Development of *Bona Fide* Physical Fitness Standards for Canadian Forces (CF) Search and Rescue Technician (SAR-Tech) Applicants

Final Report

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Chapter 1
Overview and Executive Summary

This project began in 2007 and was completed in February 2011. The purpose of the project was to develop new physical fitness tests and standards for entry to the QL5A course based at the Canadian Forces School of Search and Rescue (CFSSAR) at CFB Comox. The project was completed in several phases which included a literature review (Appendix A), analysis of the physical demands and impact of the QL5A course (Chapters 2 and 3), development of new tests with emphasis on establishing acceptable validity and reliability (Chapter 4), establishment of standards for both screening and selection (Chapter 5), and, a series of recommendations for implementation (Chapter 6). In addition, the logistical feasibility of administering the test was demonstrated on several occasions, including twice during the Pre-Selection process where in 2010 and 2011, 24 and 28 candidates were tested, respectively.

Researchers from the University of Alberta (SR Petersen and MK Stickland) submitted a research proposal in response to the request for proposals issued by the Canadian Forces Personnel Support Agency (CFPSA) on January 25, 2007. CFPSA has since been renamed as Director General Personnel and Family Support Services (DGPFSS). The research proposal was reviewed and accepted by DGPFSS and the research contract was finalized early in the summer of 2007. A third researcher from the University of Victoria (D Docherty) was invited to join the research group as a co-investigator.

The first step in the project was to identify a project management team (PMT) which consisted of representatives from the research group, DGPFSS, the Canadian Forces School of Search and Rescue, SAR-Tech Operations (1 Cdn Air Div HQ), Director Air Personnel Strategy, Judge Advocate General and Director of Air Personnel Management. The PMT met in Ottawa at least annually throughout the project. At each meeting, the researchers briefed the PMT on progress and plans for the next stage of the research. Key stakeholders were, therefore, kept apprised of the project and had the opportunity to provide feedback to the researchers. The researchers were in frequent contact with CFSSAR as all aspects of the project that involved SAR-Tech personnel were coordinated through the school. The researchers interacted with the SAR trade (e.g., SAREX) and other training units (e.g., FDU-P) as appropriate.

The main participants in the research were members of QL5A Courses 41, 42 and 43. In various phases, CFSSAR instructors, FDU-P instructors and operational SAR-Techs contributed information or acted as volunteers to assist with the project. This research could not have been done without the cooperation of these participants. All research subjects participated on a voluntary basis and were informed of the procedures and the right to withdraw at any point without prejudice. Each phase of the project was approved by the appropriate research ethics board at the University of Alberta. In addition, those phases that involved Canadian Forces personnel were also approved by the research ethics board at DRDC, Toronto.

The first phase of the project was devoted to analysis of the physical demands of the QL5A course. Researchers monitored students in Courses 41 and 42 during parts of the course that had previously been identified as physically challenging by the instructional staff at CFSSAR and by the graduating members of Course 40. The results of the physical demands analysis are described in detail in Chapter 2. In addition, physical fitness, stress and fatigue levels were monitored regularly throughout Course 41. This was undertaken due to anecdotal concerns about the cumulative effects of the physical challenges of training. However, no significant changes in measures of fitness, stress or fatigue were observed between the beginning (August 2007) and the end (June 2008) of this course (Chapter 3).

The second phase of the project focused on development of physical fitness tests that accurately reflected the physical challenges documented in Phase I. With approval from the SAR trade, a “task simulation” approach to the design of new tests was adopted to better match the physical challenges in the tests to the physical challenges of the QL5A course. Test development was guided by the requirement that the test battery had to be logistically feasible such that the tests could be administered at most CF bases by PSP staff. Each test was developed in stages that included pilot work in our laboratory at the University of Alberta, followed by pilot testing at CFSSAR. The researchers interacted with and received feedback from the SAR trade and PSP staff at 19 Wing at each stage of test development. Where appropriate, this feedback was incorporated into subsequent versions of the tests. After several repetitions of the cycle, test designs were finalized. Factors such as equipment, facility and personnel requirements were matched to existing or easily obtainable resources without compromising test validity.

Three tests were developed to evaluate the critical aspects of physical fitness required for the QL5A course. Aerobic endurance and overall work capacity is measured during the Treadmill Test. The main outcome is elapsed exercise time on the treadmill while carrying a 25-kg pack. The physical demand increases at regular intervals during the test. The longer the duration of the test, the greater the physical work capacity of the individual. Muscular strength and endurance is evaluated by performance on the Equipment Carry Test. The test subject must "shuttle" weights that are representative of the weight of equipment routinely lifted and carried during training, back and forth over a simple "out-and-back" course. Lifting and carrying the weights eight times over the 40-m course was found to be a very good replication of the kind of work involved in loading aircraft, vehicles and boats during search and rescue training. The main outcome of the Equipment Carry Test is the elapsed time required to safely complete the course. Water-based fitness is assessed by performance during a 750-m pool swim. The use of fins shifts the emphasis for propulsion from the upper- to the lower-body musculature, which better simulates the kind of swimming that is done on course during search and rescue training. The main outcome of the Swim Test is the time required to complete the distance of 750 m of swimming. Warm-up, cool-down and transition times between tests were standardized.

Validity and reliability of the tests was found to be very good. As noted, feedback from the SAR Trade was incorporated into test design whenever possible. The final confirmation of validity came from the graduating members of Course 43 who, by virtue of their experience on course, were considered expert judges. Following the completion of the test battery, each student was debriefed with a standardized questionnaire. The results indicated very strong agreement that the new tests were an accurate reflection of the kind of fitness required for success on course. The sub-study that evaluated test reliability revealed several important results. First, there is virtually no "learning effect" on test performance and the first attempt at a test often produces the best score. Second, the results provide guidance on biological variability in performance on the Treadmill, Equipment Carry and Swim tests. When the test is implemented, DGPFSS should consider using the reported confidence intervals as justification for re-test when applicants score very close to the minimum standard.

During the third phase of the project standards for screening (pass/fail) and selection (ranking passing scores) were established. Various methods were used to determine the minimum scores which denote the performance level required to pass the individual components of the Selection Test (Treadmill, Equipment Carry and Swim Tests). Care was taken to match, as well as possible, the minimum standard for performance on each test with the minimal expectations for performance during training. Selection of students for the QL5A course involves a rigorous process to identify the best possible candidates for the SAR trade. Fitness is but one component of the process but is considered important. Consequently, recognition of excellent performance is a priority for CFSSAR. Selection standards were developed by using test scores from successful QL5A students as a guide.

Logistical feasibility of the new Selection Test has been demonstrated on numerous occasions at different locations (e.g., University of Alberta, CFB Comox, CFB Edmonton). It is expected that at the point of application tests will be conducted on relatively small numbers of applicants, perhaps one or two at a time. The time required to conduct the test is approximately two hours. This allows sufficient time for check-in, equipment fitting, completing each test with standardized warm-up and cool-down, standardized transition times between tests, supervised recovery and check-out. In order to test a QL5A class at CFB Comox, a period of approximately four hours was required, with groups of four students starting every 30 minutes. The largest group tested was approximately 30 candidates at Pre-Selection at CFB Edmonton. A group of this size can be tested efficiently in approximately eight hours. While this time-frame is considerably longer than required by the “old test”, the amount and quality of information on physical fitness relevant to the QL5A course is substantially greater. While the resource implications are greater than the previous test, this is still a very simple and feasible test to administer. More importantly, as convenient as the old test was, there was absolutely no evidence of validity or reliability to justify its’ continued use. The persons responsible for testing applicants and selecting candidates for the QL5A course (PSP and CFSSAR staff) will require time to learn to administer the new tests. However, the new test battery can be used with much greater confidence to screen and select suitable applicants to enter the SAR trade.

Chapter 2
Physical Demands Analysis of the QL5A Training Course

Introduction

This chapter summarizes the data collected from August 2007 to February 2009. During this time, one or more members of the research team shadowed the Search and Rescue Technician (SAR-Tech) students throughout the various phases of their training. For each phase this process involved one or more days of data collection at the training location. During this time data were collected through the use of questionnaires, heart rate and physical activity monitors, as well as the researcher's observations, photographs, video and field notes.

For the 2007-08 class, a researcher attended all but one of the training phases; the Arctic phase was not observed due to logistical difficulties. The Winter, Arctic, and Dive phases were revisited with the 2008-09 class. This served to provide supplemental information to the data collected previously, or alternately, the opportunity to obtain data under different conditions.

Heart rate data were analyzed according to a classification designed for analysis of physically demanding occupations (Astrand et al, 2003) and were classified into the categories outlined in Table 2-1. When possible, heart rates were related to specific tasks carried out during the observation period to present a specific workload associated with a task/activity. When this was not possible, daily averages of heart rate are provided, as well as a description of the activities observed and an analysis of the heart rate by work zone.

Table 2-1. Classification of heart rate zones.

Description of work	Heart rate (beats· min^{-1})	
Classification	Astrand *et al*, 2003	Current adaptation
Light	<90	≤90
Moderate	90-110	91-110
Heavy	110-130	111-130
Very heavy	130-150	131-150
Extremely heavy	150-170	≥151

Medical Phase -2008

SAR students completed a 15-week medical phase of the training course in order to qualify for their Primary Care Paramedic (PCP) certification during September-December. During this phase, SAR students participated in structured physical training (PT) that was lead by PSP staff. This PT included 2 outdoor circuits per week, with two pool sessions a week and one day of choice of sport or run. The main circuits were plyometrics and running. The pool sessions averaged between 1500-2500 meters from circuits incorporating strength exercises and endurance swims.

Winter Operations - 2009

Touring

On January 8 and 9, students and instructors travelled to the camping and the training areas on alpine touring equipment. Fifteen students participated in these exercise (one student did not participate due to injury). Students were equipped with standard alpine touring equipment (mountaineering boots, skis with skins and poles) for this portion of the course (Plate 2-1, Table 2-2).

Table 2-2. Weight of equipment for winter operations.

Item	Weight (SD) kg	Range kg	n
Day pack	8.5 (1.3)	7.1-9.9	5
Overnight pack	22.8 (2.4)	20.4-26.0	4
Skis	4.9 (0.1)	4.8-5.1	5
Poles	0.56 (0.02)	0.5-0.6	5

Combined weight

Day trip equipment	14.0 kg
Overnight Equipment	28.3 kg

Over a two day period (January 8 and 9, 2009), three distinct ski hikes (simplified as “hikes”) were observed; skiing from the drop off area to the designated training area on the morning of January 8th (Jan-8-AM), hiking back to the pickup area on the afternoon of the 8th (Jan-8-PM), and hiking to the camp area on the morning of January 9th (Jan-9-AM). The hike out after the overnight camp on January 10 was not observed.

Each of these hikes had distinct characteristics that are outlined in Table 2-3 and are also described below. Data are presented as mean (± SD, range).

Jan-8-AM: Students were divided into two groups of seven (7) and eight (8) individuals; each group had its own route with a common end point, the training area. Students carried a day pack of equipment for activities throughout the day, including the equipment described above (Table 2-2). This hike was 101 or 114 minutes in length, depending on the group, and was characterized by frequent stops by both the group as a whole and the individual students. Stops were due to equipment failure, navigational issues (map checks, compass readings), and water or food breaks. These breaks lasted between one and eight minutes, and individual stops by students are not reflected in the present data. The hike crossed varied terrain including sections of steep and gradual uphill, downhill, and flat stretches. During this hike the students had to break trail to proceed. Due to the difficult nature of trail-breaking, students frequently switched out of the position at the front of the group. For the length of the hike, the average heart rate was 119 beats·minute^{-1} (Table 2-3), or 65 % of known maximal heart rate.

Jan-8-PM: Students left the day activity site as one group and returned to the drop off point from the morning. During this hike the students followed their earlier tracks. With no navigational issues and by following a developed trail (*i.e.* not breaking trail themselves) the group covered the distance relatively quickly without any stops in 44 minutes. Heart rate averaged 145 beats·minute^{-1} (Table 2-3), or 76 % of known maximal heart rate. The overall heart rate response to this exercise is highlighted in Figure 2-1.

Jan-9-AM: Students traveled in one group and carried an overnight pack for this ski-hike. The terrain was predominately flat or downhill, with one uphill section at the end of the hike. During this hike, the students travelled along a developed trail, with few group stops. Heart rate over the 32 minute hike averaged 111 beats·minute^{-1}, or 59 % of known maximal heart rate (Table 2-3).

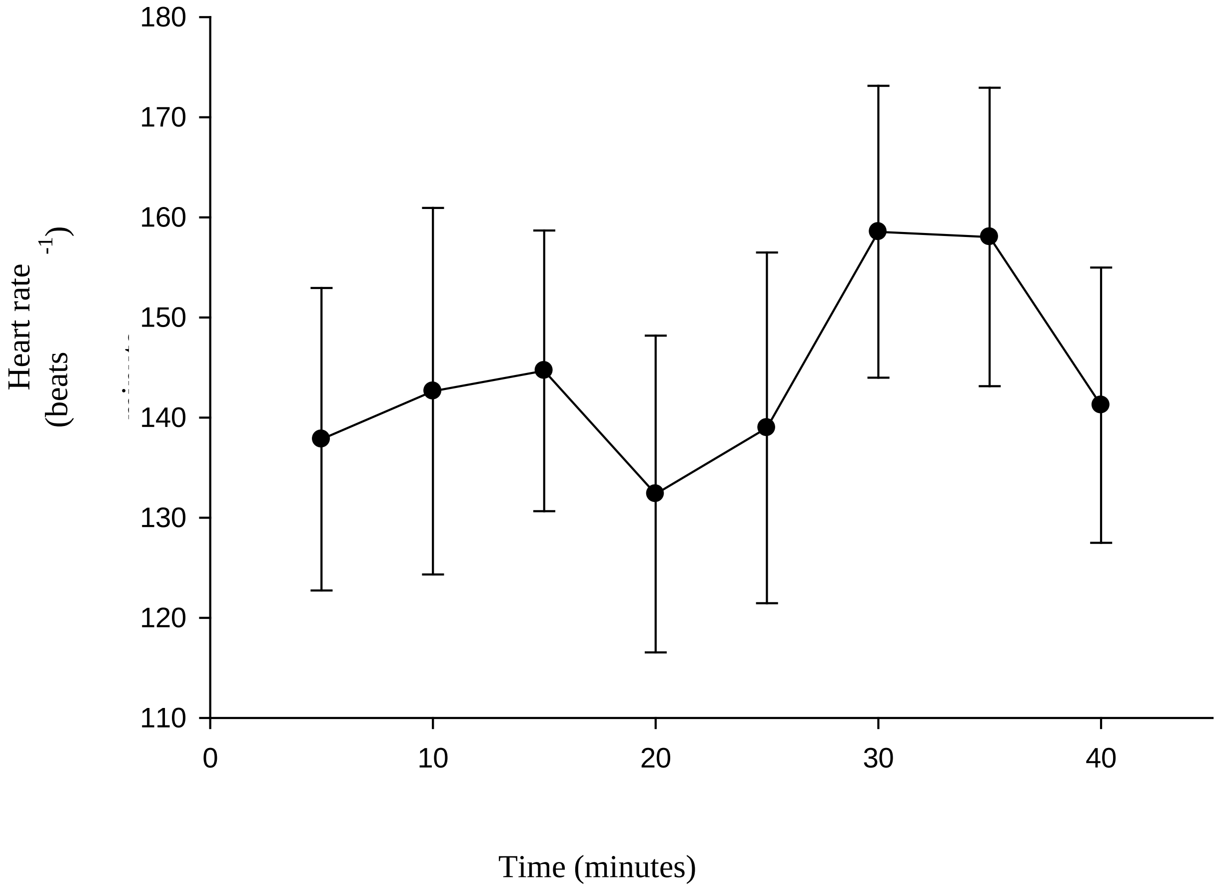

Figure 2-1. Heart rate response of SAR-Tech students to a 44 minute ski hike on January 8, 2009. Five minute averages of heart rate are presented ± SD.

Table 2-3. Heart rate response to ski touring

	Total length (min)	Number of group stops	Average HR (SD) (beats·minute^{-1})	Range	% max HR (SD) if known	Range
Jan-8-AM	101-114	3 or 5	119 (21)	69-180	65 (11)	40-97
n			13		12	
Jan-8-PM	44	None	145 (18)	98-201	76 (11)	51-96
n			10		9	
Jan 9-AM	32	1	112 (22)	69-171	59 (12)	36-91
n			14		13	

Individual Ski bouts

In order to characterize the demands of continuous skiing, group stops were omitted from the skiing data discussed above and in Table 2-3, and the resulting bouts of continuous skiing were analyzed for heart rate response and are presented in Table 2-4. In total, the 11 bouts analyzed ranged from 5-44 minutes, with an average length of 17 minutes. Values in Table 2-4 represent the mean response for the group during each bout of continuous skiing. Overall, heart rate was 121 beats·minute^{-1} or 66% of known maximal heart rate during continuous skiing.

Table 2-4. Summary of continuous ski bouts

Number of bouts	11
Average bout length (min)	17
SD	11
Range (min)	5-44

Average values	Absolute heart rate	Percent of max heart rate
HR (beats·min^{-1})	121	66
SD	17	9
Range	87-165	46-88

Heart rate zone assessment of total ski time

A total of 1393 minutes of heart rate data from 15 SAR-Tech students during skiing were obtained over the two day period. This includes all available data from the 15 students.

Table 2-5 shows the relative time spent at levels according to the above classification of heart rate zones. The majority of the documented ski time was characterized by heart rates between 111-130 beats·minute^{-1} (heavy work), and only slightly less time was spent between 131-150 beats·minute^{-1} (very heavy work) (31.1% vs. 27.4%). Furthermore, similar percentages were spent in the second lowest and highest heart rate zones, 91-110 beats·minute^{-1} (moderate work) and >151 beats·minute^{-1} (extremely heavy work), 18.4% and 19.5% respectively. The lowest heart rate zone, <90 beats·minute^{-1} (light work), represented the heart rate response to 3.5% of total ski time.

Table 2-5. Relative fraction of total ski time (1393 min) spent in specific heart rate (HR) zones

Work Level Classification	HR Range (beats·minute^{-1})	Fraction of ski time (%)
Light	≤90	3.5
Moderate	91-110	18.4
Heavy	111-130	31.1
Very heavy	131-150	27.4
Extremely heavy	≥151	19.5

Transceiver searches

Transceiver searches fell into two categories; single transceiver searches or group transceiver searches.

Single transceiver searches: This search was carried out during practice times on January 8th and as part of a skill assessment for this phase on January 9th. Students performed a transceiver search dressed in winter gear (no skis or pack), using their own transceiver and a probe and shovel. Searches took place in an area approximately 30 m x 30 m, of hard packed and easily walkable snow terrain set aside specifically for this purpose. The minimum standard for a search time was five minutes to locate and extract a pack that contained a transceiver. The pack was buried approximately 10-15 cm below the surface of the snow and was not visible. The searches lasted between two and 10 minutes and elicited heart rates of 121 beats·minute^{-1} (Table 2-6). This search intensity corresponds to 65% of known maximal heart rate. As evident from the search times, the standard search time criterion was not met for all of the observed searches.

Table 2-6. Length of and heart rate response to individual and group transceiver searches.

