim test as part of the physical fitness assessment, this activity is recognized as an essential part of a SARTech's job. Therefore, it is recommended that this test remain a part of the physical maintenance standard and be performed without time constraints.

**Conclusion**

The bona fide physical maintenance standard includes four separate components: 20-MSR, strength tests (compensatory model), lifting task, and surface swim. This standard was developed from data collected on both SARTechs and civilian samples. This report examines all of the issues and information associated with the development of this standard in addition to providing recommendations for its implementation.

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# LIST OF ABBREVIATIONS

BFOR - Bona Fide Occupational Requirement

CABA - Compressed Air Breathing Apparatus

CAFT - Canadian Aerobic Fitness Test

CF - Canadian Forces

CPAFLA - The Canadian Physical Activity, Fitness & Lifestyle Appraisal

CV - Coefficient of Variation

ERG - Ergonomics Research Group, Queen's University

mCAFT - Modified Canadian Aerobic Fitness Test

MOC - Military occupational code

20 MSR - 20 Metre Shuttle Run

PARQ - Physical Activity Readiness Questionnaire

PSA - Personnel Support Agency

SAR - Search and Rescue

SARTech - Search and Rescue Technician

SD - Standard Deviation

$VO_2$ - Volume of oxygen consumption

$VO_2$ max - Maximal volume of oxygen consumption

**Units of Measurement:**

| | | | |
|---|---|---|---|
| cm | centimetre | lb | pound |
| m | metre | mmHG | millimetres of mercury |
| ml | millilitre | mM/L | millimoles per litre |
| kg | kilogram | | |
| min | minute | | |

# Chapter 1

## STATEMENT OF WORK

In 1996, the Canadian Forces Personnel Support Agency (CFPSA) contracted with the Ergonomics Research Group (ERG) of Queen's University to develop bona fide physical maintenance standards for Canadian Forces Search and Rescue Technicians (SARTechs). As a description of the work to be carried out, the following tasks were specified:

1. Conduct a review of the literature which includes previous research, task protocols, existing standards, and military and civilian reports relating to the development and application of physical fitness standards for search and rescue work.
2. Conduct preliminary task analyses of SARTech work and identify the physically demanding and representative activities of the job.
3 From the demanding and representative tasks identified, determine which are essential to the job.
4. Characterize the physiological demands required for successful performance of the essential tasks.
5. Evaluate the impact of a range of potential performance objectives on the current SARTech population.
6. In conjunction with CFPSA, recommend a performance objective for CF SARTechs.

# Chapter 2

# REVIEW OF THE LITERATURE

## 2.1 Introduction

Occupational maintenance standards are necessary to ensure that SARTechs have the physical capabilities required to meet the demands of the job. Job capability is of utmost importance given the intensely demanding work performed by SARTechs and the implications for health and safety of both the SARTechs and the members of the public who require their services.

In the determination of occupational maintenance standards for SARTechs there are many issues to be considered. This review will focus primarily on two issues: legislation with respect to bona fide occupational requirements (BFOR); and current knowledge regarding physical requirements of demanding jobs and how those requirements can be measured.

## 2.2 Bona Fide Occupational Requirements

The Canadian Human Rights Act (1985) prohibits employment policies and practices that discriminate against individuals on the basis of race, national or ethnic origin, religion, age, sex, marital or family status or a pardoned conviction. An exception to this prohibition given in paragraph 14a) of the Act states that “it is not a discriminatory practice if any refusal, exclusion, expulsion, suspension, limitation, specification or preference in relation to any employment is established by an employer to be based on a bona fide occupational requirement ” (Government of Canada, 1985). The policy statement on BFOR is important in balancing the human rights of employees with the rights of the employer to productive, efficient workers.

For a BFOR to exist the employer must have identified: 1) the necessary tasks required by the job, 2) the capabilities required to perform these tasks in a safe, reasonable manner, and 3) a standard which can be met by performing the minimum requirements of the job (Government of Canada, 1985). To establish a BFOR, policy requires that decisions be objective and based on expert opinion and scientific or empirical evidence when available. The detailed nature of tasks to be performed, existing work place conditions and the effect of these conditions on employees must also be taken into consideration. Existing work place conditions cannot impede the performance of a BFOR if these conditions can be changed without undue hardship to the employer (Government of Canada, 1988).

While employees are required to perform occupational tasks in a safe manner, a job may not be refused simply because safety risks are present, since most life activities pose some degree of risk. It should be the right of the individual to make an informed decision as to whether or not to accept the employment. However, the Canadian Human Rights Commission believes that the health and safety of others is of paramount importance. Therefore, injury to an employee's co-workers or the public should never be risked (Government of Canada, 1988).

Assessment of an individual's capacity to perform the essential components of a job should be based on his or her abilities and limitations. The procedures used for assessment may include verbal or written questions, interviews, functional tests, training programs, probationary periods, medical examinations and investigations of a candidate's status with respect to national security or similar requirements (Government of Canada, 1988). The assessment must be relevant by measuring the capability of an individual to perform the job in a safe, efficient and reliable manner. In addition, it is required that the assessment be: (1) valid by measuring what it is supposed to measure; (2) reliable by providing consistent results and (3) accurate (Government of Canada, 1988).

## 2.3 Rescue Work

The occupational physical demands of SARTechs have not been documented. However, there are many published reports on the fitness requirements of individuals in other physically demanding jobs including firefighters (O'Connell, Thomas, Cady & Karwasky, 1986; Gledhill & Jamnik 1992), U.S. Navy SEALs (Naval Health Research Centre, 1996), and the Canadian Armed Forces (Celentano & Nottrodt, 1984; Stevenson, Bryant, Andrew, Smith, French, Thomson & Deakin, 1992; Stevenson, Deakin, Andrew, Bryant, Smith, Thomson,1994). Similar to personnel in some of these occupations, SARTechs must perform tasks involving hiking with heavy loads, strenuous lifting, carrying stretchers, and climbing. In consideration of the intense nature of these duties and the importance of public and SARTech safety, it is essential that SARTechs have the physical capabilities to meet the demands of the job.

An occupation which involves tasks similar to those performed by SARTechs is the U.S. Navy SEALs. It is reported that the primary mission of present day SEAL teams is the rescue of downed pilots and extraction of personnel from prohibited territory (Naval Health Research Centre, 1996). SEALS must conduct overland missions which involve walking while dragging or lifting injured individuals or other heavy loads. After assessing the physical requirement of these tasks, researchers estimated that aerobic endurance played a primary role in 93% of Navy SEAL missions (Naval Health Research Centre, 1996).

Similar studies have reported on the importance of aerobic capacity in other physically demanding occupations. The heavy demands placed on the cardiovascular system during firefighting have been well documented (Lemon & Hermiston, 1977; Davis, Dotson & Santa Maria, 1982; Gilman & Davis, 1993). The recommended minimal aerobic capacity required to perform firefighting tasks has been reported to be between 39 ml/kg/min and 45 ml/kg/min (Lemon & Hermiston, 1977; Davis, Dotson & Santa Maria 1978; O'Connell, Thomas, Cady & Karwasky, 1986; Gledhill & Jamnik, 1992). A summary of the minimum volume of maximal oxygen uptake ($VO_2$ max) recommended for various physically demanding occupations is displayed in Table 1.

*Table 1: Recommended minimum $VO_2$ max for physically demanding occupations*.

| Study | Occupation | $VO_2$ max Recommended |
|---|---|---|
| Lemon & Hermiston, 1977<br>Davis, et al., 1978<br>O'Connel, et al., 1986<br>Gledhill & Jamnik, 1992 | Firefighters | 39-45 ml/kg/min |
| Stevenson et al., 1988 | Canadian Armed Forces | 30-39 ml/kg/min<br>(age & sex dependent) |
| Sharp, 1991 | U.S. Air Force | 42 ml/kg/min |

Muscular strength is another component of physical fitness that is required for successful performance of many military duties. Tasks such as toboggan pulling have been reported to be associated not only with aerobic and anaerobic power, but with muscular strength and endurance (Jetté, Sidney & Kimick, 1989). Another activity which relies heavily upon muscular strength is casualty extrication using a stretcher. Evidence suggests that during stretcher carry tasks, grip strength is one of the best predictors of successful performance for both male and female soldiers (Rice & Sharp, 1994).

## 2.4 Physical Demands Assessment

### 2.4.1 Aerobic Capacity

Aerobic capacity ($VO_2$ max) is a measure of the maximum volume of oxygen consumption by the body during maximal exertion (Wilmore & Costill, 1994). It is regarded as the best overall indicator of physical fitness (Åstrand & Radahl, 1985) and an important determinant of work capacity (Åstrand & Radahl, 1970). A direct measure of oxygen consumption during a graded exercise test under laboratory conditions is considered the gold standard for determining $VO_2$ max. Technological advances have enabled researchers to measure energy expenditure under field conditions utilizing portable analysers such as the Aerosport TEEM 100 and the KB1-C. However, few studies have been conducted to assess the reliability and validity of such portable metabolic systems. It is reported that the correlation for $VO_2$ between measurments from the TEEM 100 and from an on-line computer-based metabolic data acquisition system was r=0.99 when submaximal and maximal exercise data were pooled. The test-retest reliability of the TEEM 100 was in the order of r=0.94 when subject workloads were pooled (Melanson, Freedson, Hendelman, Debold, 1996). This evidence suggests that the TEEM 100 provides valid and reliable measurements of $VO_2$ during submaximal and maximal exercise.

Most laboratory measures of $VO_2$ max require specialized equipment, considerable subject motivation and a large expenditure of time. In view of these limitations, various indirect measures of aerobic capacity have been devised which predict $VO_2$ max from maximal or submaximal exercise. These tests include the Canadian Aerobic Fitness (step) Test (CAFT) (Fitness & Amateur Sport, 1986), the 12 minute run (Cooper, 1968) and the multi-stage 20 metre shuttle run (20-MSR) (Léger, Mercier, Gadoury, Lambert, 1988).

The 20-MSR is an ideal test for predicting $VO_2$ max in an occupational setting because it is suitable for testing a large group of subjects at one time at a minimal cost (Léger, Mercier, Gadoury, Lambert, 1988). The test involves repeatedly running a 20 metre distance while keeping pace with a sound signal. As the stages progress, running speed must increase by 0.5 km/hr each minute from a starting speed of 8.5 km/hr to maintain the pace. Léger & Gadoury (1989) reported that maximal shuttle run speed is highly correlated with $VO_2$ max measured during a maximal treadmill test (r=0.90). In addition, the test-retest reliability coefficient was measured at r=0.95 for adults (Léger, Mercier, Gadoury, Lambert, 1988). In comparison to the step test (CAFT) as a predictor for $VO_2$ max (r=0.61), Léger & Gadoury (1989) found that the 20-MSR has a higher correlation with the $VO_2$ max measured during a maximal treadmill test which indicates a greater ability to predict aerobic capacity.

#### 2.4.2 Muscular Strength and Endurance

Muscular strength and endurance are required for the performance of many physically demanding tasks, including lifting, pushing, carrying and dragging heavy loads. In recent years, physical performance tests have been used to measure these abilities for occupational selection standards (Fleishman, 1989). However, before physical fitness tests can be used in selection procedures, their relationship with job performance must be established.

A construct validation approach which identifies “constructs” that underlie successful job performance is advantageous over other methods when validating the use of physical ability tests (Arvey, Nutting, Landon, 1992; Arvey, Landon, Nutting & Maxwell, 1992). A construct is often abstract or theoretical in nature (e.g. strength, endurance), but the tests used for its measurement are relatively concrete and based on observable features. Since this approach relies on a variety of information sources and contributes to a greater scientific knowledge of the observed relationships, it is recommended over other validation strategies if required to substantiate in court (Arvey, Landon, Nutting & Maxwell, 1992).

In 1964, after a review of previous research, Fleishman developed a taxonomy of human performance measurements by identifying physical constructs and determining appropriate physical tests to evaluate each one. Simple physical tests such as pull-ups, chin-ups, push-ups and handgrip dynamometer were identified as some of the best measures of strength and endurance (Fleishman, 1964). Therefore, these physical fitness tests are ideal within a construct validation strategy for the assessment of muscular strength and endurance.

## 2.5 Environmental Considerations

Unlike many other occupations, SARTechs cannot control the physical requirements of their work environment. Environmental factors can have a significant influence on metabolic demand and SARTechs must be prepared to respond to changing emergency conditions. Work in the heat can impose an additional stress on the cardiovascular system causing oxygen consumption to be approximately 5% greater than similar activity in a thermoneutral environment (McArdle, Katch, Katch, 1980). This is attributed in part to the energy requirement for heat dissipation through sweating. In addition to heat exposure, activity in a cold environment can also affect metabolic rate. In cold temperatures, metabolic rate is increased significantly by shivering while the body attempts to maintain a stable core temperature. This is particularly evident during exercise in cold water. It is reported that during exercise in 25°C and 18°C water, $VO_2$ was higher by 9% and 25% respectively, in comparison to exercise in 33°C water (McArdle, Magel, Lesmes & Pechar, 1976).

Another environmental influence on metabolic demand is the terrain of the working surface. Energy requirements during walking are associated with the surface on which the activity is performed which for SARTechs could include a hard surfaced road, sand, snow, or mud. Walking on sand or hard snow increases the metabolic cost approximately 2-fold in comparison to walking on a hard surface (Givoni & Goldman, 1971). It was further reported that during walking on soft snow with a footprint depression of 26 cm, $VO_2$ was 65% higher than treadmill walking at an equivalent speed

(Smolander, Louhevaara, Hakola, 1989). Therefore it is apparent that environmental conditions can play an important factor in the energy requirements of a task.

## 2.6 Summary of the Literature Review

This chapter has discussed a number of issues which must be considered when establishing occupational maintenance standards. Of primary importance is current legislative policy which describes the procedure to be followed when establishing BFORs. This policy requires identification of the essential components of a job as well as the skills required for successful performance of those tasks. Since there had been no documentation of the physical demands involved in SARTech work, a comparison was made with other rescue related occupations to determine their physical requirements. This demonstrated the importance of aerobic capacity and muscular strength for the performance of tasks which involve hiking with heavy loads, carrying stretchers, and strenuous lifting.

Another issue for the establishment of maintenance standards is the choice of methods to measure essential fitness components. Evidence suggests that the 20-MSR is an ideal test for assessing aerobic capacity since it is easy to administer and is reliable and valid. The measurement of muscular strength and endurance can be predicted by simple tests such as hand dynamometer, sit-ups, push-ups and vertical jump.

The final issue to be considered is the effect of external influences on job demands such as temperature and terrain of the working area. These environmental conditions can substantially increase the physical demands of a task. Therefore, it is important that they be incorporated in the assessment of job related demands.

# Chapter 3

# IDENTIFICATION OF ESSENTIAL TASKS

In order to establish trade-specific occupational requirements, the *Federal Bona Fide Occupational Requirements Guidelines* state that essential tasks which comprise the requirements of the trade must first be identified. The identification of essential tasks associated with the SARTech job was based on information gathered from numerous sources including a job analysis, SARTech mission and training reports, and an expert advisory panel.

## 3.1 Job Analysis

Whereas typical job analyses are conducted in relatively controlled environments, analysis of the SARTech job was complicated by the highly variable nature of both the job and the work environment. Day-to-day SARTech duties are dependent on a myriad of factors that include weather, unforseen emergency situations, and availability of equipment and support staff (i.e. flight crew). Upon initiation of the job analysis, the impossibility of observing all demanding and representative tasks within an acceptable time frame became evident. In addition, concerns that conducting a job analysis during a mission could interfere with the safe and efficient rescue of victims precluded the objective evaluation of SARTech work during emergencies. Therefore, the ERG turned to mission and training reports to assist in the characterization of work routinely performed by SARTechs.

## 3.2 Mission Reports

Mission reports from squadrons 103, 413, 424, and 442 for the years 1991-1995 were obtained from Air Transport Group Headquarters. Collectively, these squadrons account for a total of 80% of operational SARTechs. Information gathered from the reports included the type of mission, type of aircraft employed, method of penetration to the mission site, amount of time spent in transit, and time spent performing SARTech duties.

For these four squadrons combined, SARTechs responded to an average of 180 calls per year, the majority of which were in response to marine emergencies (Figure 1).

*Figure 1.* *Distribution of SAR emergency calls by site of emergency (1991 - 1995).*

Once a response had been initiated, SARTechs spent up to four hours or more performing SAR duties. However, the majority of missions (44.7%) were completed in less than one hour (Figure 2). Interestingly, SARTechs were not required to actually leave the aircraft on about 41% of reported missions (Figure 3). In these cases, SAR duties included searching, dropping bundles, and providing topcover (dropping flares) for other SAR aircraft.