	Individual		Group	
Total time (minutes)	78		62	
Number of searches	13		14	
Average search length	5.8		4.4	
SD	2.6		1.9	
Range	2 - 10		2 - 7	
	Overall	Per search	Overall	Per search
Average HR (beats·minute^{-1}) (SD)	120 (20)	121 (19)	122 (23)	115 (18)
Range	86-158	95-157	78-182	91-147
Average % maximum HR (SD)	63 (10)	63 (9)	66 (12)	62 (9)
Range	46-85	52-82	44-92	49-78

Group transceiver searches: These were carried out on January 8. Groups of 2-4 students performed a transceiver search as described above. During group searches, one or more students used a transceiver to locate a pack containing another transceiver while others followed with probes and shovels to assist with digging up the pack. These searches were not subject to a time limit, and each lasted 4.4 minutes. During group search exercises, heart rates averaged 115 beats·minute^{-1}. This is equivalent to 61% of known maximal heart rate (Table 2-6).

Student Comments

A summary of student comments is presented in Table 2-7. All responses are included in the table, however topics that appeared more than once are discussed in the following section. Temperatures on January 8-10 were 0 to -8ºC and the snowpack was 120 cm deep.

The student's descriptions of the intensity of the activities corroborates with the earlier physiological descriptions of the same events. Skiing, and skiing under load were rated as both light and hard aerobic. As illustrated in Tables 2-3 and 2-4, the range of intensities in workload experienced by the students was varied depending on the nature of the hike (*i.e.* continuous or with breaks) which coincides with the varied perceptions of the students. Pulling a casualty on a stretcher was also rated as a hard aerobic activity (n=2). Lifting and hoisting tasks that the students judged to be moderate to heavy were carrying casualties (n=3) and carrying or lifting backpacks (n=2). Carrying backpacks was also classified as a light to moderate task (n=3), as was digging for buried packs or casualties. Pack weights are presented in Table 2-2, the ~14 kg difference in weight between a day and an overnight pack accounts for the dual classification of carrying backpacks.

The most frequently reported physically challenging aspect of the course was skiing while carrying a backpack, and skiing in general was the second most frequent response (7 and 4 responses respectively). Acquisition of skiing skills was rated the most challenging aspect of this phase (n=6). Skiing with a load (n=2) and pulling an improvised stretcher were also rated as the most challenging aspect (n=2).

Environmental factors did not increase the perception of physical demands by the majority of the students (n=8, no and N/A combined). The remaining students reported that adjusting to changing weather and temperature (n=3), heavy snow impeding travel (n=2), and being wet (n=2) increased the physical demands for this portion of the course.

Overall it appears that skiing was perceived as the most challenging aspect of this course. The combination of learning the skill of backcountry skiing, and carrying a moderate to heavy load while doing so provided the greatest physical and overall challenge for the majority of students (n=11, n=8, respectively). Although environmental factors did not increase the reported difficulty of this phase for most of the students, those that did find the environment a challenge listed adjusting to changing weather and conditions as the main environmental factor. The student's comments highlight some aspects of this phase that are not easily address by the physiological data collected (*i.e.* personal interaction with the environment). However their reported experiences with the physical challenges of this phase concur with the preceding description of this phase.

Student comments - 2008

Feedback from SAR-Tech students of Class 41 (2008) are presented in Table 2-7, overall there is general agreement in terms of classification of physical tasks over the two years**.** Over January 10 and 11, 2008, temperature ranged from 0 to -15°C and the snowpack was above average depth (300 cm).

Unique to 2008 are the inclusion of skiing uphill and digging to hard aerobic tasks (n=4, n=3). The use of new equipment was more frequently reported as a physically challenging task by students in 2008 *vs.*2009 (7 and 1, respectively). It is unlikely that this difference is due to a skill discrepancy between the two classes as the acquisition of skiing skills was reported as the most physically challenging aspect by 6 students in 2009. Breaking trail and long periods of work (n=2, n=2) were reported as physically challenging only in 2008, and breaking trail, though not reported in 2009, was considered the most physically challenging portion of the course by 4 students in 2008. Increased difficulty due to cold was reported by 7 students, and altitude increased the physical difficulty for 3 students during winter operations.

The general sentiment of the student's perceptions of winter operations is similar from 2008 to 2009. Different ambient temperatures and snow conditions over the two years can account for some of the differences in patterns reported. Specifically, a deeper snowpack in 2008 likely contributed to the greater perceived difficulty of breaking trail, while lower temperatures would account for the perception of cold increasing the difficulty of this phase (Table 2-8).

Summary and Conclusions

To complete the winter operations portion of the course, individuals require a level of fitness that will enable them the ability to carry out aerobic activity at 76% of maximum heart rate for up to 44 minutes. This is equivalent to the longest and most intense bout of continuous exercise experienced during this portion of the course. This coincides with student comments that skiing with a pack was the most physically challenging aspect of the course. Shorter (mean 17 minutes, Table 2-4), less intense (mean 66% of HR_{max}, Table 2-4) bouts are also encountered during this portion, however the continuous bout poses a greater physical challenge. In addition to aerobic fitness, the ability to travel with a heavy pack (up to 28.3 kg, Table 2-2) is also essential to carry out the winter operations training.

Table 2-7. Summary of student descriptions of aspects of fitness challenges during winter operations

Description	Frequency	
	2009	2008
Light aerobic		
Skiing	3	6
Skiing with a pack	3	
Not challenging	1	
Mostly everything	1	
AT skis over gentle terrain	1	
Keeping warm		1
Hiking		1
Breaking trail		1
Hard aerobic		
Skiing with a pack/load	6	10
Pulling casualty on stretcher	2	
Somewhat	1	
Skiing uphill		4
Digging		3
Anaerobic		
Challenging	1	
Transceiver searches	1	
Digging victims out of snow	1	
Light to moderate lifting/hoisting		
Backpack carrying	3	12
Digging	2	4
Not challenging	1	
Moderate to heavy lifting		
Casualty carrying	3	
Backpacks carrying and loading	2	
Somewhat	1	
Physically challenging aspects of the phase		
Skiing	4	
Skiing with a pack	7	6
Overheating	1	
Use of new equipment	1	7
Short distance at a slow pace	1	
Breaking trail		2
Long periods of work		2
Most challenging aspects of the phase		
Learning skiing skills	6	
Skiing with a load	2	7
Pulling an improvised stretcher	2	
Proper clothing management	1	
Performing with lack of sleep and dehydration	1	
Breaking trail		4
Being outside in cold		1

Table 2-8. Summary of student descriptions of aspects of fitness challenges during winter operations

Description	Frequency	
Environmental factors that increased physical demands of this phase	2009	2008
No	6	
N/A	2	
Snow impeding travel	2	2
Adjusting to weather/temperature changes	3	
Being wet	1	
Altitude	1	3
Cold		7

Plate 2-1 SAR-Tech students ski touring during the Winter operations phase

Arctic operations-2009

Morning Hikes

During this portion of the course, the students were taken on a hike each morning with an Inuit teacher. Students carried day packs (average weight 10.4 kg, n=3) for the duration of the 38 minute walk (Table 2-9). The heart rate response to these walks is shown in Tables 2-10 and 2-11. Heart rates were obtained from a total of 723 minutes of data over the three days, which represents 17 of the individual responses to the morning hikes. These walks were carried out at a low intensity, with an average heart rate of 102 beats·minute^{-1}, or 55% of maximum heart rate. Fittingly, during these hikes the majority of the time was spent at heart rates associated with light or moderate workloads (33% and 37% respectively, Table 2-10). Heavy and very heavy workloads accounted for 22% and 7% of total walking time and extremely heavy work applied to 1% of walking time.

Table 2-9. Heart rate response to morning walks in the arctic

	Length (min)	HR (SD) (beats·min^{-1})	Range (beats·min^{-1})	% max (SD) If known	Range % max
Jan 18	38	101 (17)	70-152	55 (9)	39-82
n		7		6	
Jan 19	36	102 (22)	55-157	55 (15)	27-93
n		5		5	
Jan 20	41	102 (18)	74-153	56 (10)	37-83
n		5		5	
Overall	38	102 (19)	55-157	55 (11)	27-93
n		17		16	

Table 2-10. Relative fraction of total walking time spent in specific heart rate (HR) zones.

Work Level Classification	HR Range (beats·minute^{-1})	Fraction of walk time (%)
Light	≤90	33.1
Moderate	91-110	36.8
Heavy	111-130	22.1
Very heavy	131-150	7.3
Extremely heavy	≥151	0.7

Snow cave building and maintenance

On the morning of January 18th students observed a demonstration on the construction of snow caves. After the demonstration students worked in teams of two to build their own caves. During building, students were not required to carry a pack. Cave building began before lunch for a brief period. A longer (~5 hour) time was allocated to complete the caves following lunch. During this time students were not individually tracked, therefore five hours represents the typical amount of time spent constructing caves that afternoon. On the morning of January 19 students briefly (21 minutes) carried out maintenance as required on the caves. Data were obtained from ten students during the initial five hour construction time allotted on the 18th (1823 minutes), and from six students during the maintenance on the 19th (126 minutes), a summary of this data is presented in Table 2-11. Not surprisingly, construction was more difficult than maintenance of snow caves. A higher average heart rate was obtained (115 *vs.* 96 beats·minute^{-1}), and the exercise was considerably longer (300 *vs.* 21 minutes) (Table 2-11).

Table 2-11. Average heart rate responses to snow cave construction and maintenance

	Length (min)	HR (SD) (beats·min^{-1})	Range (beats·min^{-1})	% max HR (SD) If known	Range % max
Construction	~300	115 (19)	67-193	61 (10)	36-100
n		9		8	
Maintenance	21	96 (15)	70-152	52 (11)	36-82
n		6		6	

The heart rate responses to construction were assessed according to heart rate zones and are shown in Table 2-12. The greatest portion of construction is classified as heavy work (36.8%). Moderate and very heavy follow, accounting for 26.2% and 22.1% respectively of the time spent assembling snow caves. Light work made up 13.4%, and 1.5% of the time was classified as extremely heavy. Based on this analysis, the typical demands of snow cave construction entails 108 minutes at heavy workloads (111-130 bpm), 79 minutes at moderate workloads (91-110 bpm), 66 minutes at very heavy workloads (131-150 bpm), 40 minutes at heart rates of less than 90 bpm or light workloads, and 5 minutes of extremely heavy work (>151 bpm).

Table 2-12. The relative fraction of total snow cave construction time spent in specific heart rate zones. Percentages are based on analysis of a total of 1823 minutes collected from ten students.

Work Level Classification	HR Range (beats·minute^{-1})	Fraction of work time (%)
Light	≤90	13.4
Moderate	91-110	26.2
Heavy	111-130	36.8
Very heavy	131-150	22.1
Extremely heavy	≥151	1.5

Igloo Construction

Students constructed igloos on the afternoon of the 19th, and all day on the 20th of January, approximately 5 and 8 hours respectively. Students were required to cut blocks of snow, and then move theses blocks to their igloo area and place blocks in the proper formation. The blocks of snow varied in size as they were hand cut. Students were not required to carry a pack during this activity. The heart rate response to this activity is presented in Table 2-13. Over both building sessions the average heart rate was 100 beats·minute^{-1}, or 55% of maximum heart rate.

Table 2-13. Heart rate response to igloo building

	HR (SD) (beats·min^{-1})	Range (beats·min^{-1})	%max HR (SD) If known	Range % max
January 19	98 (15)	67-179	54 (9)	35-96
n	6		6	
January 20	101 (18)	62-192	56 (9)	35-100
n	6		6	
Overall	100 (17)	62-192	55 (9)	35-100
n	12		12	

Table 2-14 displays an assessment of time spend in various heart rate zones. Of the 3440 minutes of data from 12 students, moderate workloads characterized the majority of building time (44.4%). Light work comprised 30.7% of building time and 20.2% of the time was spend at heavy workloads. Very heavy work was encountered 4.4% of building time and extremely heavy work made up 0.2% of total building time. This assessment of total time is representative of the two separate bouts over the 19th and 20th of January. Based on this analysis, students worked at heart rates between 91-110 beats·min^{-1} (moderate workload) for a total of 346 minutes over the two days of igloo construction. Light workloads (<90 beats·min $^{-1}$) were carried out for 270 minutes, and heart rates of 111-131 beats·min^{-1} (heavy work) for 158 minutes over the two days. Combined, very heavy and extremely heavy workloads (>131 beats·min $^{-1}$) account for 36 minutes of construction time over the two days.

Table 2-14. The relative fraction of igloo construction time spent in specific heart rate zones. Percentages are based on analysis of a total of 3440 minutes collected from 12 students.

Work Level Classification	HR Range (beats·minute^{-1})	Fraction of work time (%)
Light	≤90	30.7
Moderate	91-110	44.4
Heavy	111-130	20.2
Very heavy	131-150	4.4
Extremely heavy	≥151	0.2

Student Comments

Feedback from students on the arctic phase is presented in Table 2-15, as with previous analysis, all data is presented in the table, however only points selected by more than one student are discussed in the following summary.

Students consistently (n=7) suggested that walking was carried out at a light intensity throughout this phase. This is in line with the heart rate responses; daily morning walks elicited heart rates of 55% of maximal heart rate, and moderate and light work combined made up 70% of total walking time. Activities associated with building igloos and snow caves were reported to be heavy aerobic work by SAR-Tech students, this included walking under load, cutting snow blocks and building snow caves (n=3, 2, 2, respectively). Again the reported physiological responses concur with the student's subjective responses. Lifting and cutting snow blocks and digging snow caves appeared as both light to moderate lifting/hoisting and heavy lifting/hoisting (light to moderate n= 5, 2, 2; heavy n=9, 3, 2, respectively). This difference in classification may be a product of self selection of both block size, and work intensity during this phase, which allows for considerable variation in these parameters.

The cold environment was rated as the most challenging aspect of this phase by 4 students and as a physically challenging aspect by 5 students. Activities associated with construction of snow caves and igloos were also classified as physically challenging for this portion of the phase (n=10) and as the most difficult aspect (n=9). Cutting snow blocks (n=4, 3) digging snow caves (n=4, 6), and blocks (n=2, 0), are included in these descriptions (n=physically challenging, most challenging). Temperature management was also considered as the most challenging aspect of this phase (n=3) and as being physically challenging.

The general sentiment of the students was that the cold environment (n=15) and the wind (n=2) increased the physical demands of this phase. Other factors that caused the students stress during this portion of the course were lack of sleep (n=4), cold (n=3), and ensuring proper food and water intake (n=2). Additionally, a small number of student (n=3) reported no other stressful factors.

Student Comments 2008

Comments from students in 2008 on the arctic phase are presented in Table 2-15. In agreement with feedback from 2009, walking was considered a light aerobic activity (n=13), and walking with a load was classified as being a heavy aerobic activity (n=9). Lifting tasks were also classified in agreement with students of 2009, lifting snow blocks and digging were classified as both light and intense lifting/hoisting (n=9 light, n=10 heavy), and cutting snow blocks was considered heavy lifting/hoisting (n=10). Carrying snow pack was included as light to moderate lifting/hoisting (n=2), and was not noted by students of 2009.

Building snow shelters was reported as physically challenging (n=6), and physical activity in the cold, fatigue and lack of sleep (n=9, 2, 2 respectively) were noted only in 2008. In agreement with the students in 2009, digging snow caves and self temperature management were considered the most challenging aspect of the arctic operations phase (n=7, 7). Igloo construction and cumulative fatigue were also reported as the most challenging aspect of this phase (n=3, 7).

Other stressful factors of this phase also paralleled the responses of the class of 2009. Lack of sleep, and food and water intake (n=10, n=2) fell into this category. Bulky gear presented additional stress for 2 students in 2008.

Summary and Conclusions

Successful completion of this phase requires an ability to work aerobically at moderate to heavy intensities for prolonged periods of time, as was necessary for snow cave and igloo construction (≥ 5 hours, heart rate: 91 -130 beats·minute^{-1}). Furthermore, during the construction of various shelters, students were required to lift large blocks of snow and work in small and/or awkward spaces. As evidenced from the student feedback, the physical challenges of this course were exacerbated by the extreme environment that was the setting for this phase, specifically the cold temperatures. The physical nature of this phase indicated the importance of aerobic fitness for success. However, the ability to manage oneself in the extreme environment may be at least as challenging as the physical work.

Table 2-15. Student descriptions of aspects of fitness challenged during arctic operations

Light aerobic	2009	2008
Walking	7	14
Staying warm without overheating	1	
Heavy clothing	1	
All	1	
Not challenging	1	
Digging		1

Heavy aerobic	2009	2008
Walking under heavy load	3	9
Cutting snow blocks	2	1
Building/digging caves	2	1
Challenging	1	
There was some	1	
Lifting snow blocks	1	

Anaerobic	2009	2008
Ridiculously challenging	1	
Hill climbs to snow caves	1	

Light to moderate lifting/hoisting	2009	2008
Lifting snow blocks	5	9
Digging	2	9
Cutting blocks	2	
Challenging	1	
A lot of clothing	1	
Carrying snow pack		2

Moderate to heavy lifting/hoisting	2009	2008
Snow blocks	9	10
Digging snow cave	3	10
Cutting snow blocks	2	10
Bad body mechanics for lifting	1	

Physically challenging aspects of the phase	2009	2008
Cold	5	
Cutting snow blocks	4	
Digging snow caves	4	
Lifting snow blocks	3	
Thermoregulation, staying warm, not sweating	3	
Building snow shelters	2	6
Constantly physically active	1	
Physical activity in bulky clothing	1	
Physical activity in extreme cold		9
Fatigue		2
Lack of sleep		2

Most challenging aspects of the phase	2009	2008
Digging snow caves	6	7
Cold	4	
Self temperature management	4	7
Cutting snow blocks	3	
Staying hydrated	1	1
Not moving during lectures	1	
Not time to adapt plan or get a routine due to high supervision	1	
Living in extreme environment	1	
Cumulative fatigue		3
Building igloos		7

Table 2-16. Student descriptions of aspects of fitness challenged during arctic operations

Other stressful factors	2009	2008
Lack of sleep	4	10
Cold	3	1
No	3	
Food and water intake	2	2
Wind	1	
Cutting snow blocks for igloos	1	
Lack of time to manage equipment	1	
Had to dig a cave in 1 hour		1
Polar bears		1
Compact snow		1
Bulky gear		2
Environmental factors that increased physical demands of this phase		
Cold	15	16
Wind	2	
Wet	1	
Overheating	1	
Dehydration		1

Dive Training - 2008

Previously, the Dive phase had been reported as one of the most physically challenging phases of the SAR-Tech training program. Therefore, two separate periods of observation were undertaken at FDU (P), Esquimalt. The first observation was early in the training phase, when SAR students were diving in wetsuits, during week 2 of the dive phase (February 5-8, 2008). Two weeks later (February 20-22, 2008) in the final week of the dive phase, after the SAR-Tech students had transitioned to dry suit diving, a second observation period was undertaken. The general layout of the dive phase included daily morning PT, morning lectures, afternoon dives, evening dives on Tuesdays and Thursdays, and various 'motivational' exercises. Observation periods included morning PT and all afternoon and night dives on the days reported

Physical Training (PT)

Morning PT consisted of a variety of endurance and strength type activities, starting at 0730 each morning. The simplest PT consisted of a general fitness run, ranging from 4 km up to 1.5 hr, or wetsuit swim, up to 50 min. More involved PT included group work carrying, marching, and doing a variety of strength exercises with tree trunks, or the FDU(P) PT test, consisting of a 1.5 mile (2.4 km) run, push-ups, sit-ups, chin-ups, a fast change into wetsuits, and then a surface swim with fins around the jackstays (approx 1 km). On two occasions (February 8 and 22) the PT test was completed as a competition between the SAR-Tech students and other dive courses. On these occasions, the push-ups, sit-ups and chin-ups were omitted.

Dives

Afternoon and evening dives covered a number of enabling and performance checks, including compass navigation, bottom searches, and deep (30 m) dives. 'Jackstay' dives required the students to follow the length of an under water cable, a 'jackstay.' Preparatory activities included dressing in wet or dry suits, carrying personal equipment from the change rooms to the jetty, and moving dive equipment (tanks, buoyancy vests, regulators, etc.) up and down the jetty and onto and off of the dive boats (Plates 2-2, 2-3 and 2-4). The maximum distance from the change rooms to the end of the jetty was 215 m. The length of the jetty, which was the maximum distance from dive staging area to compressor attachment to re-charge the dive tanks, was 90 m. Tanks were charged after almost every dive, and there were 2 or 3 dives observed each day.

Physiological data

Heart rate monitors were used throughout this phase. Monitors were worn for 1-8 hours on any of the observed days. The length of heart rate data collected throughout the phase, and the length of the dives on those days are presented in Table 2-17 and Table 2-18 displays the respective portion of time spent in specific work zones.

Feb 5-08: Heart rate monitors were worn from 0800-1100 (181 min), which included morning PT and other land-based training. The majority of this time was spent in heart rate zones associated with light, 35%, or moderate, 38%, workloads (64 and 69 minutes respectively). Heavy work intensities (21%) were maintained for 39 minutes and very heavy and extremely heavy accounted for 4% and 1%, or 8 minutes and 1 minute of the recorded time, respectively. In addition, students also took part in two dives on this day; one dive at 1300 that lasted 22 minutes, and a second evening dive at 1900 that lasted 53 minutes. Heart rate data were not collected during these two dives.

Table 2-17. Summary of heart rate data collected during observations of dive phase February 2008. Number of students refers to the number of heart rate recordings analyzed.

Date	5-Feb	6-Feb	7-Feb	8-Feb	20-Feb	21-Feb	22-Feb
Length of recording (min)	181	221	352	65	484	235	59
Number of students	12	14	15	15	13	15	10
Number of dives	2	2	2	2	2	2	0
Length of dive 1 (min)	22	41	22	7.2	20	50	
Length of dive 2 (min)	53	45	28	38	42	41	
Total dive time (min)	75	86	50	45	62	91	0

Feb 6-08: Heart rate monitors were worn from 0830-1000 and from 1300-1500 (221 min). These times include morning PT, as well as a navigation dive that lasted 35-48 minutes. During these periods, 36 minutes (16% of total time) was spent at light intensities, and 49 minutes (22%) was spent at moderate workloads. Heavy and very heavy workloads accounted for 70 and 30 minutes of total time respectively (32%, and 17% of total time). Extremely heavy workloads were achieved for a total of 28 minutes which accounts for 13% of the total time monitored on this date. The students completed a second dive (around the long jackstay) lasting 35-53 minutes however heart rate data were not obtained.

Table 2-18. The relative fraction of land based and water based work time spent in specific heart rate zones during seven days of observation with Course 41 in 2008. Percentages are based on a total of 366 man-hours of observation.

Work Level Classification	HR Range (beats·minute^{-1})	Fraction of work time (%)
Light	≤90	28
Moderate	91-110	25
Heavy	111-130	20
Very heavy	131-150	10
Extremely heavy	≧151	17

Feb 7-08: Heart rate monitors were worn from 0730-0930, 1330-1600, and 1900-2030 (352 min), which included morning PT and two dives. The first dive was a searching exercise that lasted 22 minutes, and the second dive was a night dive that lasted 28 minutes (Table 2-17). During these times, heart rate was classified as light work 31% of the time (110 minutes). Moderate and heavy work made up 102 and 88 minutes of this time (29% and 25% of total time), respectively. Very heavy and extremely heavy work was carried out for 34 and 17 minutes, respectively (10% and 5%).

Feb 8-08: Heart rate monitors were worn from 0730-0830, during morning PT (total 65 min). During this time, 5 minutes were spent at light workloads (7%), 10 minutes at moderate workloads (16%), and 12 minutes at heavy workloads (18%). Very heavy work accounted for 10 minutes (15%), and the remaining 28 minutes (43%) were carried out at extremely heavy workloads. Students also performed two dives on this day; a shorter dive of 7 minutes, and a longer navigation dive that lasted 38 minutes (Table 2-17).

Feb 20-08: Heart rate- monitors were worn for 8 consecutive hours, from 0720 until 1600 (484 min). This included morning PT and two dives. The first dive was a deep dive that lasted 20 minutes, the second dive lasted 42 minutes and was a proficiency dive (Table 2-17). Over half of this time was spend at light workloads (249 minutes, 52%), and moderate workloads account for a further 131 minutes of total time (27%). In addition, 35 minutes (7%) were spent at heavy workloads, 44 minutes (9%) were spent at very heavy workloads, and 25 minutes (5%) were spent at extremely heavy workloads.

Feb 21-08: Heart rate monitors were worn from 0730-1200 (235 min). This encompassed PT and a proficiency dive that lasted 50 minutes (Table 5-3). Light workloads made up 55% or 129 minutes of this time. Moderate and heavy workloads accounted for 71 and 19 minutes respectively (30%, 8%, respectively). Very heavy work was carried out for 9 minutes and extremely heavy work or 7 minutes (4%, 3% respectively).

Feb 22-08: Heart rate monitors were worn from 0710-0820 (59 min) which included PT only. Light intensity work accounted for 1 minute of this time. Eight minutes were spent at moderate workloads (14%) and 16 minutes were spent at heavy workloads (27%). Very heavy workloads were maintained for 7 minutes (12%), and extremely heavy workloads made up the balance of the session, 27 minutes (46%). The PT exercise consisted of running and surface swimming with wetsuit and fins.

Dive - 2009

Observations from diving exercises took place on the afternoon of February 12, 2009 at FDU(P) Esquimalt. On this afternoon, SAR-Tech students carried out two consecutive dives. Fourteen students participated in each dive, one student did not participate due to illness, and one student was remained on the jetty as a recorder during each dive. The first dive was along the long jackstay and the second dive was along the short jackstay. The heart rate responses of the students are shown in Table 2-19. Data from 12 students are presented, as two students had incomplete recordings.

Table 2-19. Heart rate response of SAR-Tech students to two dives carried out on February 12, 2009.

	Time (SD) (min)	Range (min)	HR (SD) (beats·min^{-1})	Range (beats·min^{-1})	% max (SD) If known	Range (% max)
Long	24.5 (1.2)	22-26	138 (16)	96-177	72 (11)	46-91
n			12		11	
Short	15.5 (2.1)	14-19	132 (16)	93-174	71 (11)	51-89
n			12		11	
Combined			136 (16)	93-177	72 (10)	46-91

Long and Short Jackstay

The times of the dives are presented in Table 2-19, on average the length of the dives differed by nine minutes, the long jackstay taking 24.5 minutes to complete and the short jackstay 15.5 minutes to complete. Aside from the difference in length of dive, the two dives elicited similar heart rate responses (Table 2-19, Figure 2-2). Heart rate averaged 136 beats·min^{-1}, or 72% of maximal heart rate. After an initial increase, heart rate remained consistent for the duration of the dives (Figure 2-2).

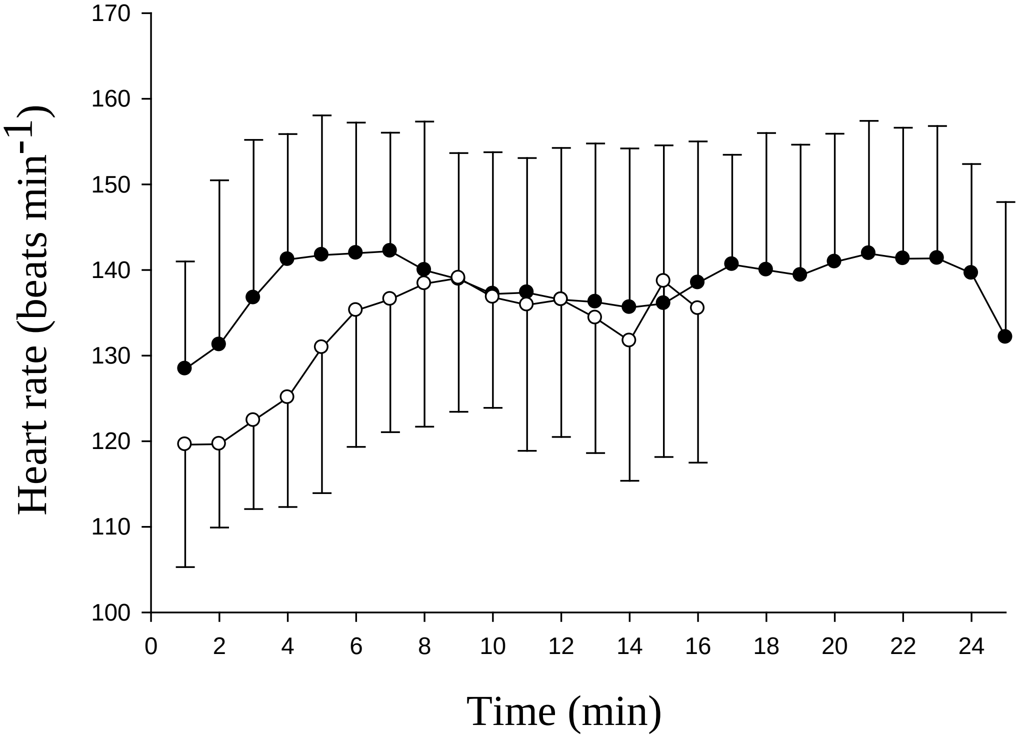

Figure 2-2. Heart rate responses to long and short dives on February 12, 2009. Closed circles are group mean for the long dive, open circles for the short dive. Bars indicate ± 1 SD.

Work zones.

Table 2-20 shows the breakdown of total dive time spent in various heart rate zones (Astrand *et al*, 2003). The majority of diving time was spent at very heavy workloads for both dives (131-150 beats·min^{-1}, 48.3% long dive, 44.3% short dive). This accounts for 11.8 minutes and 6.9 minutes of total dive time for the long and short dives. Heavy intensities (111-130 beats·min^{-1}) accounted for 7 and 4.9 minutes of dive time, or 28.9% and 31.9% of the long and short dives respectively. Extremely heavy (151+ beatsmin $^{-}$1) workloads accounted for 4.8 minutes of the long dive (19.7%) and 1.8 minutes of the short dive (11.9%). Moderate workloads (91-110 beats·min^{-1}) made up the balance of dive time 0.76 minutes, and 1.8 minutes of the long and short dives respectively (3.1% and 11.9%).

Table 2-20. The relative fraction of long jackstay dive time spent in specific heart rate zones. Percentages are based on data from 14 students.

Work Level Classification	HR Range (beats·minute^{-1})	Fraction of work time (%)
Long Jackstay Dive		
Light	≤90	0.0
Moderate	91-110	3.1
Heavy	111-130	28.9
Very heavy	131-150	48.3
Extremely heavy	≥151	19.7
Short Jackstay Dive		
Light	≤90	0.0
Moderate	91-110	11.9
Heavy	111-130	31.9
Very heavy	131-150	44.3
Extremely heavy	≥151	11.9

Land-based work

Students returned to the jetty between dives. Tanks were removed and carried to the compressor to be refilled for the second dive (90 m distance). Students then prepared their equipment for the second dive. Depending on their order in the diving rotation, students had 15-23 minutes (mean 19 minutes, Table 2-21) on the jetty between dives. After the second dive was completed, general clean-up of dive gear was done before returning to the classs-room. The clean-up work involved lifting and carrying of tanks, dive bags and weights (off of the jetty to storage), and typically, the students jogged as they carried out these activities. These activities lasted 10-31 minutes (average 21, Table 2-21). Heart rates for the two periods of dry land activities were similar; 118 and 113 bpm for the first and second break respectively (62 % and 61 % of maximum heart rate, Table 2-21).

Table 2-21. Heart rate response to on-land activities, in between, and post dives

	Length (SD) (min)	Range (min)	HR (SD) (beats·min^{-1})	Range (beats·min^{-1})	% max (SD) If known	Range (% max)
In between	19 (2.5)	15-23	118 (16)	82-165	62 (10)	37-87
n			12		11	
Post–dive	21 (7.8)	10-31	113 (15)	73-155	61 (7)	41-84
n			12		11	

Work zones

Table 2-22 reports the breakdown of on land heart rates by work zone. Similar fractions of total time were spent at heavy and moderate work rates 41.0% and 37.9% (16, 16 min respectively). Very heavy work accounted for 15.5% of on land time (6 min), and light and extremely heavy made up 4.2% and 1.5 % respectively (2, 1 min).

Table 2-22. The relative fraction of land-based work time, between and after the two jackstay dives spent in specific heart rate zones. Percentages are based on data from 14 students.

Work Level Classification	HR Range (beats·minute^{-1})	Fraction of work time (%)
Light	≤90	4.2
Moderate	91-110	37.9
Heavy	111-130	41.0
Very heavy	131-150	15.5
Extremely heavy	≥151	1.5

Student comments

2008

Student feedback from the 2008 dive phase is presented in Table 2-23. Moving all day, jogging and swimming were classified as light aerobic activities by the students (n=3, 2, 2). Hard running and swimming (n=9, 7) were considered to be heavy aerobic activities, as were PT and carrying equipment (n=4, 2). Activities classified as anaerobic by the students included short swims, diving PT and motivation sessions (n=4, 2, 2). In terms of lifting activities, gear was considered light (n=2), and heavy dive equipment and rope climbing were classified as heavy lifting activities (n=5, 2).

Students rated PT and cumulative fatigue as physically challenging aspects of this phase (n=8, 4), carrying heavy gear, and being cold and wet after diving were also considered physically challenging by the students (n=2, 2). Overall, students considered the negative reinforcement PT, volume of physical activity, and long runs the most challenging aspects of this phase (n=4, 4, 4).

In general, it was felt that the cold water increased the physical demands of this phase (n=14). In addition to the challenges discussed previously, students also reported lack of sleep as an additional stressful aspect of this phase (n=6). Dealing with heavy equipment during diving activities and the full schedule experienced by the students were also reported as stressful aspects of the dive phase (n=4, 4).

Table 2-23. Summary of student description of aspects of fitness challenges during dive phase.

Light aerobic	2008
All day moving around	3
Jogging	2
Swimming	2
Diving	1
Walking	1

Heavy aerobic	
Hard running	9
Hard swimming	7
PT	4
Carrying equipment	2

Anaerobic	
Short swimming	4
Diving PT	2
Motivation sessions	2
Beasting	1
Races	1

Light to moderate lifting/hoisting	
Gear	2
Climbing ropes	1

Moderate to heavy lifting/hoisting	2008
Heavy dive equipment	5
Climbing ropes	2
Getting out of the water with full equipment	1

Physically challenging aspects of the phase	
PT difficult	8
Cumulative fatigue	4
Cold and wet feeling after dives	2
Carrying heavy gear	2
Lots of aerobic activity	1

Most challenging aspects of the phase	
Negative reinforcement Pt	4
Volume of physical activity	4
Long runs	4
Awkward	2
Ropes	1
Shifting back into high output days under pressure	1

Table 2-24. Summary of student description of aspects of fitness challenges during dive phase.

Other stressful factors	2008
Lack of sleep	6
Lots of heavy equipment	4
Full schedule	4
Negative reinforcement	1
Environmental factors that increased physical demands of this phase	
Cold water	14
Being on dive site	1
Altitude (running)	1

Summary and conclusions.

To complete this portion of the SAR-Tech course, students must be able to perform repeated bouts of physical activity at very heavy, or extremely heavy workloads. These bouts of intense activity are embedded within other types of physical activity; therefore the ability to recover and continue to perform after these bouts is also essential for success.

Based on the observations in 2008, a typical day consists of a physical training session in the morning and 2 or 3 dives throughout the remainder of the day. Physical training varied on a daily basis. The specific bouts observed were at least one hour in length, of which 27-28 minutes were carried out at extremely heavy workloads. Characteristics of individual dives varied according to the nature of the specific exercise at hand. Data from 2009 indicate that 58-69% of active dive time was spent at very or extremely heavy workloads. Dive times ranged from 7-53 minutes in length. Student comments further attest to the physical demands of this portion of the course, as physical training, the volume of physical activity, and long runs were considered the most physically challenging aspects of this phase. Although the observations did not specifically account for environmental interactions during this phase, nearly all students (14 of 16 from 2008 data) felt that the cold water increased the physical demands of this phase. Clearly this interaction is another important factor in determining the difficulty of the dive phase.

Plate 2-2. SAR-Tech student entering the water for a dive.

Plate 2-3. Two SAR-Tech students exit the water after a dive.

Plate 2-4. A SAR-Tech student carrying tanks in preparation for a dive.

Overturned Vessel (OTV) -2008

The overturned vessel training phase took place from February 24-29, 2008. This phase is essentially a continuation of dive phase, with a change of location to the sea school in Comox, and a transition from dive specific training to using this training to learn about safe operating procedures around overturned vessels, including hull searches, entry and egress from the vessel, and searching for survivors inside the overturned hull. Observations of OTV phase were undertaken at Comox sea school Feb 27-29, 2008. Dive depths in this phase were generally shallow, not exceeding 10 m. Pairs of students cycled through the search procedure a number of times each day so that more time was spent in the water compared with the dive phase.

Heart rate monitors recorded heart rates for 8 hours on February 27 beginning at 0730. A morning and an afternoon dive were carried out on this day. Table 2-25 presents a summary of these two dives, as well as three dives carried out on February 26 for which there is no associated heart rate data.

Table 2-25. Details of dives made by SAR-Tech students during overturned vessel training on February 26 and 27, 2008.

	n	Start time range	End time range	total dive time (SD)
February 26				
Dive 1	16	0947-1207	1016-1218	32.9 (9.1)
Dive 2	12	1345-1524	1431-1556	41.8 (7.1)
Dive 3	16	1835-2005	1904-2026	24.9 (5.6)
February 27				
Dive 1	15	0815-1010	0849-1046	36.3 (15)
Dive 2	15	1225-1408	1256-1418	35.7 (7)

The heart rate data obtained is presented in Table 2-26. The group average heart rate for this time was 86 bpm and the peak heart rate was 154 bpm. Importantly, only 72 of the 480 recorded minutes were spent diving; these values reflect the overall average and not the specific times associated with diving. Over this course of the day, the percentages shown correspond to 310 minutes at light workloads (64.0%), 127 minutes at moderate workloads (27.8%), 35 minutes at heavy workloads (7.0%), and 9 minutes at very heavy workloads (1.8%).

Table 2-26. The relative fraction of dive time (total 72 minutes) during OTV training on February 27, 2008 spent in specific heart rate zones. Percentages are based on data from 15 students.