*Figure 2. Distribution of SAR mission durations.*

*Figure 3. Distribution of SAR emergency calls by method of penetration to site.*

Due to the relatively small number of emergency calls and the observation that SARTechs were not required to leave the aircraft on a relatively large number of missions, it was concluded that work on missions accounted for only a small fraction of the total SARTech work. In addition, because the physical activities of SARTechs during missions were not recorded in the mission reports, conclusions related to physical demands of emergency work performed by SARTechs could not be derived.

### 3.3 Training Reports

Each year, all operational SARTechs must comply with a training regimen which requires them to perform a specified number of SAR tasks. This regimen ensures continued proficiency and practice for a number of essential SAR skills. The frequency with which these tasks are actually performed by each SARTech is recorded in annual 2424 Reports which are completed by each squadron.

The ERG collected data from the 2424 Reports for all SAR squadrons for the years 1991 to 1995. This provided information about which tasks were performed most and least often (Figure 4).

*Figure 4.  Frequency distribution of average training tasks by SARTechs.*

The emphasis of the training regimen was on the technical, rather than the physical attributes required to successfully complete each task. As such, the 2424 Reports contained no additional information regarding the physical demands surrounding task performance. It was concluded that the physical demands of the job would require direct assessment in the form of work samples.

## 3.4 Expert Panel

Because of the limitations associated with the information gathered from the job analysis and from the mission and training reports, the ERG consulted an expert advisory panel of SARTech personnel to identify and prioritize the "most physically demanding" and "most frequently performed" components of SARTech operations. The ERG met with the expert panel at the Queen's University Electronic Decision Centre on January 10th, 1997. The panel consisted of eleven SARTechs originating from National Defence Headquarters, Air Transport Group Headquarters, Squadron 435 Winnipeg, and Squadron 424 Trenton. Table 2 lists the tasks identified by the panel as most demanding and most frequently performed.

*Table 2. Most physically demanding and most frequently performed tasks identified by the expert panel.*

| Physically demanding tasks | Frequently performed tasks |
|---|---|
| Night full equipment jumps | Load/unload aircraft |
| Mountain climbing and rescue | Wear heavy equipment for long periods |

| | |
|---|---|
| Extracting/carrying victims | Re-pack parachutes |
| Surface swim | Fly |
| Lifting of equipment | Search |
| Hiking to crash site | Climb/hike over various terrain |
| Flying in full equipment (fixed wing) | Boat hoist |
| Night CABA dive | Day training parachute jumps |
| Flying in full equipment (rotary wing) | Stokes hoist |
| Day full equipment jumps | CABA dive |

Following the identification process, the ERG studied each task individually to determine which of them would serve as the basis for the assessment of the SARTech job. Some tasks were eliminated because:

(i) excessive demand was deemed to be due to psychological rather than physical factors (eg. night parachute jump, night compressed air breathing apparatus (CABA) dive);

(ii) logistical and technical difficulties were associated with the accurate assessment of the task demands (eg. surface swim, CABA dive);

(iii) previous scientific work demonstrated a low level of physical demand (eg. parachute jump).

After applying the criteria, a list of the “most physically demanding and most frequently performed” tasks was derived from the original list provided by the expert panel (these tasks are listed in the next chapter). The physical demands associated with these tasks were then assessed using work samples.

# Chapter 4

# ASSESSMENT OF PHYSICAL DEMANDS - WORK SAMPLES

## 4.1 Purpose

Work samples were developed to assess the physiological demands associated with tasks identified as demanding and representative by the expert panel. Specific objectives included:

(i) measuring the oxygen consumption ($VO_2$) associated with the performance of SARTech tasks; and

(ii) measuring the forces involved in task performance.

## 4.2 Methods

### 4.2.1 Subjects

Subjects were 37 male operational SARTechs with an average of 8.7 years of experience as SARTechs. They ranged in age from 28 to 48 years (average age 36) and in rank from Master Corporal to Warrant Officer.

### 4.2.2 Informed Consent

All subjects provided written informed consent prior to participation (Appendix A). Subjects were made aware that they were at liberty to withdraw from the testing at any time without any penalty.

#### 4.2.3 Testing Sessions

Testing sessions were conducted over the period from January 1997 to September 1997 according to the schedule in Table 3:

*Table 3. Location and dates of testing sessions.*

| ***LOCATION*** | ***DATES*** |
|---|---|
| Jarvis Lake, Alberta | January 19 - 24, 1997 |
| Comox, British Columbia | July 2 - 13, 1997 |
| Trenton, Ontario | August 18 - 21, 1997<br>September 2 - 5, 1997 |
| Jasper, Alberta | September 10 - 17, 1997 |

Subjects were made available according to their daily work schedules. Prior to testing, subjects were provided with instructions to ensure their understanding of the testing procedures, and were encouraged to ask questions. Subjects wore military issue flight suits and boots throughout the testing sessions.

#### 4.2.4 Work Samples

Work samples were designed using the list of demanding and representative tasks from the expert panel, and from extensive on-site discussions with SARTechs. The work samples chosen reflected the varied environmental conditions experienced in general SAR work. Table 4 provides descriptions of the work samples that were completed.

*Table 4. Description of work samples.*

| ***Location*** | ***Work Samples Completed*** | ***Description*** |
|---|---|---|
| **Jarvis Lake** | 800 m snowshoe walk | While wearing personal packs (26.3 kg) subjects hiked through forested area over fresh snow. Terrain was varied and included uphill and downhill sections. |
| | 400 m toboggan pull | 2-person task pulling toboggan weighted with equivalent of 68.0 kg (150 lb) casualty. Tracked path through fresh snow over varied and flat terrain. |
| **CFB Comox and CFB Trenton** | 100 m toboggan pull<br>100 m Stokes carry | 2-person task pulling toboggan/carrying Stokes stretcher weighted with equivalent of 56.7 kg (125 lb) casualty. Terrain was varied, mostly overgrown, with uphill and downhill sections. Weather conditions were favourable. |
| | 300 m hike | 1-person hike while wearing SAR extrication kit. Terrain was varied. |
| | Stokes guideline hoist | 1-person task. Assessed demands of manning the guideline.<br>*(Heart rate information only)* |
| | Front door entry | Subjects exited the Labrador helicopter directly into water.<br>*(Heart rate information only)* |
| | Bundle drop sequence | 1-person task. Drop sequence from Hercules aircraft: message, supplementation kit, extrication kit, SAR toboggan. |
| | Flying in full equipment (fixed wing) | 1-person task. Subject (dressed to perform sarpel jump) required to stand in rear of Hercules aircraft during routine manoeuvers. |

| | | |
|---|---|---|
| **Jasper** | Mountain rescue | Multi-person task. Included high-line rescue, crevasse rescue, one-on-one rescues and Stokes rescues involving various pulley systems. |
| | Glacier climb | 1-person task involving climbing out of a deep crevasse using ice axes and crampons. |
| | Long-distance uphill hike | 1-person task climbing uphill for approximately 30 minutes to reach glacier. |

During the performance of the work samples, SARTechs wore a Polar Vantage XL monitor which recorded heart rates at pre-determined intervals. Where possible, a portable oxygen analyser (KB1-C) was also worn to measure the $VO_2$ requirements associated with task performance. Subjects were instructed to complete the tasks at a pace consistent with that of a mission.

## 4.3 Results and Discussion

### 4.3.1 Oxygen Consumption ($VO_2$)

The capacity of humans to sustain strenuous work diminishes as a function of time and is most accurately determined by an individual's maximal oxygen consumption (Åstrand and Rodahl, 1985). While very highly trained individuals have the capacity to work at a near maximal level (~80% $VO_2$ max) for a prolonged period of time, the untrained must work at a much lower intensity (~40% $VO_2$ max) in order to complete the work (Åstrand and Rodahl, 1985). Our analysis of the 86 SARTechs who were tested during the 1997 Annual Physical Fitness Testing revealed that the majority of SARTechs had predicted $VO_2$ max results consistent with moderately trained individuals. Thus, we determined that SARTechs should be capable of performing tasks at approximately 65% $VO_2$ max to sustain work for a prolonged period of time (1 to 2 hours), without undue fatigue (Åstrand and Rodahl, 1985). This capability would also enable successful performance of the most demanding work sample, the self-paced 400 m toboggan pull over snow, which required SARTechs to work at an intensity of approximately 64% $VO_2$ max (see Table 5).