Work Level Classification	HR Range (beats·minute^{-1})	Fraction of work time (%)
Light	≤90	64.0
Moderate	91-110	27.8
Heavy	111-130	7.0
Very heavy	131-150	1.8
Extremely heavy	≥151	0.0

Student comments

Student comments taken after completion of OTV phase are presented in Table 2-27. Walking and swimming were reported as light aerobic activities (n=4, 2), and walking under load was classified as a heavy aerobic activity by 3 students. Lifting and hoisting equipment was reported as a light to moderate lifting activity (n=4), and moving heavy equipment was classified as a heavy lifting activity (n=6). No aspects of anaerobic fitness were challenged during this phase according to student responses.

Student responses indicate that the equipment posed a physical challenge during the OTV phase of training (n=6). SAR-Tech students considered coordination of lines in water, dealing with patients, and constant cold and wet as the most challenging aspects of this phase (n=2, 2, 2).

The cold and wet environment experienced during this phase of training increased the physical demands of the training (n=13). Furthermore the large amount of gear in this phase presented an added stress for 3 students. Two students indicated that this phase was not physically challenging.

Summary and conclusions.

Both the heart rate and student comment data presented above suggest that the overturned vessel phase was not a physically demanding phase. The vast majority of the observed time was spent at light and moderate workloads, with students spending only 44 minutes at heart rates above 110 bpm. Student comments further attest to the relative ease of this portion of the course in relation to physical fitness. The inclusion of cold and wet conditions by most students (13 of 16) as a factor that increased the physical challenges during this stage, underscores the importance of the environment as a challenging aspect of OTV phase.

Table 2-27. Student descriptions of aspects of fitness challenged during overturned vessel phase

Light aerobic	2008
Walking	4
Swimming	2
Gear prep	1

Heavy aerobic	
Walking under load	3
Hard swimming	1

Anaerobic	
None	

Light to moderate lifting/hoisting	
Lifting/hoisting equipment	4

Moderate to heavy lifting/hoisting	2008
Moving heavy equipment	6

Physically challenging aspects of the phase	
Constantly in the water/cold and wet	1
Equipment	6

Most challenging aspects of the phase	
Constant cold and wet	2
Controlling fear in the boat	1
Multiple rescues	1
Dealing with patients	2
Coordination of lines in water	2

Table 2-28. Student descriptions of aspects of fitness challenged during overturned vessel phase

Other stressful factors	2008
Lots of gear	3
Heavy lifting	1

Environmental factors that increased physical demands of this phase	
Constant cold and wet	13

Sea Operations - 2008

Based on the observations recorded during this phase, it appears that it was intended for the students to become familiar with the airframes currently used in operational SAR at 442 Squadron in Comox: the Buffalo airplane and the Labrador helicopter. During the two days of observations, students were split into three groups, and rotated between a down team, check-rides in the Buffalo, and hoisting activities from the Labrador. There were some complaints of physical discomfort (*i.e.* airsickness) in the back of the Buffalo, but there was no apparent physical work undertaken during the check-rides. When hoisting in or out of the Labrador, there was a marginally higher level of physical activity, as students maneuvered to the door of the airframe, clipped into the hoist line, and were either winched or rappelled down to the ground, which was either reasonably open ground (infield of the airport) or confined (clearings in the trees around the sea school on Goose Spit). Once on the ground, students either unclipped from the hoist line (winch), or gave a signal to drop their rope (rappel). Students had to recover their ropes and then were hoisted back into the Labrador.

On the second day of observation (March 27, 2008), students again practiced hoisting out of and back into the Labrador helicopter, but this time onto the stern (rear) deck of a boat. While this may have increased the complexity of the task, and therefore the associated stress, it is unlikely that it significantly changed the physical demands of hoisting. In addition to hoisting themselves, students also observed the delivery and recovery of a Stokes litter.

Heart rates of the students were recorded with heart rate monitors on March 26 and 27. These were worn for approximately 8 hours on both days beginning at 0800 on the 26th, and at 0730 on March 27th. Data from 15 students were collected on the 26th and from 16 students on the 27th. A summary of the recordings are presented in Table 2-29. As noted above, similar activities were carried out on both days and the heart rate data are presented in Table 2-30.

Table 2-29. Details of heart rate recordings of SAR-Tech students during two days of the sea operations phase.

	Length of recording (mins)	Average HR (SD) (beats· min^{-1})	Maximum HR
26-Mar	461	82 (7.5)	152
27-Mar	420	83 (8.8)	142

The vast majority of the observed time was spent at heart rates associated with light work (73.5%) as this made up 363 minutes of each observed day. Moderate workloads accounted for 19.9% of the total time, or 96 minutes. Heavy work made up 4.0% of the time that heart rate monitors were worn (19 minutes). Very heavy and extremely heavy work were carried out for 9 minutes and 1 minute respectively, or 1.9% and 0.3% of the observed time.

Table 2-30. The relative fraction of work time (approximately 16 hours for each of 16 students) during sea operations training on March 26 and 27, 2008) spent in specific heart rate zones

Work Level Classification	HR Range (beats·minute^{-1})	Fraction of work time (%)
Light	≤90	73.5
Moderate	91-110	19.9
Heavy	111-130	4.0
Very heavy	131-150	2.3
Extremely heavy	≥151	0.3

Student comments 2008

A summary of student comments from 2008 is presented in Table 2-31. Walking was considered a light aerobic activity (n=8), and was the only aerobic activity reported by students in this phase. Students classified moving equipment off of the plane as a light lifting and hoisting activity (n=7).

Nausea was reported by 5 students as a physically challenging aspect of sea operations, and fighting nausea was considered the most challenging aspect of this phase by 4 students. Acquisition and implementation of new skills was also reported as the most challenging aspect of sea operations (n=3).

Environmental factors that increased the physical demands of this phase were the cold and wet conditions (n=5). A factor that increased the student’s stress levels during this phase was the new equipment (n=2).

Table 2-31. Student descriptions of aspects of fitness challenged during sea operations

Light aerobic	2008
Walking	8

Heavy aerobic	
None	

Anaerobic	
None	

Light to moderate lifting/hoisting	
Moving equipment off plane	7

Moderate to heavy lifting/hoisting	2008
Heavy equipment	1

Physically challenging aspects of the phase	
Nausea	5
Hoisting and rappelling	1

Most challenging aspects of the phase	
Boat hoist	1
Turbulence	1
Acquiring and implementing new skills quickly	3
Down time followed by go time	1
Fighting nausea	4

Table 2-32. Student descriptions of physical challenges during sea operations

Non-environmental factors that increased the physical demand	**Number of responses**
Flying for the first time	1
Jet Lag	1
New equipment	2
Long hours	1
Air sickness	1
Dehydration	1
Environmental factors that increased the physical demand	
Wet and cold	5

Summary and conclusions

Based on the observations reported above, the sea operations phase does not pose a great physical challenge for the SAR-Tech students. Although heart rates did increase to levels considered to be moderate or heavy work, these lasted for a short duration each day, and constitute considerably less volume than other phases. As such, students that have completed all of the phases leading up to sea operations should not be limited in their ability to complete the physical aspects of this phase. Student comments indicated that this phase did not present significant challenges to fitness, but that seasickness and environmental factors provided challenges not related to physical fitness.

Parachute Training 2008

Due to logistical issues with air support in Comox, initial ground training for para phase was conducted in Comox, and follow up ground and the majority of parachute work was conducted in Eloy, AZ, at SkyDive Arizona (www.skydiveaz.com). A final week of parachute jumping into confined spaces with the full equipment of bush suits and sarpels, was conducted in Comox. Observations in Eloy were conducted from April 28-31 (week 5) and in Comox from May 6-9 (week 6). One SAR-Tech student was injured and did not participate in the physical activities of this phase, data from the remaining 15 students are presented in the following summary.

Eloy, AZ; April 28, 29 and 30

Activities during parachute phase were dependent on weather and in particular, wind conditions. In Eloy, the general trend during the week of observation was for low winds in the morning, building throughout the afternoon, until either the day's objectives had been accomplished, or the wind was too high to continue jumping safely. The training occurred in a civilian setting where not all of the students could jump at one time. Furthermore, the uncertainty of the wind conditions prevented students from jumping specifically as planned. As such, students were at different levels of completion for their training. Weather conditions in Eloy during this week were warm (low of 18-20 ºC; high of 31-35 ºC), dry (average humidity of 14%) and windy (average windspeed of 13 km/h; gusting up to 50 km/h)

On the first day of observation (April 28), students were divided into two groups. Training commenced at 1400 h with ground practice of the aerial manoeuvres designated for that training jump. Some students practiced one on one with the instructor with whom they were jumping while more advanced students practiced with each other. When the first flight of the afternoon was ready to depart, a truck picked up the students and transported them to the aircraft. As a result, walking under load (wearing the parachute and any other equipment) was kept to a minimum. Students completed two jumps each during the day, packed at least one parachute each, and prepared for an evening jump, for a total of three jumps that day (Plates 2-5, 2-6 and 2-7). In between jumps students packed their own parachutes and checked the packing of other students.

At the end of the day the staging area was cleaned up and torn down, to reduce the likelihood of wind damage overnight, and all equipment was moved into secure storage.

On the second day of observation, April 29, students practiced ‘relative work’ with a partner - docking in free fall, rotations, and other aerial manoeuvres. Briefing and ground practice started at 0830 in the morning because of forecast high wind conditions, and because of expected time constraints, the rotation from landing to being prepared for the next jump was much faster. From 0945 to 1430, most students accomplished 3 jumps, after which the expected wind conditions had developed, and no more jumps were possible. At 1515, all students and instructors assembled for a briefing for the planned morning jump, after which students packed any remaining parachutes and again cleaned up the staging area.

On the final day of observation, April 30, wind only one jump was completed because of unfavorable winds. Due to the short duration of activity, this day was not included in the overall analysis.

Comox; May 7 and 8

Confined area parachute jumps were observed in Comox from May 7 to May 9. Daytime temperatures during this time ranged from a morning low of 8ºC to afternoon high of 19ºC. Difficulty of the jumps increased over the duration of the week with the gradual inclusion of more equipment (bush suits/helmets/Sarpels/Elmo) and progression in difficulty of the landing zone (smaller landing area/more trees/hazards upon approach) and culminated in full equipment night jumps (not observed). Morning and afternoon jumps were planned but the number of jumps per day was primarily influenced by availability of support aircraft and wind conditions. One morning of jumps was cancelled mid-flight due to wind speeds rising above acceptable safely limits. Lack of available of aircraft twice forced changes to the jump schedule but allowed the students to catch up on duties (primarily packing/checking chutes) at CFSSAR. After a pre-flight briefing students were driven to the runway to begin dressing in the required equipment for the upcoming jump. Once properly encumbered, students shuffled approximately 100 m to enter the aircraft and await take off. Students assembled on the aircraft according to the order of their exit which, once airborne, kept physical work to a minimum. Students exited the aircraft in pairs approximately every three minutes and according to directions from the jump master. Upon successful landing, students immediately removed their equipment and bush suits and carried everything approximately 100 m to awaiting ground support vehicles.

Physiological data

Heart rate data were acquired from 13-14 students over five days during this phase. One student was not monitored during this phase due to an injury that prevented him from participating. As noted earlier, the data from April 30 are omitted from the present analysis. Table 2-33 presents an overview of this data, and Table 2-34 shows the breakdown of total time by heart rate zone.

Table 2-33. Overview of heart rate data collected from SAR-Tech students during para phase in 2008.

Date	n (students)	Length of recording (min)	Average heart rate (SD) (beats·min^{-1})	Maximum heart rate (beats·min^{-1})
April 28	14	296	109 (15.3)	193
April 29	13	328	104 (11.8)	193
May 7	14	450	85 (14.1)	184
May 8	13	183	101 (10.3)	188

April 28-08: Heart rate monitors were worn for a total of 296 minutes, of which, 25 minutes were spent at light intensities, and 119 minutes at moderate intensities (9.1 and 41.8 % respectively). Heavy intensities accounted for 100 minutes of this total time, very heavy and extremely heavy made up 30 and 10 minutes respectively (35.1, 10.5 and 3.5%).

April 29-08: Heart rate monitors recorded a total of 328 minutes of heart rate data on this day. Light work made up 51 minutes, moderate work intensities were reached for 134 minutes, and heavy work was carried out for 104 minutes (16.1, 42.4, and 32.9%). Very heavy work and extremely heavy work accounted for 22 and 5 minutes of the recorded time, respectively (7.0, and 1.6%).

May 7-08: Heart rate monitors were worn for 450 minutes. Light work intensities account for 312 minutes (71.0%), moderate intensities made up 93 minutes (21.1%), and heavy intensities were achieved for 24 minutes (5.4%) of this time. A total of 7 minutes were spent at very heavy intensities (1.6%), and 3 minutes of this recorded time was spent at extremely heavy intensities (<1%).

May 8-08: Heart rate monitors were worn for a total of 183 minutes. Light work was carried out for 63 minutes, moderate work for 76 minutes, and heavy work for 31 minutes (34.5 41.5, and 16.9%, respectively). Very heavy work intensities were achieved for 9.9 minutes (5.4%) and extremely heavy work was achieved for 3.1 minutes (1.7%).

Table 2-34. The fraction of work time during parachute operations training on April 28-29 and May 7-8, 2008) spent in specific heart rate zones. Data shown represent approximately 285 man-hours of observation.

Work Level Classification	HR Range (beats·minute^{-1})	Fraction of work time (%)
Light	≤90	33
Moderate	91-110	37
Heavy	111-130	23
Very heavy	131-150	6
Extremely heavy	≥151	2

Overall daily heart rate averages fell into light and moderate work intensities (Table 2-33). This is consistent with data presented in Table 2-34, which shows that the majority of time on each day was spent at moderate and light workloads (< 131 bpm). Heavy intensities accounted for a larger portion of time than very heavy and extremely heavy intensities combined, and at most, students achieved these heavy intensities for 104 minutes in one day. Previous research has shown that heart rate increases above 110 bpm (‘heavy’ in the classification scheme) in both experienced and novice parachutists during a jump. As such, it is possible that some of the time classified as heavy, very heavy, and extremely heavy workloads, is not representative of physical activity, but rather, the increased heart rate is the result of stressful emotions experienced before and during a parachute jump (Roth *et al*, 1996).

Student comments

Table 2-35 presents a summary of student comments regarding the parachute phase of training. Light aerobic activities encountered in this phase were walking, packing, and jogging (n=6, 3, 3). Walking under heavy load was reported to be hard aerobic activity (n=5). Parachute and kits, and packs were classified as light to moderate lifting activities (n=7, 2), and lifting activities of a similar intensity were also encountered during equipment jumps (n=2). Parachuting with penetration kits were classified by the students as a heavy to moderate lifting activity (n=4).

Students reported that carrying loads in heat, packing parachutes, landing parachutes and acquiring new motor skills posed physical challenges during this phase (n=7, 3, 2, 2). Being nervous for their first jumps was the most challenging aspect of this phase for 4 students, others reported the body coordination during free fall was the most challenging aspect (n=2), and finally 2 students reported that this phase was ‘tough on the back.’

Nearly all students indicated the hot environment increased the physical demands of this phase (n=13). Other stresses included in the student feedback questionnaires were the fear of getting hurt and associated anxiety (n=4), as well as the heat (n=3).

Table 2-35. Summary of SAR-Tech student comments from the para phase of training

Light aerobic	2008
Light jobs	1
Packing	3
Walking	6
Jogging	3
Heavy aerobic	
Walking under load	5
Anaerobic	
None	
Light to moderate lifting/hoisting	
During equipment jumps	2
Parachutes and kits	7
Packs	2

Moderate to heavy lifting/hoisting	2008
Parachutes with penatration kits	4
Pack and equipment	1
Physically challenging aspects of the phase	
Adrenaline high followed by crash	1
Learning new motor skills	2
Carrying loads in heat	7
Completing every check in the box	1
Packing parachute	3
Jumping with full equipment	1
Landing	2
Long days	1
Lower back pain from hunching over chutes	
Most challenging aspects of the phase	
Packing the chute after the jumps	1
Adrenaline rushes left body drained	1
Nervous about first jumps	4
Tough on back	2
Body coordination on freefall	2
Mental stress	1
Approaches	1
Minimal breaks	1
Dehydration	1
Long debriefs	1

Table 2-36. Summary of SAR-Tech student comments from the para phase of training

Other stressful factors	2008
Fear of getting hurt/anxiety	4
Heat	3
Lack of sleep	1
Being away from family	1
Environmental factors that increased physical demands of this phase	
Heat	13

Summary and conclusions

The observed days of the para-phase of training for the SAR-Tech students indicate that the majority of the day is spent at intensities that do not pose a great physical challenge (moderate and light intensities). Students did attain higher workloads during the observation periods (heavy, very heavy and extremely heavy), however these were achieved for much shorter time periods. At most these heavier workloads accounted for 104 minutes of the day, of which, some must be attributed to the increased psychological stress associated with parachuting rather than straight physiological work. Student comments indicate that the load carriage was a factor in the physical challenges of this phase, and that the hot environment added to the physical demands of this phase. Additionally stresses not specifically related to the physical demands of this phase were apparent in the feed back, such as anxiety and the acquisition of new motor skills. In closing, for successful completion of this phase students must be able to work in a hot environment while carrying out moderate intensity work, specifically work related to load carriage. Furthermore nervousness and/or anxiety are likely to be encountered with parachuting, and therefore the ability to cope with these emotions may also be necessary.

Plate 2-5. A SAR-Tech student exits plane for parachute jump.

Plate 2.6. Landing a parachute.

Plate 2.7. Landing a parachute in water.

Mountain operations - 2008

Mountain Ops was led by civilian personnel who are experts in the field. Mountain Ops is usually split into two segments: rock climbing and high angle rescue; and, snow and ice climbing and rescue. The order, arrangement, and successful completion of Mountain Ops is largely dependent on snow pack and avalanche risk in the back country, which in turn are dependent on the weather. As such the schedule for this phase can be variable.

Rock and high angle rescue

Observations of the rock and high angle rescue segment of this phase were completed over 2 days in Jasper National Park. On the first day (May 21), instructors and students met at 0800 for instruction on rope setup, and then drove out to the rock area used for practice. The hike from the parking lot to the top of the rocky outcrop was approximately 500 m. Once there, students practiced a number of rope activities, including setting secure and redundant anchor systems, and lowering a stokes litter and attendant on a single length of rope (Plate 2-8). In the afternoon, students were introduced to the use of pulley systems and the mechanical advantage of the systems to make the raising of the litter, patient, and attendant less physically demanding. Students then practiced lowering, rigging pulley systems for raising, transitioning rope systems from lowering to raising, and raising the litter and attendant on various pulley systems. The afternoon ended at approximately 1645, after which everybody returned to Jasper town-site together.

On the second day of observation (May 22), students and instructors met at 0800 to practice similar scenarios as the previous day, but made more complicated by the issue of ropes joined together with knots. This was done on flat ground to first demonstrate, and then practice, lowering and raising rope systems with knots. Students also were sized and fitted for personal prusik systems. After lunch, everyone drove out to the practice site, and split into two groups. The first group used the personal prusik system, jumars and rappel systems to practice ascending and descending cliff faces while the second group practiced lowering and raising a loaded stokes litter and attendant on knotted ropes.

After about 3.5 hours, the groups switched positions and practiced the other task. The second day ended at approximately 1900h.

Snow and ice

Two days of observation were also undertaken in the snow and ice portion of Mountain Ops. Usually this segment is completed before the high angle work, as a partial introduction to rope work, belays, etc., and also to get the ice work out of the way before weather becomes an issue. In 2008, due to a late spring and unsettled weather during the phase, the snow and ice work were delayed as late as possible, and then conducted quickly in order to complete the requisite tasks.

The third day of observation (May 28) started at approximately 0800 h on the side of the Columbia Icefields Parkway. After unloading the trucks of the students' personal gear, the group took a short walk (under 800 m) to a snow-covered hill for instruction and practice of self-arrest techniques. This included multiple slides, arrest practices, and walks back up the hill, and lasted 90 minutes. After the self-arrest practice, everybody walked approximately 1 hour (less than 1500 m) to a second staging area. Upon arrival there was a break for lunch, and then instruction and practice on snow anchor systems and crevasse rescue. Students worked in pairs, as they would most often be working in pairs operationally, to practice rescuing their partner from a fall into a crevasse. After approximately 3 hours of practice on anchors and crevasse issues, everybody packed up the ropes and equipment, and hiked back out to the vehicles. The practice day ended at about 1530.

Due to the delays to beginning the snow and ice portion, and due to the continued uncertainty in the weather, the major exercise of Mountain Ops was completed on the second day of this portion; the fourth day of observation (May 29). The training group left Jasper at 0230 to travel to the Columbia Icefield visitors centre, the base of the climb up Mt Athabasca. After the 1hour drive and preparation at the parking lot, the hike started at about 0400. The climb started over scree and rockfall, then transitioned to snow on the lower slopes of the mountains, and finally to glacier travel (Plate 2-9). It took roughly 6 h to travel approximately 5 km, rising from roughly 2000 m to 3336 m at the top of the mountain. There were a number of stops for snacks, rest breaks, and changes to equipment, including strapping on crampons, and roping up into 4-man teams for safety. After a short stop at the summit, the return trip took about 3.5 h, for a round trip time of 9.5 hours, covering about 10 km.

Physiological data

Heart rate monitors were worn for the duration of the four days observed for 468-772 minutes. These data are summarized in Tables 2-37 and 2-38. Daily average heart rates ranged from light to heavy work (<90 to >111 bpm) and tended to be higher during the snow and ice portion of this phase. An analysis of heart rate by work zone is presented in Figure 2-5.

Table 2-37. Heart rate data for mountain operations phase

Date	n	Length of recording (min)	Average HR (SD) (Beats·min^{-1})	Peak HR (Beats·min^{-1})
21-May	15	468	91 (11)	179
22-May	15	598	87 (9.4)	207
28-May	15	554	96 (96)	172
29-May	14	771	117 (12)	173

Table 2-38. The relative fraction of work time spent in specific heart rate zones during four days of observation during mountain operations with Course 41 in 2008. Percentages are based on a total of 585 man-hours of observation.

Work Level Classification	HR Range (beats·minute^{-1})	Fraction of work time (%)
Light	≤90	38
Moderate	91-110	25
Heavy	111-130	16
Very heavy	131-150	19
Extremely heavy	≥151	1

May 21-08: Heart rate monitors were worn for a total of 468 minutes, from approximately 0715 onwards, as the students were learning and carrying out anchor and pulley roping systems. Light work made up 49.1 % of this time (230 min), moderate

work accounted for 35.9% (168 min), and heavy work was carried out 8.5% of the time (40 min). Very heavy work was carried out 5.6% of this time (24 min), and extremely heavy work accounted for 0.9% of the recorded time (4 min)

May 22-08: Students wore heart rate monitors for 598 minutes, commencing at 0800. The activities were similar to those carried out on May 21, with an emphasis on more complex rope, anchor, and pulley systems. Light work accounted for 58.7% of this time (351 min), moderate work made up 29.7% of this time (177 min), and heavy work made up 7.1% of this time (42 min). Very heavy work was carried out 3.9% of the time (24 min), and extremely heavy work was carried out 0.7% of the time (4 min).

May 28-08: Heart rate monitors were worn by SAR–Tech students for 554 minutes beginning at approximately 0800. Students spent the morning practicing self arrest technique and hiking, and the afternoon practicing both snow anchor and crevasse rescue systems. Light work was carried out for 35.9% (199 min), moderate work for 20.2% (156 min), and heavy work for 15.2% of the total time (84 min). Very heavy work accounted for 19.1% (106 min) and extremely heavy work for 1.4% (8 min) of the time.

May 29-08: Students wore heart rate monitors for 771 minutes, commencing at 03:00. The day was spent hiking a total of 10 km (return) over an ascent of 2000 m. Students had numerous breaks throughout the day. Light work accounted for 8.5% (66 min), moderate work 12.4% (96 min), and heavy work 30.8% (238 min) of the total time. Very heavy work was carried out 46.1% (356 min) of the recorded time, and extremely heavy work made up 1.9% (15 min) of the day’s activity.

These observations indicate that the rock and high angle rescue portion was less physically demanding compared with the snow and ice portion of Mountain operations. Students carried out low work intensities (light and moderate) for the bulk of the observed days of the rock and high angle rescue training. Heavy work intensities were encountered at most for less than an hour per day (40-42 min), and very and extremely heavy work intensities were encountered for only 26-30 minutes per day. During the Snow and Ice portion, the percentage and absolute amount of time spent at heavy and very heavy workloads increased dramatically. Students spent at least double the amount of time at heavy intensities (84-238 min), and an even greater amount of time was spent at very heavy intensities (106-356 min).

Student comments

Student comments are summarized in Tables 2-39 and 2-40. Morning runs were classified as both hard and light aerobic activity (n=4, 4), and hiking under load was considered to be a hard aerobic task by 13 students. Lifting and hoisting activities considered light were the rescues loads and pulley systems (n=4). Students indicated that the litters used for rescue and packs qualified as moderate to heavy lifting (n=3, 2).

The vast majority (n=13/15) of students reported that climbing Mt Athabasca was physically challenging, and was considered the most challenging aspect of this phase by 7 students. Climbing with load was also considered to be the most challenging aspect (n=5). This is confirmed by the data discussed above. The day of the climb, 75% of the time was spent at heavy or very heavy workloads (heart rates 111-150 beats·min^{-1}).

Comments from the students indicate that the environment increased the physical difficulty of this phase. Specifically, altitude, changes from hot to cold, and cold weather were reported to increase the physical challenges of mountain operation (n=5, 5, 4). Other stressful factors in this phase were the heavy loads encountered (n=2).

Table 2-39. Summary of SAR-Tech student comments from the Mountain operations phase of training.

Light aerobic	2008
Morning runs	4
Walking/easy hiking	1

Heavy aerobic	
Morning runs	4
Climbing	1
Hiking under load	13

Anaerobic	
Morning runs	1

Light to moderate lifting/hoisting	
Rescue loads/pulley system	4
Carry equipment	1

Moderate to heavy lifting/hoisting	2008
Litters for rescue	3
Lifting/hoisting packs	2

Physically challenging aspects of the phase	
Cumulative fatigue	1
Climbing mount Athabasca with gear	13
Heights - fear of falling	1

Most challenging aspects of the phase	
Early mornings	1
Mt Athabasca	7
Understanding rescue systems with little practice	1
Climbing under heavy loads/altitude	5

Table 2-40. Summary of SAR-Tech student comments from the Mountain operations phase of training.

Other stressful factors	2008
Early starts for PT	1
Lack of sleep	1
Fear of falling	1
Information about fire hose	1
Long days	1
Physically demanding	1
Heavy loads	2
Lead climbing above protection	1
Crampons on the boots	1
Environmental factors that increased physical demands of this phase	
Altitude	5
Changes from hot to cold	5
Cold/windy	4
Heat	1

Summary and conclusions

Both the physiological data and comments from students suggest that the most physically challenging aspect of the observed mountain operations was the climb on May 29, 2008. During this climb, students spent nearly six (6) hours at very heavy workloads, and an additional 4 hours at heavy workloads. As such, the ability to carry out exercise at these intensities (heart rates: 111-150 beats·min^{-1}) for prolonged periods of time is essential to successfully complete this phase. Although not physically challenging, the acquisition of new skills (rope and pulley systems etc), likely posed additional challenges to students during this phase. Furthermore, student sentiment indicates that environmental factors (*i.e.* cold, altitude, *etc*) also increased the physical demands of this phase. In summary, for success in this phase of training, students require both a high level of physical fitness and the ability to adapt to a mountain environment.

Plate 2-8. SAR-Tech students use a pulley system with a litter during the rock and high angle rescue portion of mountain operations.

Plate 2-9. SAR-Tech Students ascending Mt Athabasca as part of the snow and ice phase of mountain operations.

Final Operations - 2008

Jarvis Lake, AB

Three days of observation were undertaken through Final Ops, which covered medical exercises in the field and parachute jumping at higher altitude. A typical morning schedule for a day began with driving from Jarvis Lake to the Hinton-Jasper air field, a morning parachute jump into a confined area for all the students, and a medical exercise for 4 students. After lunch there was a second jump into a different area.

The first day of observations for Final Ops followed this schedule exactly (June 3), but was the last day of medical exercises. After the two jumps, there was a demonstration and then practice of rigging equipment for parachute delivery into a drop zone.

On the second day of observation (June 4), half of the students jumped into one drop zone, and the second half went on to conduct a search pattern, dress on board the Buffalo, and then jumped into a second drop zone. In the afternoon the groups were reversed, so that each student had a chance to practice spotting and then dressing to jump in the back of the aircraft.

The final day of observations (June 5) was a simulation of a major air disaster (Plate 2-10 and 2-11). Students completed a single jump into the exercise area, performed triage on the casualties, and then began treating casualties in triage order. There were a number of unexpected situations thrown into the simulation (*i.e.* having the initially selected team leader turn into another simulated casualty). This was the only activity of this final day.

Physiological data

Heart rate data were collected for each of the three days. These data are summarized in Tables 2-41 and 2-42.

Table 2-41. Heart rate data collected from SAR-Tech students during final operations on June 3-5, 2008.

Date	n	Length of recording (min)	Average HR (SD) (Beats·min^{-1})	Max HR (Beats·min^{-1})
June 3	15	339	96 (12)	176
June 4	15	508	87 (11)	194
June 5	15	217	92 (10)	185

Table 2-42. The relative fraction of work time spent in specific heart rate zones during four days of observation during mountain operations with Course 41 in 2008. Percentages are based on a total of 585 man-hours of observation.

Work Level Classification	HR Range (beats·minute^{-1})	Fraction of work time (%)
Light	≤90	38
Moderate	91-110	25
Heavy	111-130	16
Very heavy	131-150	19
Extremely heavy	≥151	1

June 3-08: Heart rate monitors were worn for 339 minutes commencing at 0830. Students took part in 2 parachute jumps and a medical exercise over the course of this day. Light work made up 33.6 % (134 min), moderate work 36.8% (146 min), and heavy work made up 18.2 % (72 min) of this day. Very heavy work was carried out for 10.6% (42 min) of the day, and extremely heavy work accounted for 0.9% (4 min) of the total time.

June 4-08: Students wore heart rate monitors for a total of 508 minutes, beginning at 0815. The days exercises consisted of 1 jump preparation in an aircraft, 2 parachute jumps, and a search pattern practice. Light work made up 55.7 % (283 min), moderate work 26.4% (140 min), and heavy work made up 10.4 % (53 min) of this day. Very heavy work was carried out for 5.4% (28 min) of the day, and extremely heavy work accounted for 1.0% (5 min) of the total time.

June 5-08: Heart rate monitors were worn for 217 minutes, beginning at 11:45. This day consisted of a simulation exercise with various unexpected events. Students worked at light intensities for 48.1% (60 min) of the total time, moderate and heavy work accounted for 27.6% and 12.5% of the total time respectively (60 and 27 min). Very heavy work made up 10.6% (23 min), and extremely heavy work made up 1.1% (3 min) of the total time.

Overall, students spent the majority of the observed time in the light and moderate workloads. Based on heart rate data, June 3 was the most physically challenging day, with 72 and 42 minutes spent at heavy and very heavy workloads respectively.

Student comments

A summary of student comments regarding their experiences during this phase in 2008 is presented in Table 2-43. Easy hiking, morning run and jogging, and walking were considered light aerobic activities (n=5, 6, 4). SAR-Tech students classified hard running and morning runs, and walking under load as hard aerobic activities (n=9, 2). Sprinting exercises were classified as an anaerobic activity (n=2). Light lifting and hoisting activities included general lifting and hoisting and lifting patients during med-exes (n=5, 2). Moderate to heavy lifting and hoisting included lifting all gear to jump and carrying supplies and equipment (n=2, 2).

Students reported that jumping with equipment and a heavy load was physically challenging (n=5). Morning runs and PT, as well as getting dressed in bush-suit and equipment (extreme heat) also posed physical challenges to the students (n=3, 2). The most challenging activities reported by students were; focusing on jumping into confined spaces, morning PT and runs, hard landings with medical supplies, and medical exercises (n=3, 2, 2, 2).

Students reported that altitude and heat (n=7, 3) added further physical stresses to this phase. Two students reported that the phase was easy and was not challenging.

Table 2-43. Responses of SAR-Tech students for physically challenging aspects of the final operations phase of the training course

Light aerobic	2008
Easy hiking	5
Morning run/jogging	6
Walking	4

Heavy aerobic	
Running/morning runs	9
Walking under load	2
Moving around with SAR PELS and chute	1

Anaerobic	
Sprinting	2

Light to moderate lifting/hoisting	
Lifting/hoisting	5
Loading/unloading vehicles	1
Lifting patients during med ex's	2
SAR PELS and parachute getting onto and off Buffalo	1
Moving kit	1

Moderate to heavy lifting/hoisting	2008
Lift all the gear to jump	2
Carrying supplies/equipment	2
Lifting/hoisting	1
mental fatigue from jumping	1

Physically challenging aspects of the phase	
Jumping with equipment/heavy load	5
Morning run with PT	3
Long days	1
Getting dressed in bush suit and equipment - extremely hot	2
Tight schedule	1

Most challenging aspects of the phase	
Major exercise	1
Morning PT/runs	2
Everybody is tired	1
Focusing on jumping into confined spaces	3
Hard landings, medical supplies after jumping	2
Med exercises	2
Hot when fully dressed	1
Packing parachute at end of day	1
Keeping the switch "on" until the last day - staying aware/motivated	1

Table 2-44. Responses of SAR-Tech students for physically challenging aspects of the final operations phase of the training course

Other stressful factors	2008
put everything together	1
not a lot of time for recovery	1
confined areas	1
end of course motivation going down	1
Environmental factors that increased physical demands of this phase	
altitude	7
heat	3

Summary and conclusions

Based on the data presented above, the most physically challenging aspect of this phase would be those conditions encountered on June 3. To complete this day, students were required to spend 71 minutes at heart rates of 111-130, and an additional 42 minutes at heart rates of 131-150. The two other observed days also entailed physical activity, however the activity encountered on these days was less than that experienced on June 3. In addition to these physical demands student comments indicate that aspects of landing a parachute (n=5) were the most challenging aspect of this phase. Student comments also indicate that altitude increased the difficulty of this phase.

Plate 2-10. SAR-Tech students move a casualty during the air disaster simulation.

Plate 2-11. A SAR-Tech student performs triage on a casualty during the air disaster simulation.

Table 2-45. Weight of typical equipment used in SAR-Tech Training

Equipment	Weight (kg)	Range
Empty Sarpel	9.2	
Training Sarpel	21.0	17.8 – 23.9
Parachute	21.0	
Helmet (Model 190-C)	1.8	
ELMO	2.4	
Bushsuit	4.2	4.0 – 4.3
Personal Deployment Bag (PDB)	29.0	26.5 – 32.0
Triage Kit	3.1	3.0 – 3.2
Primary Medical Kit	13.6	13.5 – 13.8
Warming Kit	4.6	4.5 – 4.7
Oxygen Kit	4.6	
Secondary Medical Kit	17.0	16.7 – 18.2
Day Pack	8.5	7.1 – 9.9
Overnight Pack	22.8	20.4 – 26.0
Skis and Poles	5.6	
Mountain Equipment Kit	25.0	24.6 – 26.1
Stokes Litter	24.4	
Plastic Litter	7.0	
Plastic Scoop Litter	8.7	
Metal Scoop Litter	10.0	
Self-erecting Tent	38.7	
1-person Life Raft	4.5	
Dive Tanks (Twin 80)	37.0	
Personal Dive Gear (drysuit, mask, fins, weights etc)	26.0	23.0 – 29.0

Summary

This chapter presents a summary of data collected during two of the search and rescue technician courses, from August 2007 to June 2009. The extent of the analysis was constrained somewhat by the requirement that the research could not interfere with the training process. Therefore, while in some cases, more detailed analysis of physical demands might have been desirable, such data collection was not possible. The research methods in this phase were limited to what could be accomplished during the actual training without interference to the very demanding schedule.

Analysis of the physical demands primarily focused on heart rate recordings and feedback from standardized questionnaires completed by the students at the end of each phase. This approach allowed a consistent method of documenting the physical stresses of each phase. In addition, field observations by the researchers included notations on other physical challenges such as the weight of equipment, distances travelled and so on. In combination, this information was used to provide an estimate of the physical stresses encountered by the students during the QL5A course. Clearly, this method does not address every specific aspect of the student experience, however, it provides a snapshot of the demands of those parts of training that were identified by the instructors to be the most challenging.

Training activities may be classified according to length: longer activities lasting several hours (e.g., Arctic and Mountain operations), and shorter activities of less than an hour duration but repeated (e.g., Winter operations and Dive phase). The most physically demanding activity of longer duration was the mountain climb during Mountain operations, where students hiked for a total of 10 hours at heavy intensities and were carrying packs. The most difficult short-duration activities occurred during the dive phase and winter operations, where students were required to perform repeated bouts of exercise (repeated ski tours or dives) at very heavy work intensities for 16-44 minutes. For the dive phase, this was in addition to daily PT that lasted 60-180 minutes.

Students were required to carry packs and were involved in a wide variety of lifting activities throughout the course. During Winter and Mountain operations students carried packs (up to 28.3 kg, Table 2-45) for up to 10 hours. The requirement to lift and move equipment was encountered regularly in every phase of the training course. Often students would need to carry several pieces of equipment at the same time (e.g., bush-suit plus sarpel plus parachute) so the total weight could easily reach 50-60 kg). Frequently, the challenge of lifting and carrying equipment was increased because of awkward clothing (e.g., dry-suits or bush-suits) or terrain (slope, slippery footing, uneven surfaces).

Student feedback indicated that environmental factors increased the physical difficulty of every part of the course. Students experienced a wide range of climates, Arctic (-40° C) to very hot conditions (30° C, Arizona). In each climate, students were required to carry out the various types of physical activities in these conditions and had to adjust to local conditions. Other environmental factors such as altitude, and combination of cold and wet were also reported to increase the physical demands of the phase.

Other factors that did not affect all students, but that increased the perception of difficulty or stress for others, were nausea and seasickness. These were encountered either while at sea or while traveling in aircraft. Finally, skill acquisition, and having to apply new skills also induced stress for some SAR-Tech students.