From the data gathered during the work samples, and presented in Table 5, average $VO_2$ values were calculated for each of the tasks observed. The intensity of these tasks was calculated as a percentage of $VO_2$ max which was based on the individual's predicted $VO_2$ max results from the 20-MSR (protocol in Appendix B). The highest work intensity was observed during the 400 m toboggan pull over snow which proved to be the most demanding of the SAR tasks tested.

*Table 5. Average oxygen consumption observed during work samples.*

| **Task** | **Number of Subject Trials** | **Subject predicted $VO_2$ max* (ml/kg/min)** | **Observed $VO_2$ (ml/kg/min)** | **Percentage of $VO_2$ max (%)*** |
|---|---|---|---|---|
| 400 m Toboggan Pull over snow | 6 | 53.13 | 34.08 | 64.14 |
| 100 m Toboggan Pull over varied terrain | 20 | 48.13 | 30.15 | 62.64 |
| Long-Distance uphill hike with personal pack | 2 | 50.48 | 27.75 | 54.97 |
| 800 m Snowshoe Hike | 3 | 44.09 | 27.55 | 62.48 |
| 300 m Hike with Extrication Kit | 8 | 47.33 | 27.13 | 57.31 |
| 100 m Stokes/Lit-O-Splint | 22 | 48.04 | 26.45 | 55.04 |

| | | | | |
|---|---|---|---|---|
| Carry | | | | |
| Glacier Climb | 2 | 52.18 | 16.11 | 30.87 |
| Bundle Drop Sequence | 1 | Not available | 14.37 | Not available |
| Flying in Full Equipment (fixed wing) | 1 | Not available | 12.22 | Not available |

** $VO_2$ max was predicted by 20-MSR from the 1997 Annual Fitness Testing Data*

The volume of oxygen consumption measures for flying in full equipment, the glacier climb and the long-distance uphill hike with pack confirmed that the physical demands of these tasks were substantially less than the remaining work samples. Given their $VO_2$ requirements were less than 20 ml/kg/min, these tasks were removed from subsequent analyses (Table 6).

*Table 6. Average oxygen consumption values observed during demanding work samples.*

| Task | Number of Subject Trials | Subject predicted $VO_2$ max* (ml/kg/min) | Observed $VO_2$ (ml/kg/min) | Percentage of $VO_2$ max (%)* |
|---|---|---|---|---|
| 400 m Toboggan Pull over snow | 6 | 53.13 | 34.08 | 64.14 |
| 100 m Toboggan Pull over varied terrain | 20 | 48.13 | 30.15 | 62.64 |
| Long-Distance uphill hike with personal pack | 2 | 50.48 | 27.75 | 54.97 |
| 800 m Snowshoe Hike | 3 | 44.09 | 27.55 | 62.48 |
| 300 m Hike with Extrication Kit | 8 | 47.33 | 27.13 | 57.31 |
| 100 m Stokes/Lit-O-Splint Carry | 22 | 48.04 | 26.45 | 55.04 |
| **Average Task Values** | | **48.5** | **28.9** | **59.4** |

** $VO_2$ max was predicted by 20-MSR from the 1997 Annual Fitness Testing Data*

Table 6 illustrates the $VO_2$ requirements for the remaining work samples. On average, the SARTechs completed the six demanding work samples with an observed $VO_2$ of 28.9 ml/kg/min. This value represents approximately 60% of their $VO_2$ max. The relative fitness level of these subjects is evident from both their average $VO_2$ max of 48.5 ml/kg/min and the efficiency of their aerobic system reflected in the ability to carry out the work required using only 60% of their $VO_2$ max. The cost of completing the same work load of 28.9 ml/kg/min for a slightly less trained individual is reflected in the percentage of $VO_2$ max required to complete the task. As per earlier discussion, assuming that a work intensity of approximately 65% of $VO_2$ max will allow for prolonged effort, the necessary $VO_2$ max would be 44.4 ml/kg/min. This level of aerobic fitness is approximately that required for completion of stage 8 on the 20-MSR (44.6 ml/kg/min). A $VO_2$ max of 44.6 ml/kg/min is also consistent with the recommended minimum requirements in other physically demanding occupations such as firefighting and the U.S. Air Force (Table 1, page 6).

It should be noted that the average SARTech who completed the work samples did not exceed 65% of his $VO_2$ max on any of the tasks. This supports the conclusion that subjects were working at a level consistent with the request to self-pace at a rate that would allow for prolonged performance. Additional evidence that SARTechs were working at submaximal intensities during the work samples is provided by blood lactate measures. These samples were collected 5 minutes after the SARTechs performed selected work sample tasks (100 m toboggan pull over varied terrain, 100 m Stokes carry, and 300 m hike with extrication kit) (Appendix C). It is known that blood lactate concentration is an indicator of exercise intensity, first appearing in the blood at approximately 50 to 60% of an individual's $VO_2$ max, and reaching a peak after 6 to 9 minutes post exercise (Åstrand & Radahl, 1977; Fujitsuka, Yamamoto, Ohkuwa, Saito, & Miyamura, 1982) At a maximal exercise intensity, blood lactate concentration measures between 11 to 14 mM/L, but may exceed 20 mM/L in trained individuals between the ages of 20-40 years of age (Åstrand & Rodahl, 1977). The blood lactate concentrations for the three work sample tasks ranged from 6.13 mM/L to 7.76 mM/L.

#### 4.3.2 Muscular Strength and Endurance

The importance of muscular strength and endurance for performing the SARTech job became evident through the work samples which included lifting and carrying SAR equipment and/or casualties. For the lifting tasks, the strength demands are fairly straightforward and can be easily replicated in a testing situation. For other tasks, however, the quantification of the underlying muscular components is complicated by the variable nature of the job and by the inherently complex nature of multi-dimensional tasks. For example, the muscular demands associated with mountain rescues are dependent on the pulley system that is employed. This allows the SARTechs performing the rescue to self-select the strength and endurance requirements by altering the pulley ratio. The demands associated with casualty evacuation tasks are also difficult to quantify because they are dependent on the environment (i.e. the quality of the soil, the presence of obstacles, and the grade of any uphill or downhill sections). In addition, the complexity of the task makes it difficult to assess the contributions of individual muscle groups. As a result of these difficulties, the ERG initiated a validation study to determine whether the muscular strength and endurance components of three physically demanding tasks could be modelled using predictive physical fitness tests. The validation study and its components are described in the next chapter.

# Chapter 5

# VALIDATION STUDY

## 5.1 Purpose

The objective of the validation study was to determine relationships between standardized versions of physically demanding SAR tasks and common physical fitness measures in order to produce a predictive performance model. A model based on simple physical fitness tests would eliminate problems associated with the need for specialized equipment, individualized testing and appropriate space to perform the simulations.

## 5.2 Methods

### 5.2.1 Task Construction and Validation

For the purpose of the validation study, the ERG identified and operationalized three physically demanding SAR tasks which taxed the strength and endurance of various muscle groups: a 40 kg lifting task, a 100m toboggan pull and a 100m Stokes stretcher carry.

The lifting task was identified from the task statement for SARTechs under the heading of Military Occupational Code (MOC) related duties. It involved lifting a 40 kg extrication kit from the ground to a height of 1.5 m, without the use of external aids. The toboggan pull and Stokes stretcher carry were completed over a 100 m indoor circuit (Appendix G). The circuit consisted of a flat straight run on rubber mats and two uphill and downhill portions created by a wooden ramp constructed specifically for this purpose. The toboggan contained a 40.8 kg (90 lb) weight which simulated one half of a 81.6 kg (180 lb) casualty. The stretcher also contained a 40.8 kg (90 lb) weight which simulated one half of the force at the hands when carrying a 68.0 kg (150 lb) casualty from the head end. The rationale for simulating one half of a 68.0 kg (150 lb), rather than a 81.6 kg (180 lb) casualty on the stretcher, was due to the extreme difficulty of the task when the heavier weight was used.

To verify that the simulations accurately reflected the demands associated with the SARTech job, the ERG consulted operational SARTechs who performed the tasks and commented on the validity of the simulation. Following minor alterations, the experts agreed that the simulations were representative of actual SAR tasks.

#### 5.2.2 Subjects

Based on the homogeneous physical fitness levels of SARTechs and their relatively small number, the validation study was expanded to include the broader civilian population stratified by age and gender. Civilian subjects were remunerated to the amount of fifty dollars upon completion of the tests. In total, 164 civilian volunteers and 49 operational SARTechs (total n = 213) participated in the study. The breakdown of the two groups of subjects by age and gender is presented in Table 7.