In closing, it is clear that the physical demands of the search and rescue technician training course challenge a number of physical fitness components. Students must be able to perform shorter bouts of intense activity (up to 44 minutes, average heart rate >131 beats·min^{-1}) repeatedly throughout a day, as well as maintain lower intensities for prolonged periods of time (greater than 5 hours, average heart rate 111-130 beats·min^{-1}). They must also be able to hike and ski while carrying packs (28.3 kg), and be able to lift and carry various combinations of equipment (up to approximately 60 kg) repeatedly over short distances. Finally, students must be able to cope with the environmental conditions associated with learning search and rescue skills in the field.

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Chapter 3

Summary of Demands of the QL5A Course

The three main purposes of the first part of the research project, analysis of the QL5A course, were to:

1. Document the physical and physiological demands of the QL5A course
2. Evaluate any changes in physical fitness during the course
3. Evaluate the accumulation of stress and fatigue during the course

A brief summary of the outcomes of the first part of the research project is provided below.

Summary of Physiological Demands

The main results of the observations detailed in the previous chapter revealed that the physiological demands of the QL5A course included frequent exposure to periods of endurance work, typically under load; repeated lifting and carrying of heavy loads over short distances; and, water-based activities such as surface swimming and diving with equipment. The students engaged in physical training (PT) on a regular basis which often included running, resistance exercise and swimming.

The endurance exercise during PT was typically running for 30 - 40 minutes. Periods of load carriage exercise during hiking or back-country skiing typically lasted between 15 and 45 minutes and elicited heart rate responses of approximately 140 – 170 bpm. Loads were of approximately 20 – 30 kg and were normally carried in large, high quality, properly-fitted packs (e.g., 80-L Arcterex pack).

The lifting and carrying work generally occurred during operations where vehicles, boats or aircraft were being loaded in preparation for training activities. This work was often done with a sense of purpose and in some cases, urgency. The weights of various pieces of equipment are listed in the previous chapter. Typically, students preparing for dive operations would be dressed in dive ensembles (~13 kg) and carried equipment (e.g., dive tanks weighing approximately 37 kg). Students preparing for parachute operations would be dressed in a protective clothing ensemble (e.g., bush suit, helmet, boots) weighing approximately 8 kg and carried various pieces of equipment (e.g., parachute, sarpel, personal deployment bag) with total weight of approximately 50 – 70 kg).

In many cases, each student was responsible for his own gear but often the first students to complete a training evolution would assist others. A frequently observed pattern involved a group of students being tasked to load enough equipment for the class. In those cases, students would be required to lift and carry equipment to and from storage locations to a destination (e.g., dive tanks to boat). This type of "shuttle" operation would require 4 – 8 repetitions covering distances of 20 – 50 m. In other situations such as mass casualty simulations (Final Operations Phase), students would find, assess, treat and carry victims. Loads would vary but typically would include combinations of personal deployment bags, sarpels, litters and patients. The task of lifting and carrying patients was often shared with one or two other students.

Water operations normally included some configuration of dive equipment (wet or dry suits, fins, tanks, etc). During dive training at FDU-P, students frequently completed surface swims in open water of up to 850 m or underwater swims of between 350 and 800 m. PT during Medical training at 19 Wing frequently included pool swimming.

While the researchers did not actually observe students climbing ropes, the instructional staff at CFSSAR insisted that the rope climb mimics other activities such as scrambling up cargo nets during dive and sea operations and managing a parachute in flight. Of note, during a confined space parachute jump with full equipment (Final Operations, June 2008), a member of Course 41 crashed into and became entangled in a spruce tree approximately 15 m above the ground. He was required to lower himself and his gear to the ground using a pulley system ("Elmo"). This operation lasted approximately 25 minutes and was observed to be extremely difficult work. This event, while not common, illustrates the need for "rope-related" skill and the muscular strength and endurance required for managing

It should be noted that the work that the SAR-Tech students accomplish is almost exclusively outdoors and often in inclement weather. While adjustments to the training schedule are made in the interests of safety, the reality is that rescues must be undertaken in bad weather, so students learn rescue techniques in virtually all conditions. The students are frequently exposed to extremes of cold, heat, water and wind conditions. Days are long and rest days are few. Students often live and sleep in rough accommodation. The less-than-optimal work and living conditions make training more challenging, and while this is difficult to quantify, the overall effect cannot be ignored.

In summary, successful completion of the QL5A course requires significant aerobic endurance, strength and muscular endurance, and swim fitness.

Physical Fitness

In order to accomplish the second purpose, the 16 members of Course 41 completed four physiological assessments (August, January, March and June). The physiological assessment included a treadmill test to measure sub-maximal and maximal responses to weight-bearing exercise as well as predicted one-repetition maximum strength tests for bench press.

The sub-maximal portion of the treadmill test was designed to simulate an exercise challenge of approximately 60-70% of VO_{2peak}. Following a standardized warm-up period, the subject walked at 3.5 mph and 12% grade for six minutes which was sufficient time to reach a physiological steady-state. There were no significant differences in any of the selected exercise responses at this standardized exercise load (heart rate, ventilation, oxygen uptake) suggesting no evidence of altered physiological economy.

Table 3-1. Selected physiological responses (mean ± SD) to standardized sub-maximal treadmill exercise on four occasions during Course 41 (n=16)

Variable	August	January	March	June
VO_2 ($ml^{\cdot}kg^{-1\cdot}min^{-1}$)	30.3 (0.8)	31.1 (0.9)	30.8 (0.8)	30.5 (0.8)
RER	0.92 (0.05)	0.95 (0.03)	0.96 (0.04)	0.95 (0.03)
V_E ($L^{\cdot}min^{-1}$)	55.0 (6.6)	58.7 (7.7)	58.2 (8.8)	59.2 (8.2)
Heart Rate (bpm)	141 (12)	135 (11)	134 (15)	137 (10)

Sub-maximal responses to exercise (Table 3-1) showed no evidence of improved or worsened physiological economy. We reasoned that accumulated fatigue or stress would be evinced by increased steady-state exercise responses (e.g., higher heart rate), but that was not the case.

The peak exercise responses to the treadmill tests are shown in Table 3-2 and were also consistent across the four test occasions showing that the 11-month training course did not alter peak aerobic fitness. Therefore, it seems reasonable to conclude that the training course had no effect on aerobic fitness.

Predicted one-repetition maximum for the members of Course 41 on the bench press exercise with free weights was 86 (± 11.9) kg in August and 89 (± 18.2) kg in June suggesting that strength did not change during the course. The anecdotal evidence from the SAR trade that fitness level worsens during the QL5A course is not supported by the data acquired by systematically tracking the members of Course 41.

Table 3-2. Selected physiological responses (mean ± SD) to maximal treadmill exercise on four occasions during Course 41 (n=16)

Variable	**August**	**January**	**March**	**June**
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)	55.0 (4.1)	54.1 (5.5)	56.5 (6.3)	54.2 (4.4)
RER	1.23 (0.03)	1.19 (0.04)	1.21 (0.05)	1.20 (0.04)
V_E ($L \cdot min^{-1}$)	155.4 (14.8)	146.0 (15.9)	152.2 (13.0)	150.3 (9.8)
Heart Rate (bpm)	189 (7)	189 (9)	190 (7)	189 (7)

Stress and Fatigue

Anecdotal evidence from the SAR trade and CFPSA staff led to the concern that the arduous nature of the QL5A course might lead to an accumulation of stress and fatigue, which could in turn, affect physical capacity towards the latter parts of the course. If true, then it might be necessary to set higher fitness standards at entry in order to compensate for diminished capacity towards the end of the course. In order to test this concern, the members of Course 41 (n=16) completed a Stress and Fatigue Inventory five times during the course. The inventory was completed at the same time as the physical fitness evaluations (Aug, Jan, Mar, Jun) and in addition, during Ground Operations in September.

The Stress and Fatigue inventory is a self-reported evaluation of various aspects of stress, health, and well-being. We felt that the students might be unfamiliar with this form of questionnaire and as such, the answers at the August evaluation may not be completely accurate. Therefore, we added in a second evaluation in September to allow two experiences with the questionnaire near the beginning of the course. This provided a "reliability check" at two time points early in the course when it was reasonable to expect relatively positive responses.

The Stress and Fatigue inventory was adapted from an instrument developed for a major study on overtraining that Sport Canada conducted the National Rowing program in 1986. Dr. Murray Smith (professor emeritus) was one of the principal investigators for that project and recommended this instrument as a sensitive predictor of accumulated stress and fatigue. Dr. Smith supervised the modifications to ensure the continued validity of the instrument. In brief, the modifications were limited to word changes such as from "athletes and coaches" to "students and instructors". The inventory tracked information on:

- the amount of exercise (either PT or work);
- the amount of travel;
- health status (3 questions); and,
- personal feelings of confidence, satisfaction and well-being (11 questions).

For the sections on health status and personal feelings, students responded to questions on a 5-point scale. Each point on the scale was linked to a descriptor such as "very low" (equivalent to 1) or "very high" (equivalent to 5). In each case, the more positive descriptor (equivalent to better health, less fatigue, more confidence, higher satisfaction and so on) would convert to a lower numerical score. The complete Stress and Fatigue Inventory can be found in Appendix B.

There was generally very strong agreement in the responses obtained in August and September which suggests good reliability for this instrument. Overall, the majority of the responses are <3.0 which is the “positive” side of the 5-point scale. There is a trend for some scores to increase slightly as the course progressed which would indicate less general satisfaction, however as noted, the scores are still in the positive zone.

Health Questions #1 and 3 evaluated the degree of muscle and joint discomfort and general fatigue, respectively. The results show no significant change during the QL5A course. Personal Questions #1 and 6 evaluated tolerance for hard work and overall satisfaction with the course, respectively. While there was a trend towards a sense of reduced work tolerance by the final assessment, overall satisfaction with the course remained high. It should also be noted that while the student’s perception of reduced work tolerance must be respected, the students completed all aspects of the course to the satisfaction of the instructional staff. Furthermore, the sense of reduced work tolerance was very consistent during the three evaluations between January (following Christmas break) and June (Graduation Week).

Overall, the responses to the Stress and Fatigue Inventory revealed little evidence to suggest that fatigue and stress were problematic during the QL5A course. Taken in combination with the results of the physical fitness evaluations, there seems little tangible evidence that this arduous course had negative effects on physical fitness or work capacity.

Table 3-3. Summary of Responses (mean ± SD) from members of Course 41 (n=16) on health and personal feelings sections of the Stress and Fatigue Inventory on five occasions.

Question	**August**	**September**	**January**	**March**	**June**
Health #1	2.3	2.0	1.6	1.8	2.0
Health #2	1.3	1.2	1.5	1.3	1.7
Health #3	2.0	1.9	1.7	1.9	2.3
Personal #1	1.7	2.1	2.8	2.4	2.8
Personal #2	2.1	2.1	2.3	2.4	2.6
Personal #3	1.9	2.0	2.2	2.7	3.1
Personal #4	1.9	2.0	2.1	1.8	2.1
Personal #5	1.9	1.8	1.9	2.1	2.6
Personal #6	2.9	3.0	2.3	2.1	2.3
Personal #7	1.2	1.4	1.5	1.8	1.9
Personal #8	1.6	1.6	1.6	1.7	2.0
Personal #9	1.8	1.7	1.7	1.7	2.0
Personal #10	2.2	2.1	2.3	2.3	2.5
Personal #11	2.1	1.9	1.9	2.1	2.5

Chapter 4
Development of Physical Fitness Tests

Overview

The process for development of physical fitness tests for the selection of candidates entering the SAR-Tech trade occurred during the period between June 2008 and July 2009. Test development involved several steps and at each point, the research team interacted with the SAR-Tech trade to ensure that the proposed tests accurately reflected the physical demands of the QL5A course.

In addition to the extensive interaction with the students and instructors that occurred during the analysis of the QL5A course (Chapter 2), there were several significant meetings that provided direction to the test development stage of the project.

CFSSAR, June 2008

This meeting took place during "grad week" for Course 41 and included CWO Andy Morris, six instructors, Jacquie Laframbroise, David Docherty and Stewart Petersen. Docherty and Petersen provided a brief overview of the research to date, emphasizing our observations that the main physical demands appeared to be aerobic endurance (especially the requirement to work for long periods under load) as well as the requirement to repeatedly carry relatively heavy loads over short distances. These two requirements reflect the kind of activity frequently observed on the QL5A course.

Further discussion centered on the relative merits of "task simulation" (TST) and "fitness component" (FCT) tests. There was consensus that addition of a load carriage element would be useful because so much SAR-Tech work in both training and operations requires endurance under load. Issues around consistency in test procedures and ease of administration were discussed.

The instructors agreed that it was necessary for regular interaction with the researchers and volunteered to act as test subjects when pilot protocols were developed. The researchers emphasized that detailed feedback from experts in the trade would be an essential part of establishing the validity of any new tests.

Chief Morris emphasized that a valid test would be useful for evaluation during the course should questions about fitness for duty arise.

SAREX , 2008

David Docherty and Stewart Petersen attended SAREX in Thunder Bay, ON in September 2008. Our involvement consisted of a briefing to the SAR-Tech leaders on September 23. The meeting was convened by M. Maltais and was attended by 11 SAR-Tech leaders.

The researchers gave a brief slide presentation outlining the purpose of the project and progress to date which included evaluation of the physical demands of each phase of training, monitoring of physical fitness during the 11 month course and evaluation of accumulated stress and fatigue during the course. The main physical demands appeared to be aerobic endurance (especially the requirement to hike or ski for relatively long periods under load), the requirement to repeatedly carry relatively heavy loads over short distances, and a significant amount of water work, usually with dive equipment. These requirements reflect the kind of activity frequently observed on the QL5A course. We suggested consideration of a load carriage test for endurance fitness, *similar in concept* to the test widely used to test work capacity for wildland firefighters. In brief, test subjects complete a 5 km hike as quickly as possible with a 20.5 kg pack (Sharkey 1997). We also suggested development of a shuttle-type test in which representative weights would be carried back and forth several times over a simple course (e.g., 20 m) to simulate the kind of work involved in loading equipment in vehicles, boats or aircraft in preparation for a training exercise.

These suggestions were received favourably by the group. There was some discussion to clarify the nature of the proposed tests and suggestions from the SAR leaders on how to proceed. Some SAR leaders pointed out their concerns with the “fitness component” approach to testing physical fitness which mainly focussed on working against one’s own body weight (as opposed to an “absolute” load), relevance to the job and inconsistencies in test administration. In general, the SAR leaders were favourably disposed towards the use of “task simulation” tests to evaluate fitness in the SAR trade. The generally positive feedback provided direction for the development of new tests.

CFSSAR June 2009

Initial feedback from instructors suggested that the current swim test required a level of competence in the water sufficient for the specific training on course involving diving and water-based rescue. During our testing of the members of Course 42 at CFSSAR in June 2009, the new treadmill and equipment carry tests were piloted, however the ‘old’ swim test protocol had been retained. Subsequently, input from several senior members of the SAR trade (Oakes, Curtis, Carnigan and Hollman) strongly suggested development of a new swim test protocol that involved equipment, specifically the use of fins for propulsion. Based on the recommendation of the senior SAR staff, the researchers developed a new swim test protocol that reflected two major changes from the former swim test. First, the use of fins altered the emphasis from mainly upper body to mainly lower body propulsion. Second, because water-based fitness had been identified as an important element for success on course and on the job, it was decided to recognize performance outcomes in the selection process.

Test Development (November 2008 – May 2010)

Development of the new physical fitness tests occurred between November 2008 and May 2010 following the general conceptual framework illustrated in Figure 4-1. Briefly, this phase involved a significant amount of interaction between the researchers and the SAR trade. Typically, the researchers would develop a pilot version of the test which was then followed by pilot testing at CFSSAR. In some cases, the QL5A students (Courses 42 and 43) were the test subjects. In other cases, SAR-Tech operators from Squadron 442 who were recent QL5A graduates, CFSSAR instructors, members of a QL6A course (May 2009), and applicants to the SAR trade (Pre-Selection 2010) acted as test subjects. In each case, subjects completed the pilot versions of the test and then were debriefed by the researchers to obtain feedback on matters related to test validity, logistics and/or procedures. Additional feedback was obtained from the CFSSAR instructors (observers), subject matter experts from the SAR Trade (observers) and PSP staff who observed and/or assisted with test administration.

The researchers approached the test development process recognizing the need to strike a balance between several important and potentially competing factors. The main objective was to establish a test protocol that demonstrates excellent validity and reliability but is also time efficient and simple enough that it can be readily replicated in numerous locations (e.g., CF bases across the country). Therefore, while validity (testing what we want to test) and reliability (scores are reproducible) are essential, these critical elements must be achieved through protocols and procedures that are not so resource-intensive and cumbersome as to be impractical. Input from the Project Management Team, the SAR trade and PSP throughout this phase helped the researchers achieve this goal.

Several key steps occurred during this time of development. For example, we began with the concept of using a simulated forced march under load (e.g., carrying a pack around a track) to evaluate aerobic endurance fitness. While the concept was generally well received, the logistics of administering the test were challenging. Following trials of tests modelled on the forced march concept in the fall of 2008, we recognized that many of the logistical and test administration concerns could be solved if we were able to develop a load carriage test using a treadmill.

The treadmill can be calibrated to ensure consistency between test sites and because the test is done indoors, variations in weather and walking surface were no longer of concern. The pack selected for the treadmill test is the same pack issued to QL5A students on course. The pack is available in a range of sizes in both male and female models. Therefore, it is possible to accommodate virtually all body types and sizes with an optimal fit. The organization of the weight and volume of the load carried in the pack was standardized.