*Table 7. Frequency distribution of subjects by age, gender, and population.*

| | Civilians | | SARTechs | |
|---|---|---|---|---|
| Age Category | Males | Females | Males | Females |
| 24 - 29 | 23 | 21 | 4 | 1 |
| 30 - 34 | 24 | 18 | 10 | 0 |
| 35 - 39 | 20 | 21 | 16 | 0 |
| 40 - 44 | 19 | 15 | 12 | 0 |
| ≥ 45 | 2 | 1 | 6 | 0 |

### 5.2.3 Pre-Screening

All subjects passed a screening for medical contraindications to exertion prior to participating in the study. The screening process included the Physical Activity Readiness Questionnaire (PAR-Q) and measurements of resting heart rate and blood pressure. Exclusion criteria included a resting heart rate exceeding 100 beats/minute; resting systolic blood pressure above 140 mmHg; and resting diastolic blood pressure over 90 mmHg.

### 5.2.4 Instructions to Subjects

Preliminary instructions were given to subjects prior to participation. Subjects were requested to abstain from exercise 24 hours prior to testing, and not to eat, smoke, or drink beverages containing caffeine for at least two hours before the test. Subjects were also provided with instructions pertaining to the recommended dress for participation.

### 5.2.5 Informed Consent

All subjects provided written informed consent prior to participation (see Appendix D and E for sample consent forms). Subjects were aware that they were at liberty to withdraw from the study at any time.

### 5.2.6 Testing Sessions

Testing occurred between November 17, 1997 and May 22, 1998. Each subject completed a total of three testing sessions. For the civilian subjects, the testing sessions took place at the Physical Education Centre at Queen's University. The three sessions were scheduled at least 24 hours apart to allow for adequate recovery.

Testing of the SARTech subjects was conducted at CFB Comox and CFB Trenton. Due to their limited availability, the SARTechs completed the three testing sessions within a 24-hour period.

### 5.2.7 Physical Fitness Tests

During the first testing session, all subjects completed a battery of physical fitness tests. Tests common to both the civilian and SARTech samples consisted of the mCAFT, curl-ups, push-ups, vertical jump, combined handgrip, and chin-ups. Subjects were limited to performing 100 curl-ups. Except for chin-ups all tests were conducted according to the protocols established by the Canadian Physical Activity, Fitness, and Lifestyle Association.

In addition to the tests listed above, the civilian subjects performed the Beiring-Sorensen back endurance test. This test was eliminated from the test battery administered to SARTechs following preliminary statistical analysis which indicated that it did not correlate with task performance in the civilian population. All fitness testing protocols are included in Appendix F.

**5.2.8 SAR tasks**

During the second and third testing sessions, subjects completed the 100 m toboggan pull, the 100 m Stokes stretcher carry, and the 40 kg lift. Prior to testing on each task, a tester demonstrated a variety of possible techniques for task performance. Subjects were encouraged to try these techniques prior to testing. The techniques ultimately employed during testing were left to the subjects' discretion. Standard instructions were read to the subjects prior to the start of each test. Testers recorded the time required for subjects to complete each task. Circuit design and protocols employed for testing of the SAR tasks are included in Appendix G.

**5.2.9 Statistical Methods**

Statistical analyses were performed using the SAS statistical package (1996), and the SPSS statistical package (1997). Descriptive statistics (means, standard deviations (SD), minima and maxima) were calculated for all variables in the study data set, for all subjects (n = 213) and for subgroups of interest (by gender, by SARTech/civilian group). Transformations of variables were identified which produced approximately normal distributions. The transformed variables were weight, chin-ups, push-ups, curl-ups, combined handgrip, vertical jump, stretcher time, and toboggan time. Pearson correlations for all pairs of variables (subject characteristics, test variables and task variables) were computed for the entire study sample (n = 213), transformations being used to promote extraction of linear relationships. Multiple linear regression was used to derive predictive models for the toboggan pull and stretcher carry variables in terms of the physical test and subject characteristic variables, transformed where necessary.

Identification of the final predictive models was achieved through a sequence of regression analyses and diagnostic assessment of the resulting regression models. To assess stability of the final predictive models, stepwise selection was performed with a range of entry and removal criteria for model terms, and with a subphase holding the variables age and sex fixed in the models. Quality of the final predictive models was assessed by R-squared statistics (the percentage of variation in the dependent variable explained by the independent variables), and by the coefficients of variation (CV) (the root mean squared error from the regression as a percentage of the mean of the dependent variable). The relative importance of variables in the final models was assessed by their significance probabilities (P-values), beta coefficients, and partial R-squares. Residuals were examined for stability of variance, outliers and influential observations.

## 5.3 Results

### 5.3.1 Descriptive Statistics

The physical characteristics of the subjects who participated in the study and their performance on the physical fitness tests are summarized in Table 8.

*Table 8. Summary statistics for subject demographic variables and test results from the validation study (n = 213).*

| ***Variable*** | ***Mean*** | ***Standard Deviation*** | ***Minimum*** | ***Maximum*** |
|---|---|---|---|---|
| Age (years) | 34.8 | 6.2 | 24 | 49 |
| Height (cm) | 173.8 | 9.1 | 151 | 195 |
| Weight (kg) | 75.0 | 16.9 | 40 | 148 |
| mCAFT $VO_2$ max (ml/kg/min) | 44.19 | 6.89 | 21.8 | 58.7 |
| Chin-Ups*⁻ (consecutive) | 6.6 | 6.7 | 0 | 25 |
| Push-ups (consecutive) | 24.6 | 17.2 | 0 | 90 |
| Curl-ups⁻ | 48.9 | 34.5 | 0 | 100 |
| Vertical Jump (cm) | 40.6 | 11.8 | 3 | 74 |
| Combined Handgrip (kg) | 82.9 | 30.5 | 22.0 | 155.0 |

* n = 211

⁻ *Note: 12% of civilians and 61% of SARTechs performed 100 curl-ups; 33% of civilians and 0% of SARTechs performed 0 chin-ups.*

Table 8 clearly demonstrates the wide range of physical fitness levels observed in the overall sample. Upon examination of the separate samples, however, distinct differences emerged between the SARTech and civilian subjects. As a group, the SARTechs generally performed better than their civilian counterparts and displayed a narrower range of scores. Conversely, scores among the civilian population varied greatly and sample means were lower. An example of these differences is illustrated by the results on combined handgrip strength depicted in Figure 6. This pattern is typical of the differences between SARTechs and civilians across the various tests.

*Figure 5. Illustration of differences in performance between civilians and SARTechs using combined handgrip scores.*

**5.3.2 Lifting Task**

The 40 kg lift proved to be much more difficult for the females in the civilian validation study than for the males. Only 17 of the 77 females who participated were successful at lifting the extrication kit to the required height. This represents a 22% success rate. Conversely, 100% of the 134 males successfully completed the lift. The 100% success rate by male participants created difficulties associated with modeling this task. For this reason and also because this task had been observed frequently during the ERG site visits to SAR bases, the lifting task was chosen as one of the components of the SARTech physical maintenance standard. Consequently, it was not included in subsequent analyses.

**5.3.3 Circuit Completion Times**

In general, the toboggan task was completed more quickly than the stretcher task with the mean completion times (plus or minus standard deviations) for the overall sample of 87.5 ± 45.7 seconds and 109.7 ± 87.7 seconds, respectively. As with the physical fitness scores, comparison of the civilian and SARTech performances showed substantial differences. Once again, relative to the civilian population SARTechs completed both tasks more quickly and their performances were much more homogeneous (Table 9).

*Table 9. Circuit completion times for the toboggan and stretcher tasks by group.*

| | **SARTech** | | | | **Civilian** | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean (s) | SD (s) | Min (s) | Max (s) | Mean (s) | SD (s) | Min (s) | Max (s) |
| Toboggan | 51.5 | 8.9 | 35 | 70 | 98.3 | 46.7 | 44 | 332 |
| Stretcher | 56.6 | 10.0 | 40 | 80 | 125.5 | 94.2 | 42 | 504 |

### 5.3.4 Correlation of Test Variables

Table 10 provides the correlation coefficients for the test and task variables for the combined sample of civilians and SARTechs. The high correlation (0.92) between time to complete the stretcher carry and time to complete the toboggan task suggests that those who performed well on the stretcher also performed well on the toboggan, and vice versa. Combined handgrip is the fitness variable most highly correlated with both SAR tasks (-0.85 for stretcher; -0.86 for toboggan). Curl-ups was not expected to correlate highly with other task variables due to its lack of variation induced by the cutoff of 100.

*Table 10. Correlation coefficients between test variables (transformed where necessary).*

| Variable | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Sex | 1 | | | | | | | | | |
| 2. mCAFT | -0.47 * | 1 | | | | | | | | |
| 3. Weight (tr) | -0.61 * | -0.12 | 1 | | | | | | | |
| 4. Chin-ups (tr) | -0.77 * | 0.63 * | 0.28 * | 1 | | | | | | |
| 5. Push-ups (tr) | -0.72 * | 0.66 * | 0.32 * | 0.83 * | 1 | | | | | |
| 6. Curl-ups (tr) | 0.33 * | 0.44 * | 0.08 | 0.52 * | 0.53 * | 1 | | | | |
| 7. Combined Handgrip (tr) | -0.86 * | 0.33 * | 0.70 * | 0.73 * | 0.69 * | 0.39 * | 1 | | | |
| 8. Vertical Jump (tr) | -0.70 * | 0.52 * | 0.34 * | 0.72 * | 0.71 * | 0.38 * | 0.67 * | 1 | | |
| 9. Stretcher Time (tr) (tr) | 0.78 * | -0.54 * | -0.53 * | -0.75 * | -0.78 * | -0.48 * | -0.85 * | -0.69 * | 1 | |
| 10. Toboggan Time (tr) | 0.80 * | -0.45 * | -0.62 * | -0.74 * | -0.74 * | -0.46 * | -0.86 * | -0.69 * | 0.92 * | 1 |

* Significant at P≤0.001; tr= transformed

**5.3.5 Modeling Stretcher Carry Time**

A predictive model for stretcher carry time in terms of test variables was developed (see Appendix H) using stepwise multiple linear regression with the transformed variables as identified in Table 10. The significant variables in the resulting model, in order of increasing significance, were curl-ups, push-ups, $VO_2$ max, and combined handgrip. A regression model was then estimated containing these variables plus a group indicator (SARTech vs. civilian) to adjust for group differences. This was adopted as the final predictive model for stretcher carry time. The percentage of variation in stretcher carry time (R-squared) explained by the 5 variables in the model is 82%, and the root mean squared error as a percentage of the mean stretcher carry time has a Coefficient of Variation = 19.1%. The high value for R-squared and the small value for Coefficient of Variation indicate a strong relationship between stretcher carry time and the selected test variables. The model equation expressed in terms of the beta coefficients (with P-values in parentheses) is:

$$\underset{}{\text{Stretcher*}} = 0.000 - \underset{(0.1223)}{0.051\ \text{Group}} - \underset{(0.0001)}{0.597}\ \text{Combined Handgrip*} - \underset{(0.0001)}{0.173\ VO_2\ \text{max}}$$

$$- \underset{(0.0001)}{0.209\ \text{Push-ups*}} - \underset{(0.1017)}{0.069\ \text{Curl-ups*}}$$

* denotes a transformed variable

#### 5.3.6 Modeling Toboggan Pull Time

A predictive model for toboggan pull time was obtained in a similar manner (section 5.3.5; Appendix H). In this case, the initial stepwise regression identified the same significant variables as in the equation for stretcher carry time. The final model with group indicator (SARTech vs. civilian) added had a percentage of variation explained equal to R-squared = 79%, Coefficient of Variation = 4.9%, and the model equation with beta coefficients is given by:

$$\text{Toboggan}^* = 0.00 - \underset{(0.1432)}{0.059}\ \text{Group} - \underset{(0.0001)}{0.654}\ \text{Combined Handgrip}^* - \underset{(0.0026)}{0.178}\ \text{Push-ups}^*$$

$$- \underset{(0.0471)}{0.090}\ VO_2\ \text{max} - \underset{(0.2077)}{0.050}\ \text{Curl-ups}^*$$

* denotes a transformed variable

The strength of the relationship for toboggan pull time is similar to that for stretcher carry time, and again combined handgrip is the major predictor.

#### **5.3.7 Curl-ups**

In an attempt to observe a wider range of performances on curl-ups, a slight adaptation was made to the Canadian Physical Activity, Fitness and Lifestyle Appraisal (CPAFLA) protocol. Rather than limit the scores to 75 (CPAFLA), the maximum number was set at 100. Despite this adaptation, 12% of the civilians and 61% of the SARTechs achieved this maximum score. Therefore, the data recorded for curl-ups were not useful in differentiating individual abilities, particularly among the high performing SARTech group. Results for standard CF military sit-ups, obtained from annual SARTech testing (1997), were substituted for curl-up scores in subsequent analyses to determine performance criteria involving only the SARTech population, as described in more detail in the next chapter.

# Chapter 6

# DEVELOPMENT OF THE PHYSICAL FITNESS TEST

## 6.1 Establishing the Gold Standard

In order to determine performance criteria for the predictor variables, gold standard times had to be established for both the toboggan pull and the stretcher carry tasks (see section 5.2.1). This was accomplished through the use of converging lines of evidence from: 1) Astrand and Radahl's predictions associated with prolonged aerobic work, and 2) work sample data for the toboggan and stretcher tasks. Given the specific requirements for SARTechs to sustain a workload consistent with the work samples for up to 2 hours, their working $VO_2$ should not reach 65% of their maximum. The work sample data from the 3 toboggan and stretcher tasks revealed an average working $VO_2$ of 30 ml/kg/min (Table 6). For this work load to represent 65% of maximum, the predicted $VO_2$ max would be approximately 46 ml/kg/min. The predicted failure rate in the SARTech sample associated with this $VO_2$ max was 31%. The time to completion associated with 31% failure rate in the SARTech sample was determined for both the toboggan and stretcher tasks. This resulted in gold standard times of less than 59 seconds for the toboggan pull task and less than 65 seconds for the stretcher carry task.

Use of the gold standard tasks and the 20-MSR as the annual physical fitness test for SARTechs would be a legitimate choice for the CF. However, given both the stated preference of the SAR group for a fitness test battery, as well as the space and equipment constraints associated with constructing and storing identical task simulations within each squadron, the ERG pursued the development of a predictive model for implementation.

## 6.2 Strategies for the Determination of Performance Criteria

Following establishment of the gold standards for the two tasks, it was necessary to identify a strategy for determining performance criteria for the three strength related predictor variables. The strategy of using the lowest physical fitness test scores associated with passing performance on the gold standards was rejected due to the characteristic unstable nature of extreme scores. Alternatively, given the stability of measures of central tendency, the ERG adopted a strategy whereby test scores corresponding to deviations from the mean were entered into the model equations S4 and T4 given in Appendix H, and the predicted task completion times were evaluated with respect to the gold standard times.

Table 11 lists the mean test scores as well as the scores corresponding to one and two standard deviations below the means for each of the three predictor variables. The predicted completion times for the toboggan pull and stretcher carry result from substitution of the test scores into the model equations S4 and T4. From these results it is clear that test scores equivalent to the mean minus one standard deviation lead to predicted completion times of 59 seconds (toboggan) and 69 seconds (stretcher). These values are similar to, and not faster than the gold standard times of 59 seconds (toboggan) and 65 seconds (stretcher).

*Table 11. Predicted toboggan and stretcher task times for three performance criteria.*

| Criteria | Combined Handgrip* | Push-ups* | Sit-ups | Predicted Toboggan Time | Predicted Stretcher Time |
|---|---|---|---|---|---|
| mean minus two standard deviations | 86.9 | 22.9 | 29.0 | 78 | 92 |
| mean minus one standard deviation | 98.8 | 34.0 | 37.0 | 59 | 69 |
| mean | 111.5 | 45.0 | 45.3 | 51 | 61 |

*All data is based on results from the Annual Fitness Testing 1997 (n=86);*
** denotes untransformed values of the transformed data*

## 6.3 The Compensatory Model

Results from the modeling exercise suggested that if performance floors were to be established they would correspond with the criterion "mean minus one standard deviation" for each of the three predictor variables. Specifically the floors would be scores of 99 for combined handgrip, 34 for push-ups and 37 for sit-ups.

The ERG identified two factors that resulted in a decision to move toward a compensatory model whereby, instead of invoking an absolute floor on each test, subjects would be allowed to trade off poorer performance on one test with superior performance on the remaining test items.

As a first consideration, SARTech work is highly varied by nature, due in part to the need to adapt to widely varying environments and rescue situations. Secondly, SARTechs work in teams, frequently in pairs, allowing the strengths of one team member to be traded off against the weaknesses of another.