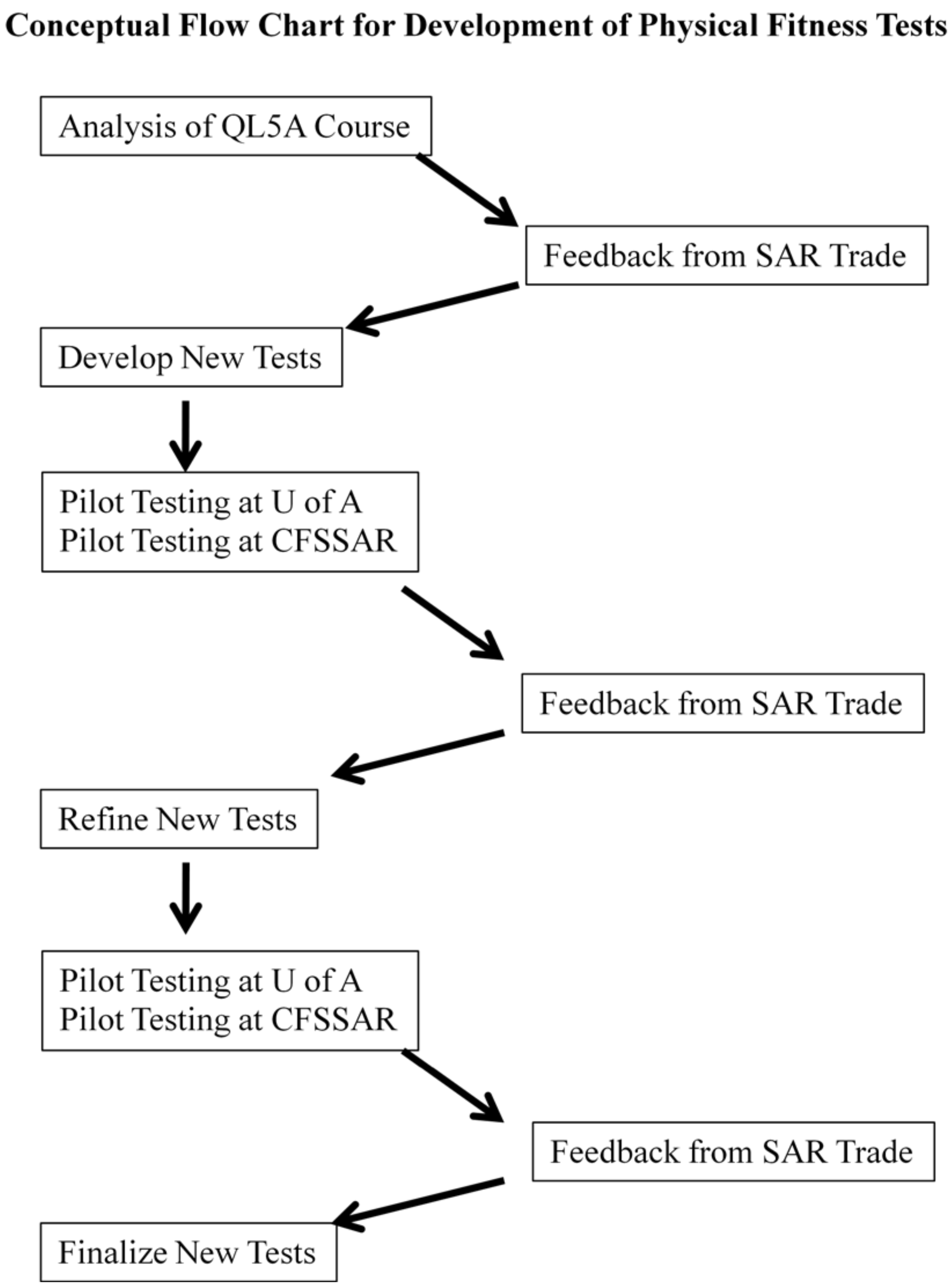

Figure 4-1. Schematic view of the process for development of new physical fitness tests

During this period of pilot testing, the order of tests and the amount of time between test stations was standardized. Time between stations was minimized based on input from the SAR trade, however given the variability in the physical layout of various fitness facilities at potential test sites, adequate transition time to move from one station to the next was considered. Feedback from PSP suggested that the final timings could be achieved at virtually all potential test sites. The feedback from the SAR trade suggested that the Rope Climb was an important element of the physical assessment in spite of our failure to observe this activity during the analysis of the physical demands of the QL5A course. It was decided to retain this element as a competency rather than a performance element until a final decision was made. Subsequently, a legal opinion from the JAG representative on the PMT provided compelling arguments to remove this element from the physical assessment program. The layout of the Equipment Carry Test was optimized to fit in any gymnasium and the weights used in this test should be readily available at all CF fitness facilities. The Swim Test can be completed in either a 25 meter or 25 yard pool. The researchers selected a type of fin that is used in the SAR trade, requires relatively little familiarization prior to use and is available in an array of sizes to accommodate almost any foot.

Establishing test validity was initially the main focus during this phase of the project. In lay terms, validity may be described as “testing what you actually want to test”. In reality, it means that the test is a reasonable reflection of the aspect of fitness that is under study and importantly, that the test presents the same kind of fitness challenges found during training operations. Validity includes factors such as type of fitness (e.g., strength) as well as the way in which that fitness component is used in the activity of interest (lifting and carrying absolute loads). For example, we frequently observed QL5A students lifting and carrying relatively heavy equipment, or combinations of equipment, back and forth over relatively short distances. Therefore, the design of the Equipment Carry test took into account factors such as the weight of equipment, the distance the equipment was carried and the number of repetitions that might be completed. While the Equipment Carry Test does not specifically represent any single activity, the kind of fitness required to complete the task and the way that the fitness is used in the test are representative of numerous activities in SAR training. Loading equipment in vehicles, boats and aircraft is a common activity in preparation for training exercises. In many cases, this work is done with a sense of purpose and in other cases (e.g., loading aircraft for search and rescue mission scenario during Final Operations) it must be done with a sense of urgency. During the preliminary stages of test development, feedback from the SAR Trade on factors such as the weight of equipment, the number of repetitions, the distances carried was used refine the test procedures and increase the validity of the task simulation.

As noted previously, feedback from the SAR trade, combined with many observations of water-based activities on course led to the development of a swim test that reflected two substantial changes to the way that swim competency had been evaluated in the past. First, the addition of fins changes the emphasis of propulsion from mostly upper-body to mostly lower-body, which is consistent with the observations made during the QL5A course. Second, in contrast to the pass-fail nature of scoring swim performance in the past, a decision was made to reward superior water-based fitness and consequently, swimmers were encouraged to complete the distance as quickly as possible. Feedback from QL5A students and CFSSAR personnel throughout the project underscored the importance of fitness to success on course so it seemed logical to incorporate water-based fitness evaluation (rather than simple competency) into the selection procedure.

The final step in validation of the test battery was completed in May 2010 by the members of Course 43. At that time, the details of the test battery had been finalized and the members of Course 43 were sufficiently familiar with the demands of the course that they could offer expert opinion on how well the tests evaluated the types of physical fitness required for successful completion of the QL5A course. The final version of the test battery is outlined briefly below:

- Treadmill test (with 25 kg pack) for aerobic endurance and overall work capacity
- Equipment Carry for muscular strength and endurance
- Fin Swim for water-based fitness

Each element of the test battery is followed by a short transition time of five minutes for the subject to proceed to the next station. The transition time following the Equipment

Carry was extended to 10 minutes to allow the subjects to change from exercise clothing to swim attire.

Treadmill Test Development

As noted in Chapter 2, aerobic endurance is a central aspect of physical fitness in the QL5A course. With the exception of endurance activities in regular PT (e.g., running), virtually all the prolonged work involves load carriage. Day packs are typically in the range of 8-9 kg while mountain packs and overnight packs are in the range of 22-28 kg. During Winter Operations, students carried loads of approximately 34 kg while skiing. The basic mountain rescue kit (exclusive of personal gear) weighs approximately 25 kg. Therefore, we chose a weight of 25 kg, properly loaded in the 80-L Arcteryx pack, which is used on course. This pack comes in male and female models and a range of sizes to accommodate various body types and sizes.

Typically as described in Chapter 2, endurance work under load lasts for 15 – 40 minutes before a rest or relief period. Based on heart rate responses in the field (e.g., Winter Ops, Chapter 2) and the relationship between heart rate and oxygen consumption recorded during graded exercise testing of Courses 41 and 42, it was determined that QL5A students must sustain exercise under load for at least 15 minutes at a work rate where oxygen uptake is approximately 38 ml/kg/min.

Pilot work revealed that the average oxygen uptake during 15 minutes of treadmill walking, carrying a 25 kg pack, at a speed of 5.6 kph and a grade of 8% was 37 ml/kg/min. Therefore, an accurate simulation of the type of aerobic work expected of SAR students can be made on the treadmill. The 15 minute constant work period is preceded by a standardized, progressive warm-up phase of 6 minutes duration. Feedback from the SAR trade emphasized the importance of using fitness as one of the criteria on which applicants to the course are selected. Consequently, on completion of the constant work period, a progressive test to exhaustion follows where the treadmill grade and/or speed is increased each minute until the subject cannot continue. This phase of the test is followed by a standardized cool-down period of 5 minutes duration. During the test development period, various iterations of load carriage tests were piloted until the final version evolved. The following section outlines how the field observations (Chapter 2) and physiological data obtained during physical fitness testing of Courses 41 and 42 were integrated to direct the development of the treadmill test.

Physiological Responses to Graded Exercise

Members of Course 41 and Course 42 were tested on treadmills with continuous gas exchange data acquired with the TrueOne metabolic measurement system. HR was acquired each minute from a telemetry system (Polar). The test protocol used for Course 41 began with a standardized warm-up and then progressed to a 6-minute steady work phase at 3.5 mph and 12% grade. This phase was followed by a one minute “transition” stage where the grade was lowered to 2% and the speed increased to 5.5 mph. Subsequent stages of 60-s duration increased speed in 0.5 mph increments to 7.0 mph and then grade in 2% increments until exhaustion. Twenty-two HR-VO_2 data points (X-Y pairs) were generated leading to the regression relationship shown below in Figure 4-1. A similar procedure was used to establish the relationship between heart rate and oxygen uptake during graded exercise for Course 42. There were no differences between the responses for the two classes.

HR Responses to Load Carriage in Training

Two of the best examples of “prolonged” work under load in training are the back-country ski trips during Winter Operations and the ascent of Mt. Athabasca during Mountain Operations. We made observations which included HR records during Winter Ops in January 2008 with Course 41 and January 2009 with Course 42. We obtained HR records from the Athabasca trip with Course 41 in May 2008.

During two days of operations in the mountains near Comox, the students completed 11 bouts of continuous skiing with an average duration of 17 min. The average HR was 121 bpm. A good example of a very demanding bout of continuous skiing under load is shown in Figure 2-1 (Chapter 2). The average HR response to this bout of skiing was 145 (18) bpm.

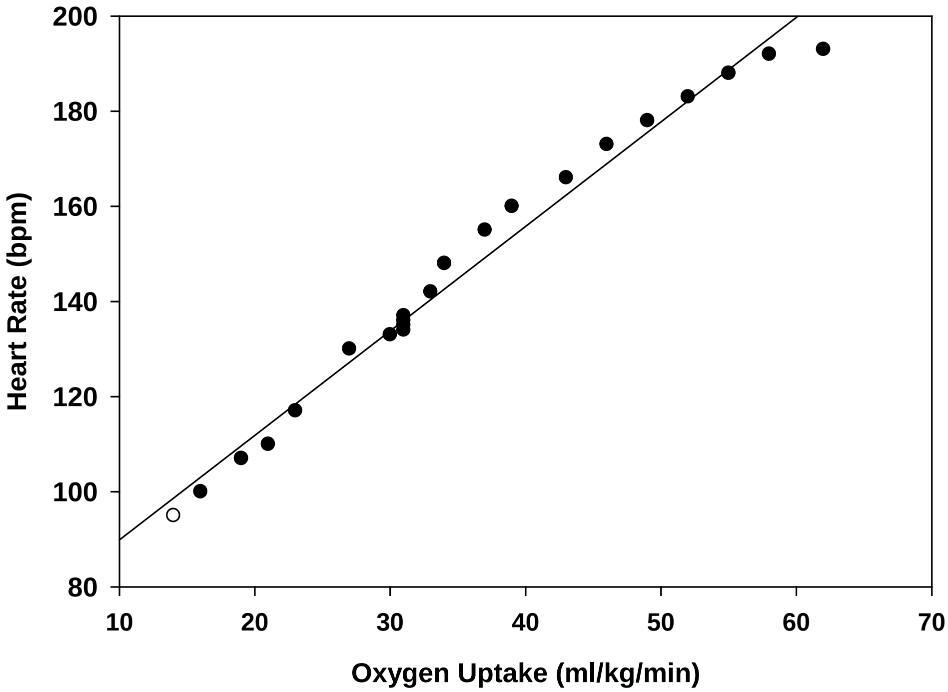

Figure 4-1. Relationship between heart rate and oxygen uptake during graded exercise for the members of Course 41 (16 students). The data shown in this figure represent the average response with all 16 data sets pooled.

A total of 1393 minutes of heart rate data from 15 students during skiing were obtained over the two day period. This includes all available data from the 15 students. The majority of the ski time (31%) was characterized by heart rates between 111-130 beats·min^{-1} (heavy work), and only slightly less time (27%) was spent between 131-150 beats·min^{-1} (very heavy work). Eighteen percent of ski time was classified as moderate work, (91-110 beats·min^{-1}) and 20% of skiing fell into the extremely heavy work category (>151 beats·min^{-1}). Less than four percent of total ski time was classified as light work (<90 beats·min^{-1}).

During the ascent of the Athabasca glacier on May 29, 2008, students wore heart rate monitors for 609 minutes, commencing at 03:00. The day was spent hiking a total of approximately 12 km (return) over an ascent of about 1500 m. Students had numerous breaks throughout the day. Light work accounted for 8.5% (66 min), moderate work 12.4% (96 min) and heavy work 30.8% (238 min) of the total time. Very heavy work accounted for 46.1% (356 min) of the recorded time, and extremely heavy work made up 1.9% (15 min) of the day's activity.

Integration of HR-VO_2 Relationships and Physical Demands of Training

Analysis of the HR responses to back country skiing suggests that SAR students need to, on average, maintain a HR of 121 bpm for 17 min (Table 2-3). The data in Figure 2-2 show that the typical HR response falls between 111 and 150 bpm. The mid-point of this range (heavy and very heavy categories combined) is 130 bpm. The mean HR response to the most demanding continuous ski bout shown in Figure 2-3 was 145 bpm. If one argues that all students need to be able to tolerate the most difficult aspects of training then logically, maintaining an average HR of 145 bpm might indicate the "target" metabolic demand for skiing under load. Using the HR-VO_2 relationship for Course 42 shown on in Figure 4-1, the HR response of 145 bpm predicts an average VO_2 of 37 ml/kg/min sustained for 44 min.

Analysis of the HR responses to mountain operations (glacier ascent) suggests that the typical HR response falls between 111 and 150 bpm for 77% of the total time, or approximately 6 hours. The mid-point of this range (heavy and very heavy categories combined) is 130 bpm. Many of the students rated this day as one of the most demanding in the training course, so logically, maintaining an average HR of 130 bpm might indicate the "target" metabolic demand for hiking (climbing) under load. Using the HR-VO_2 relationship for Course 41 shown in Figure 4-1, the HR response of 130 bpm predicts an average VO_2 of 28 ml/kg/min sustained for 594 min. It should be kept in mind that the six hours of work is broken up into numerous shorter periods of variable length and separated by brief rest periods. In order to evaluate the physical capacity of SAR applicants, it seems reasonable to choose a treadmill load (combination of speed and grade) that will require a metabolic demand of approximately 37 ml/kg/min. Under normal conditions, this metabolic rate would need to be sustained for at least 15 minutes and under some training conditions, up to 45 minutes.

The QL5A students were frequently observed to carry loads in the range of 25 kg (see Table 2-2 and Table 2-42). These loads were carried in properly fitting, modern packs (e.g., Arcteryx Bora 80 L). Pilot work in the laboratory revealed that when carrying the Arcteryx pack, loaded to 25 kg (see Operations Manual p. 32 for loading plan), uphill treadmill exercise at 3.5 mph and 8% grade elicited the desired metabolic demand in most individuals. After a standardized warm-up, twenty-two young healthy subjects (18 male, 4 female) carried the 25 kg pack while walking on the treadmill at 3.5 mph and 8% grade. The average VO_2 for this bout of exercise as 36.4 ± 2.95 ml/kg/min.

Equipment Carry Test Development

As previously mentioned SAR students were frequently observed to lift and carry equipment, often making several trips between the storage location and the destination (e.g., aircraft). This activity was always done with a sense of purpose and often done with a sense of urgency. Clearly, organizing and loading essential equipment in an expedient manner is key to effective search and rescue work. This became very obvious during Final Operations when loading equipment on an aircraft was part of a search and rescue scenario. Similarly, during the air disaster scenario, students were engaged in moving equipment and patients in a simulation where urgency was obvious.

We designed this test as a replication of the kind of lifting and carrying work frequently observed during SAR training. The weights chosen are representative of various combinations of equipment (e.g., dive tanks, dive bags, parachutes, medical kits). Students were frequently observed carrying equipment weighing between 40 and 60 kg over variable distances between 20 and 100 m. “Equipment” was simulated with simple weight training apparatus found in virtually any fitness centre. We selected an “easy-curl” bar weighted with 2 x 45 lb plates and collars for the bilateral carry, and 2 x 55 lb dumb-bells for the unilateral carry. A 40 m distance was selected for each repetition as this was similar to many observations in the field. Eight repetitions under load (alternating between unilateral and bilateral carries) separated by unloaded repetitions simulate eight trips from the storage location (e.g., hanger) to the destination (e.g., aircraft). We developed several iterations of this test before the final version evolved. Safety was a major concern when subjects were lifting and lowering weights quickly as well as turning while under load. A series of simple rules were established to ensure safety while allowing the subjects to complete the tasks as quickly as possible. It was gratifying to hear experienced students and SAR operators report “Great test! This is what we do!”

Swim Test Development

A significant part of the QL5A course involves water-based search and rescue activities, almost always with dive equipment (e.g., breathing apparatus, wet or dry-suit, fins). Feedback from the SAR trade suggested two significant changes to the evaluation of water-based fitness. First, following the same conceptual path as with load carriage on the treadmill, it was suggested that swimming with some equipment would be a more valid approach to evaluating water-based fitness for SAR training. Second, the historical approach to water-based fitness has primarily been demonstration of competency in the water. That is, students were asked to swim a moderate distance in a generous time, however, faster completion of the task did not result in any credit towards selection. As noted clearly in Chapter 2, water-based fitness is important training for search and rescue in Dive, OTV and Sea Operations. The feedback from the trade was clearly in favour of rewarding fitness in the water in the same manner as on land.

The Swim Test evolved to meet these two concerns from the trade. The first step involved the inclusion of fins to place the propulsion emphasis on the lower body rather than the upper body, which is consistent with rescue swimming and dive work. We established the distance at 750 m based on the length of open water swims frequently completed during dive training.

Confirming Validity of the SAR Tests

While the establishment of validity as an ongoing process during the test development phase, the final validity check was in May 2010 when the members of Course 43 completed the test and provided their feedback on the relationship of the tests to the demands of the course. It is important to note that at the end of the course, the students are the best judges of the goodness of this match. In order to evaluate validity, the students provided feedback on how well the various elements of the test evaluated the kind of fitness essential to success on course. The students used a 5-point scale where the choices were “Strongly Agree”, “Agree”, “Neutral”, “Disagree” and “Strongly Disagree”. The responses are summarized in Table 4-1.

With very few exceptions, the members of Course 43 either agreed or strongly agreed that the new tests were a good reflection of the kind of fitness necessary for success in the QL5A course. The “worst” response was neutral which indicated no strong beliefs for or against. There were no responses that could be categorized as disagreement with the relevance of the new tests to the QL5A course. Overall, the results of feedback from the “experts” provide compelling evidence of the validity of the new tests.

Table 4-1. Debriefing questions and responses from members of Course 43.