These factors argue for basing the criterion of performance for the tests on a single combined score which is the sum of the scores on each of the four tests standardized to comparable scales. The effect of this strategy is that a variety of combinations of performance on the tests can lead to the same ultimate measure of fitness based on the combined score.

### 6.3.1 Development of the Scoring System

In determining performance criteria for the predictor tests, the goal was to develop a compensatory model which would permit tradeoffs between strengths and weaknesses on an individual basis. To accomplish this goal, a special scoring system was devised. In essence, test results for push-ups, sit-ups, combined handgrip and $VO_2$ max were expressed in units of standard deviations from the mean (yielding standardized scores) and were added across the four component tests to obtain a combined score. The standardized scores, rescaled to result in a combined score ranging from 0 to near 100, are displayed in tables in Appendix I. These tables provide all possible score values and can be used at the testing site to assign scores to each test result. The determination of a pass or fail would then be based on the combined score.

### 6.3.2 The Special Role of $VO_2$ max

It became clear that volume of oxygen consumption is the most important limiting physical factor for SARTech activities. This was apparent by the work sample data and by analysis of previous research on other physically demanding occupations such as Firefighters and U.S. Navy SEALs. As indicated by the work samples (section 4.3.1), a minimum performance level for $VO_2$ max is 44.6 ml/kg/min, corresponding to stage 8 on the 20-MSR. Therefore, in developing the performance criteria, the ERG wished to enforce a minimum requirement for $VO_2$ max. Thus, a $VO_2$ max value below the cutoff of 44.6 ml/kg/min will result in a failure of the entire fitness test, regardless of the achievement on the three strength related tasks (push-ups, sit-ups, and combined handgrip). In addition, the test scores for $VO_2$ max would be computed differently from those for the three strength related variables, as will be explained in section 6.3.3.

### 6.3.3 Construction of the Score Tables

For the three strength tests, push-ups, sit-ups and combined handgrip, the means and standard deviations for calculation of the standardized scores were computed from test results gathered during the annual physical fitness testing at Comox in 1997 (n=86). For this purpose, the test results were transformed to ensure validity of statistical procedures based on the normal distribution. A "test score" is derived for a particular result on a strength test as follows. The test result is first transformed by the normalizing transformation and is then standardized by the mean and standard deviation obtained as explained above. This yields a z-score corresponding to the strength test result. The associated "test score" which appears in tables in Appendix I is obtained from the z-score by adding 3 and multiplying the result by 5. These latter operations serve to yield positive test scores for all strength test results greater than 3 standard deviations below the mean and result in a combined test score for the four test variables in the range 0 to 108.8. Negative test scores are set to zero, limiting a contribution to the combined score only if the component score is in the passing range. These steps are demonstrated by the following formulas:

z-score = (test result - mean) / standard deviation

test score = 5 (z-score + 3), if positive;

0, if negative.

The results of these computations for a range of results on the strength tests appear in tables in Appendix I.

The test scores for $VO_2$ max are computed differently. Because the actual $VO_2$ demands for SARTech activities could be determined from work samples, the minimum required $VO_2$ max was found to be 44.6 ml/kg/min corresponding to stage 8 on the 20-MSR. This value is used in place of the mean in computing z-scores. The standard deviation for $VO_2$ max was computed from the 1997 annual fitness test (n=86). The z-score for a particular $VO_2$ max result is calculated by subtracting 44.6 and dividing by the standard deviation. The corresponding test score is obtained as 5 times the z-score, except that negative values are set to zero (i.e., if the $VO_2$ max falls below 44.6 ml/kg/min). These calculations are summarized as follows:

z-score = ($VO_2$ max - 44.6) / standard deviation

test score = 5 (z-score), if positive;
0, if negative.

As a reminder of the separate $VO_2$ max requirement, the corresponding scoring table in Appendix I shows the value "fail" for 20-MSR stages 7.5 or below, even though the value 0 should be the contribution of $VO_2$ max to the combined score.

The performance criterion is based in part on the combined score which is the sum of the test scores for the three strength tests and $VO_2$ max. The ERG determined that a value of 30 for the combined score is the requirement for passing this component of the maintenance standard. A score of 30 is equivalent to an average performance of approximately one standard deviation below the mean for the three strength tests and completion of stage 8 on the 20-MSR. The special role of $VO_2$ max (section 6.3.2) requires that the performance criterion for the physical fitness test be stated as follows:

| |
|---|
| a combined score of 30 or more for the four fitness tests AND a score of 44.6 or more on the $VO_2$ max component (20-MSR stage 8 or higher). |

To illustrate the impact of the compensatory model, Table 12 presents hypothetical scores associated with a number of different performance levels on the three strength predictor variables. The score for $VO_2$ max is not included in Table 12 and is discussed separately in this section for the purpose of demonstrating its impact on the overall test score.

As shown in Table 12, test results approximately equivalent to two standard deviations below the mean on each of the three variables would achieve a total strength score in the order of 15. Meanwhile, performances nearly one standard deviation below the mean, or at the mean itself, would achieve scores of approximately 30 and 45, respectively.

*Table 12. Test scores based on various hypothetical performance levels for the three strength variables.*

| Performance Level | Push-ups | Sit-ups | Combined Handgrip | Total Strength Score ($\Sigma$ Test Scores) |
|---|---|---|---|---|
| Approximately Mean minus 3 Standard Deviations | 17 | 20 | 78 | |
| **Test Score** | 0 | 0 | 0 | **0** |
| Approximately Mean minus 2 Standard Deviations | 25 | 29 | 88 | |
| **Test Score** | 4.8 | 5.2 | 5.1 | **15.1** |

| | | | | |
|---|---|---|---|---|
| Approximately Mean minus 1 Standard Deviation | 34 | 37 | 99 | |
| **Test Score** | 9.9 | 10 | 10.1 | **30** |
| Approximately Mean | 44 | 45 | 111 | |
| **Test Score** | 14.9 | 14.8 | 15 | **44.7** |
| Approximately Mean plus 1 Standard Deviation | 56 | 53 | 124 | |
| **Test Score** | 19.7 | 19.7 | 19.7 | **59.1** |
| Approximately Mean plus 2 Standard Deviations | 69 | 61 | 140 | |
| **Test Score** | 25.2 | 24.5 | 24.9 | **74.6** |
| Approximately Mean plus 3 Standard Deviations | 83 | 70 | 158 | |
| **Test Score** | 30.1 | 29.9 | 30.1 | **90.1** |

A score of 30 can be obtained by numerous other combinations of scores on the four predictor tests. Table 13 represents an illustration using hypothetical data of how $VO_2$ max can compensate for the strength tests to obtain a passing score (subject 3). Also demonstrated is the impact of a "fail" on the $VO_2$ max test on the overall performance of the model. The scores for subject 2 demonstrate that a "fail" on the $VO_2$ max component results in an overall "fail" on the test regardless of the fact that a combined score of 39.8 was obtained.

*Table 13. Case studies based on various performance levels for the four predictor variables.*

| **Case** | **Push-ups** | **Sit-ups** | **Combined Handgrip** | **20-MSR ($VO_2$ max ml/kg/min)** | **Total Score (Sum of Test** | **Pass/ Fail** |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | **Scores)** | |
| **Subject 1 Performance Level** | 44 | 29 | 124 | stage 8 (44.6) | | |
| **Test Score** | 14.9 | 5.2 | 19.7 | 0 | 39.8 | **Pass** |
| **Subject 2 Performance Level** | 44 | 29 | 124 | stage 6 (38.6) | | |
| **Test Score** | 14.9 | 5.2 | 19.7 | 0 (fail) | 39.8 ** | **Fail*** |
| **Subject 3 Performance Level** | 34 | 37 | 93 | stage 9.5 (49.1) | | |
| **Test Score** | 9.9 | 10 | 7.5 | 4.7 | 32.1 | **Pass** |
| **Subject 4 Performance Level** | 34 | 37 | 93 | stage 8 (44.6) | | |
| **Test Score** | 9.9 | 10 | 7.5 | 0 | 27.4 | **Fail** |
| **Subject 4 Performance Level** | 52 | 64 | 120 | stage 11 (53.6) | | |
| **Test Score** | 18.4 | 26.3 | 18.3 | 9.4 | 72.4 | **Pass** |

** Fail is based on $VO_2$ max results*

## 6.4 Impact Analysis

### 6.4.1 $VO_2$ max

The impact of a performance objective equal to 44.6 ml/kg/min for $VO_2$ max on the current SARTech population is depicted in Figure 6. Based on their 1997 Annual Fitness Test results (n = 86), 15 operational SARTechs would not have met this performance objective resulting in a 17% failure rate. Of these, however, 8 were within one 20 MSR stage (equivalent to 3 ml/kg/min) of attaining this objective and could most likely attain the cutoff with more effort or physical training.

*Figure 6. Frequency distribution of SARTech $VO_2$ max results from 1997 EXPRES testing (n = 86).*

**6.4.2 Compensatory Model**

Similarly, the combined scores for the three predictor variables that represented an average performance level of the mean minus one standard deviation would also result in a 17% failure rate across the 86 operational SARTechs tested. The convergence of findings related to impact in addition to the association between this level of performance on the tests and the predicted toboggan and stretcher completion times led to the establishment of 30 as the minimum cutoff score.

Using the results from annual physical fitness testing, scores based on the three muscular strength tests were calculated for 86 operational SARTechs. Figure 7 illustrates the distribution of the obtained scores. As expected, the majority of the scores range from 30 to 60 which reflects performances within one standard deviation above and below the mean on each variable. Very few SARTechs obtained scores less than 30 (n = 6) or greater than 60 (n = 4).

*Figure 7. Frequency distribution of scores based on three muscular strength tests for 86 operational SARTechs.*

Evaluation of the $VO_2$ max results for the 6 SARTechs who scored less than 30 on the three strength tests (Figure 7) revealed that none achieved a high enough $VO_2$ max value to obtain passing scores for the compensatory model. In fact, only 1 of the 6 “failing” SARTechs passed the $VO_2$ max cutoff (44.6 ml/kg/min, stage 8). Since this $VO_2$ max value is the minimum requirement, the assigned score of 0 (Appendix I) did not raise the combined score for the compensatory model to 30. Conversely, evaluation of the 76 SARTechs who obtained scores between 30 and 60 on the three muscular strength tests (Figure 7), revealed that 10 would receive “failing” scores on the $VO_2$ max test. Therefore, these SARTechs would fail the compensatory model and thus the total number of overall failers for the model would be equal to 16 SARTechs (a 19% failure rate). These examples illustrate the impact of $VO_2$ max performance on the overall success of passing the compensatory model and the maintenance standard.

## 6.5 Rationale for Gender Neutral Standard

Given that there are a variety of methodologies related to physical maintenance standards currently in use within the CF, it is prudent to summarize the logic related to the development of a common standard for SARTech personnel. First, it is clear that there are *bone fide* occupational requirements associated with the successful completion of the SAR job profile. Minimum physical performance attributes are essential in this occupation. Second, the fact that a common set of predictor variables was identified when both group and gender were controlled for, as well as when group and gender status were ignored, reinforces the choice of a common set of test variables. Third, the introduction of the compensatory model allows for variability across all subjects on individual tests without compromising the integrity of the overall test which holds the fundamental relationship with gold standard performance times. In this way, individual (or group) differences have the capacity to be accommodated, while confidence in overall competency related to job performance can be maintained.

# Chapter 7

# RECOMMENDATIONS

## 7.1 Introduction

The goal of this contract was to develop a bona fide physical maintenance standard for CF Search and Rescue Technicians. The work reported represents an undertaking consistent with the rules governing the establishment of BFORs as set out by the Government of Canada. The ERG makes the following recommendations with respect to the implementation of performance objectives for all operational SARTechs.

## 7.2 Performance Objectives

Based on the work presented in this report, the ERG recommends a physical maintenance standard comprising the following elements:

### 7.2.1 Maximal Oxygen Consumption

From the assessment of the SARTech job through work samples, the ERG recommends a minimum $VO_2$ max of 44.6 ml/kg/min for all operational SARTechs. This requirement is equivalent to the completion of stage 8 on the 20 Metre Shuttle Run test.

### 7.2.2 Muscular Strength and Endurance

Based on the analyses from the validation study, the ERG has demonstrated that sit-ups, push-ups, and combined handgrip are significant predictors of performance on physically demanding SAR tasks.

Using these predictor variables, along with $VO_2$ max, the ERG has devised a compensatory model for the assessment of muscular strength and endurance capabilities of CF SARTechs. The ERG recommends an overall score of 30 as the minimum passing score calculated by the scoring charts included in Appendix I.

### 7.2.3 Lifting Task

In addition to the performance of push-ups, sit-ups, and combined handgrip, the ERG recommends the inclusion of a lifting task in the SARTech maintenance standard. Although the lifting task is classified as a trade standard, it has been determined to be an important physical component of a SARTech's job and therefore should be included in the physical fitness testing battery. It is suggested that the task be as authentic as possible and simulate lifting heavy equipment onto an aircraft under standardized but real conditions. The protocol should involve lifting a 40 kg extrication kit into a Hercules aircraft without the use of outside aids or a time limit. Depending on the availability of the appropriate aircraft, a table can be constructed with a height of 1.5 m for use in this task.

### 7.2.4 Surface Swim

Although the surface swim was excluded from assessment due to technological limitations, the ERG recognizes that the ability to perform this task is essential to the SARTech job. Similar to the lifting task, the swim test is part of the annual trade requalification battery. Since it is recognized as an important physical fitness component of a SARTech's job, it should be tested as part of the annual physical fitness testing. As such, the ERG recommends that the 1000 m surface swim remain a part of the SARTech maintenance standard. Since the performance of this task is largely affected by the environmental conditions, and since no objective information was collected during this study, the ERG recommends that this be a pass/fail exercise only (i.e. no time limit).

## 7.3 Implementation Schedule

It is suggested that a one year implementation period be adopted to allow SARTechs to improve their fitness levels and for familiarization with the new physical maintenance standard. SARTechs should be provided with information on the new test battery including protocols and cutoff scores in order to develop an awareness of the new standard. A user friendly device such as a conversion wheel could be provided to the SARTechs to allow for quick computation of test scores.

For the first year following the acceptance of this report, the current maintenance standard should be used alongside tests introduced in the new standard. However, during this time period, a SARTech's fitness should not be evaluated based on his or her performance on the new maintenance standard.

## 7.4 Testing Schedule and Protocol

1) Prior to participation in all components of the physical testing battery (including swim test and all retests), SARTechs must complete a health appraisal questionnaire, and have resting heart rate and blood pressure assessed.

2) The 20-MSR, the muscular strength tests (compensatory model), and the lifting task should be completed on the same day. The following guidelines should be adhered to:

    1) The 20-MSR should be the first test segment completed by SARTechs.

2) The muscular strength tests and the lifting task should only be performed after a 30 minute recovery period following the 20-MSR.

3) The swim test should be conducted no sooner than 24 hours and no later than 60 days after the main physical testing battery. A separate health appraisal questionnaire must be completed prior to the swim test if it is conducted more than 7 days following the 20-MSR.

4) Only third-party trained and qualified staff should administer the test protocol.

## 7.5 Retest After Remedial Training Option

If a SARTech does not meet the passing standard for the 20-MSR, the compensatory model, the lift task or the swim test, it is recommended that he or she be given the option to be retested following a training program. If a SARTech does not pass the compensatory model, all three of the strength tests as well as the 20-MSR must be performed again. The decision to provide this retest option after remedial training should be made by the CF and time deadlines should correspond to current CF guidelines.

## 7.6 Attempting the Gold Standard Option

If after remedial training a SARTech is still unable to attain a passing score for the compensatory model, it is recommended that he or she be given the option to perform the "gold standard" from which these strength predictor tests have been derived. A pass would involve performing the actual toboggan task in less than 59 seconds and the stretcher task in less than 65 seconds.

## 7.7 Incentives

The implementation of an incentive program is recommended to reward those SARTechs who scored in an elite category with respect to physical fitness level. After analyses of the data collected for this report, it is apparent that only 9 SARTechs obtained a passing score on the 20-MSR and a score above 65 on the compensatory model. Therefore, it is suggested that individuals in this category in the future be recognized for their exemplary performance.

## 7.8 Future Considerations

Due to the innovative nature of the aforementioned compensatory model, the physical maintenance standard should be reevaluated in the future. Therefore, it would be of benefit if the results of this physical testing were collected and archived. If this is problematic for the CF, PSA should consider contracting out this task. It is recommended that the SARTech performance scores be reexamined in 5 years time to analyse the distribution of scores and reassess the fitness standard.

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