Question	**SA**	**A**	**N**	**D**	**SD**
Physical fitness is important for successful completion of the QL5A course.	11	2	0	0	0
The 15 min Constant Work part of the Treadmill Test reflects the physical demands of activities like hiking and skiing on course.	5	7	1	0	0
This kind of fitness is important for successful completion of the course.	4	9	0	0	0
The maximal part of the Treadmill Test is a good measure of peak aerobic fitness for most challenging parts of course.	3	9	1	0	0
The Equipment Carry Test reflects the physical demands of lifting and carrying gear on course.	6	6	1	0	0
This kind of fitness is important for successful completion of the course.	6	6	1	0	0
The Swim Test reflects the kind of water-based fitness needed for dive and rescue components of the course.	7	6	0	0	0
This kind of fitness is important for successful completion of the course.	6	7	0	0	0
The new Selection Test reflects the most important aspects of fitness required on course	3	10	0	0	0
The Selection Test is physically demanding and challenged your fitness level	9	4	0	0	0

SA – Strongly Agree; A – Agree; N – Neutral; D – Disagree; SD – Strongly Disagree

Confirming Reliability of the SAR Tests

A sub-study was conducted to evaluate the reliability (or reproducibility) of test scores on the Treadmill, Equipment Carry and Swim tests. In brief, the concept of “good” reliability infers that a subject will achieve, within reasonable tolerances, the same score each time the test is completed. In reality, any measure of reliability must consider the possibility of both technical and biological variability. Technical variability may be influenced by factors such as equipment, calibration, clothing, environmental conditions, test administration, and extrinsic motivation. Reproduction of the same test score on separate occasions may be influenced by biological factors such as diurnal variation, nutrition, fatigue, practice, and intrinsic motivation. When every attempt is made to minimize both biological and technical variability, we can identify the variability that, in most cases, cannot be controlled. It is relatively simple to control technical variability through consistent administration of the test and calibration of the test equipment and set-up. The day-to-day variability in the biology of the human subject is beyond the control of the tester. One view of the matter is that the "tester" is responsible for minimizing technical variability. On the other hand, it is fair to say that while the "subject" is responsible for management of biological variability, since many of the factors listed above fall into the area of "behavior". In practical terms, there are several fundamental questions in regard to reliability, such as:

- If a subject achieves a performance of "X" today, can we expect the same result tomorrow?
- What is the expected change in any test score (plus or minus) that could be explained by biological variability?
- Does the score obtained on the first attempt at a test accurately reflect the individual's "best" performance?

The better the reliability, the more confident CFSSAR can be that the applicants have the necessary fitness to complete the QL5A training program.

The reliability of scores was established on the individual tests and not the complete test protocol. We recruited a group of subjects to do the land-based tests (Treadmill and Equipment Carry) and a second group of subjects who were competent swimmers and familiar with fins to do the water-based test. Some subjects participated in both parts of the reliability study.

Each subject completed the tests on three separate days. Sequential tests were scheduled at approximately the same time of day with 48-72 hours between tests. Sixteen subjects (1 female, 15 males) completed the Treadmill and Equipment Carry tests. Sixteen subjects (7 female, 9 males) completed the Swim test. The subjects were physically active male and female volunteers. While the subjects were regularly engaged in related activities (e.g., swimming, running, hiking, weight training), none of the subjects "trained for the test" prior to the sub-study. Subject characteristics are reported in Tables 4-2 and 4-3.

Table 4-2. Subject characteristics (Mean, SD and range) for the group completing the Treadmill and Equipment Carry Tests (1 female, 15 males)

Variable	**Mean**	**SD**	**Range**
Age (yr)	31.9	11.5	21-59
Height (cm)	181.9	6.2	170-193
Mass (kg)	81.5	8.9	65-96

Table 4-3. Subject characteristics (Mean, SD and range) for the group completing the Swim Test (7 females, 9 males)

Variable	**Mean**	**SD**	**Range**
Age (yr)	32.6	8.4	19-41
Height (cm)	179.4	11.1	158-196
Mass (kg)	74.9	13.4	53-95

Each test was administered in exactly the same manner with strict adherence to the correct testing protocols. Participants used the same equipment (e.g., treadmill, pack, fins) each day and were asked to dress in the same clothing. Participants were asked to give their "best" effort on each test each day. Following a standardized warm-up, each participant completed the test according to the standardized protocol. Participants were not informed of their test scores until the final test had been completed.

Data were analyzed to address several issues and questions related to reliability. Repeated measures analysis of variance (ANOVA) was used to test for differences between the three test results. Notwithstanding the possibility for day-to-day variability in performance for any individual subject, the group scores reflect the average variation in performance. The 95% confidence intervals were calculated to identify the expected variability in performance. Finally, linear regression was used to evaluate the predictive power of the first test score relative to the best score for each test.

Test scores (group means and SD) for each test are shown in Table 4-4. Repeated measures ANOVA revealed no significant differences between the scores (performance time) from the three tests.

Table 4-4. Mean (±SD) performance times for Treadmill, Equipment Carry and Swim tests completed on three separate days (n=16)

	Test 1	**Test 2**	**Test 3**
Treadmill Time (min)	22.9 (6.5)	22.7 (6.6)	22.9 (6.0)
Equipment Carry (min)	5.7 (1.0)	5.7 (1.0)	5.6 (1.2)
Swim Test (min)	12.3 (2.2)	12.4 (2.2)	12.1 (1.9)

Confidence intervals were calculated using the standard deviation of the three tests for each individual subject. The results are reported in Table 4-5.

Table 4-5. Average individual standard deviation (Ind SD) and Confidence Intervals for Treadmill, Equipment Carry and Swim tests

	Ind SD	**68% CI**	**95% CI**
Treadmill Time (s)	39.0	±39.0	±76.4
Equipment Carry (s)	12.6	±12.6	±24.7
Swim Test (s)	18.6	±18.6	±36.5

Linear regression analysis revealed strong significant relationships between the score on the first test and best score from the three tests. The results are shown in Figures 4-2, 3 and 4.

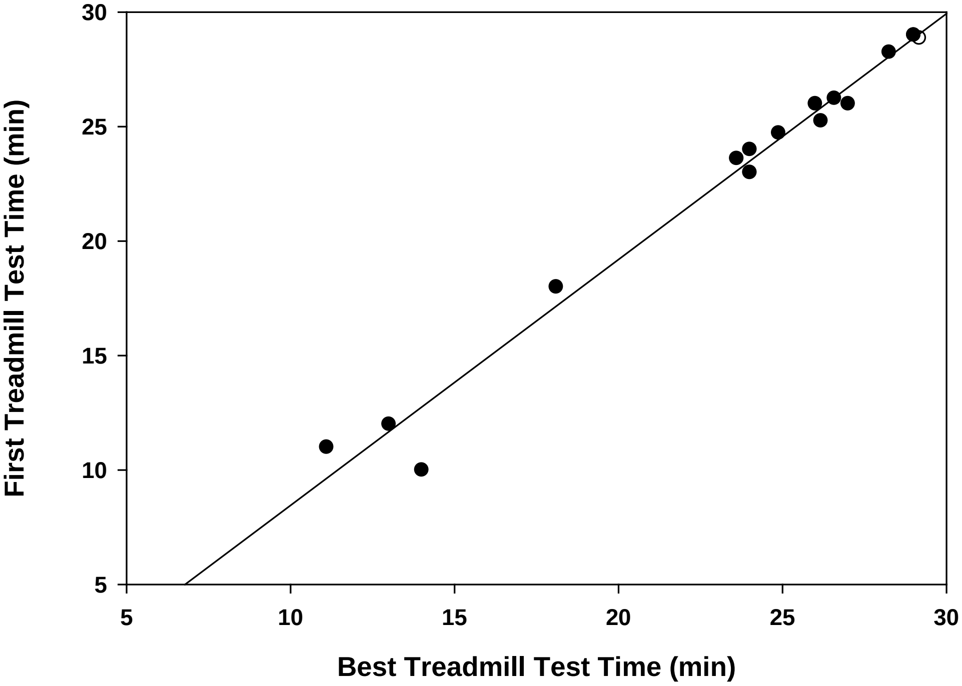

Figure 4-2. Linear regression analysis showing the relationship of the score from the first treadmill test to the best test score (n=16). $R^2 = 0.981$

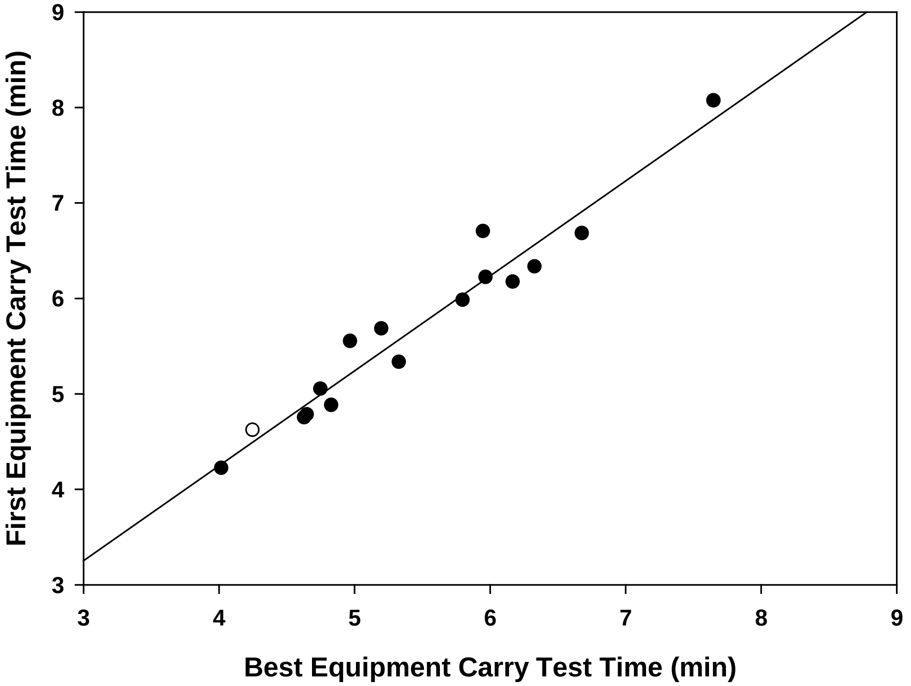

Figure 4-3. Linear regression analysis showing the relationship of the score from the first Equipment Carry test to the best test score (n=16). $R^2 = 0.947$

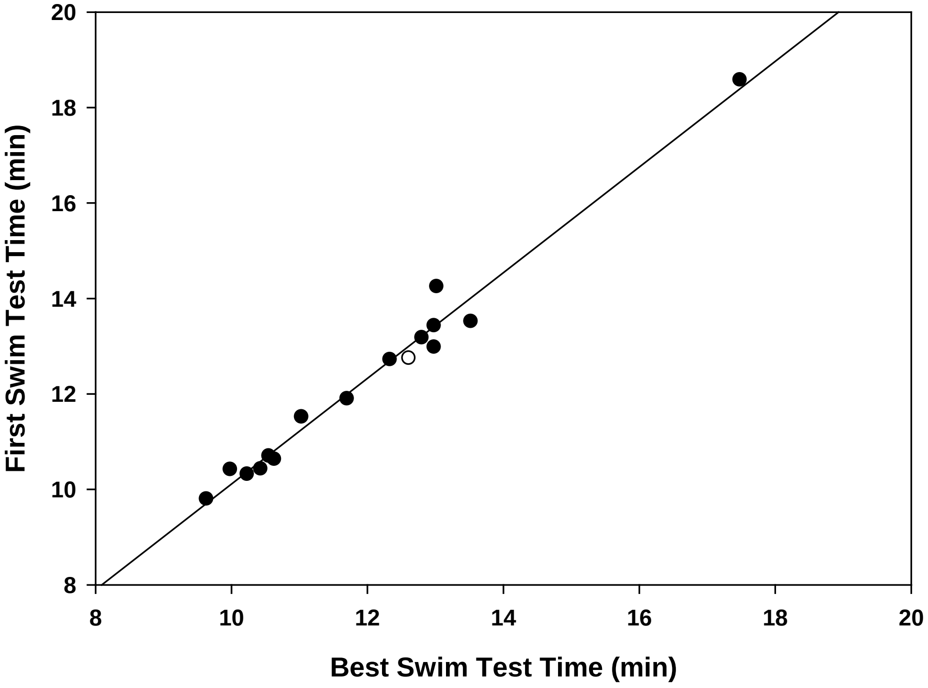

Figure 4-4. Linear regression analysis showing the relationship of the score from the first Swim test to the best test score (n=16). $R^2 = 0.980$

The group means were not significantly different for scores from the three tests which shows that there is no systematic improvement between the first attempt at the test and the third attempt at the test. One might be tempted to speculate that people should get better with practice, however in the absence of such an improvement, we conclude that the influence of practice on optimal performance is negligible.

Calculation of the individual standard deviation between the scores from the first, second, and third tests reflects the expected variability on any test. For example, the average individual standard deviation on the Treadmill Test indicates there is a 68% probability that an applicant's test time will be within 39 s (plus or minus) of that person's mean time (average of many tests). Logically, we can be more confident if we extend the bandwidth of the time allowed for the consideration of performance variability. By including two standard deviations there is a 95% probability that the subject's test time will be within 77 s (plus or minus) of their mean time. Put another way, if a subject's treadmill test time was 25 min, we can be confident 95% of the time that the applicant's best time will not exceed 26:17 (25 min + 77 s) or alternately their worst time would be 23:43.

The results shown in Figures 4-2, 3 and 4 reveal very strong relationships between the score from the first test and the best test. It is encouraging that the first test result has strong predictive power for the best result that an individual can achieve when given three opportunities. It is also encouraging that subjects achieved their best scores on the either the first, second or third attempt. In other words, the probability of a well-prepared and motivated subject giving a strong indication of his/her best performance on the first attempt is very high. Equally important, the probability of such a subject showing continued improvement if given more attempts on any test is very low. Using the R^2 value as a guide, these results infer that for the Treadmill, Equipment Carry and Swim Tests, we can be confident that 98, 95 and 98% of the variance in a person's best score is accounted for by the score from the first test.

Although we can expect excellent reproducibility between test days, it must be acknowledged that there will always be some variability in human performance. Part of this may be explained by biological variability, technical variability and mental state. Biological variability is generally minimized by advising the subject to maintain good sleep and nutrition habits and through careful scheduling. That is, the second test should occur at the same time of day as the first test. There must be adequate recovery time between the tests (e.g., 24 - 48 hours), yet not enough time (e.g., weeks) to allow either training or detraining to occur. Technical variability is minimized by careful attention to the organization of the testing environment. In the case of these tests, factors such as consistency of clothing, packs and fins, test set up (e.g., distances, testing surface, equipment weight), and test administration (e.g. instructions) will keep technical variability to a minimum. Mental state may include factors such as motivation and understanding of the task. Motivation is largely beyond the control of the tester, however maintaining a positive test environment with encouragement for the subject may help. Understanding the task is clearly an essential element of reliability and the tester must always ensure that the subject knows exactly what is expected each time.

Notwithstanding every effort to minimize variability in biological, technical and mental state, there may always be some degree of variability in test scores from day to day. For example, our subjects were asked to refrain from other heavy exercise during the sub-study so that fatigue would not influence performance. However, the willingness of the subject to comply with that request is beyond the control of the investigator. Similarly, the investigator cannot control the motivation of the subject to provide a maximal effort each time.

Although the potential variability in human performance must be recognized, there is little evidence to suggest that these tests do not show reasonable reliability from day to day. Also, there is no evidence to show any systematic improvement after the first test, which suggests that the applicants do not gain from performing the test other than the initial familiarization to the test.

Overall, we conclude that the reliability of these tests is very strong when biological, technical and mental factors are controlled to the extent possible. In implementing the test protocol, it is absolutely essential to create an environment that allows applicants to do their best. For example, the implementation process should provide thorough knowledge of the tests and optimal training programs to prepare for the test at least 3-6 months prior to the test date. Applicants must be provided with guidelines for good preparation (e.g., nutrition and rest) in the days leading up to the test. On the test day, there must be full and consistent instruction to complement the warm-up and practice components. The testing process must include the opportunity for the applicant to question procedures to ensure understanding of each element of the protocol. All of these steps will improve the general concept of test reliability. In the final analysis, good reliability implies that the test result is determined by fitness level, not other factors such as experience or lack of knowledge about the test and expectations of performance.

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Chapter 5
Development of Physical Fitness Standards

Overview

The development of performance standards was undertaken following confirmation of acceptable validity and reliability of the tests. Our approach to standards involved two distinct steps. First, we identified the level of performance on each test that was consistent with a passing or failing score. For the purposes of this report, we have elected to call this the *screening* standard. In our approach to occupational fitness, we use the term screening in a systematic way to distinguish between passing or failing scores on any test. The second step involved classification of passing scores into categories (e.g., below average, excellent). The second step was undertaken based on several factors. Feedback from the trade informed us that fitness is considered to be an essential attribute for success in the demanding QL5A course. Our observations of the physically demanding parts of training (Chapter 2) confirmed this. Fitness has traditionally been rated highly as part of the selection process for entry into the QL5A course. Consequently, in order to allow test results to be used for *selection* purposes, it seemed logical to provide a system for rating passing scores.

Much of the feedback from the SAR Trade (both operational and training) informed us that SAR-Techs must be fit enough to get to the problem ("search") in a safe and effective manner with enough physical reserve to be able to deal with the problem ("rescue"). Frequently, victims are injured or suffer from exposure to the elements. SAR-Techs must be fit enough to overcome difficult conditions while searching for the victims without succumbing to exhaustion themselves. Then, once at the scene, must have sufficient physical reserve to attend to the medical needs of the victim without taking time to recover from the stresses of getting to the problem. All of our contact with the SAR Trade led us to believe that physical fitness was very important and the greater the physical fitness of the SAR-Tech operator or student, the greater the likelihood of a positive outcome from the rescue. While it is readily acknowledged that training is not necessarily the same as actual operations, our interaction with the trade and our observations (Chapter 2) suggest that the demands of training provide unique fitness challenges. The volume and density of training exercises are often much higher than in operations. For example, students typically complete approximately 60 jumps in the condensed time period devoted to parachute training, which is several fold more than an operator would make in a typical year. It seems logical that individuals with higher fitness levels will tolerate the demands of training better than their lower-fitness counterparts, which justifies selection based, at least partly on fitness. For the purposes of this report, *selection* standard is used systematically to distinguish between relative fitness levels.

A good example of the concept that “more is better” is illustrated in Figure 5-1. The data were obtained from an experiment in the laboratory where 22 young, healthy subjects (18 male, 4 female) completed, on separate days, two exercise challenges in random order. One challenge was the SAR Treadmill Test as previously described. In this challenge, the primary outcome variable was test duration in minutes. The second challenge was a time-to-exhaustion trial where the subject worked as long as possible at the same exercise load as previously found representative of the type of work SAR students must be able to complete on course (3.5 mph and 8% grade, carrying 25 kg load). The time-to-exhaustion trial was terminated if the subject reached 60 minutes of exercise at the required metabolic rate. The results of the physical demands analysis (Chapter 2) revealed that the longest period of continuous, hard work without a break observed during the QL5A course was 44 minutes, therefore exercise duration beyond 60 minutes was not relevant to this project. As shown in Figure 5-1, six of the subjects were stopped after 60 minutes of work. The primary outcome variable was exercise duration before task failure (unable to continue due to fatigue).

The data show that the longer the duration of the treadmill test, the longer the duration of work (up to 60 minutes) under load (25 kg) at the metabolic rate previously shown to be representative of SAR work. Also shown is that completion of less than 20 minutes of the SAR Treadmill test protocol is inconsistent with the ability to work for more than 15 minutes at the required metabolic rate before succumbing to fatigue.

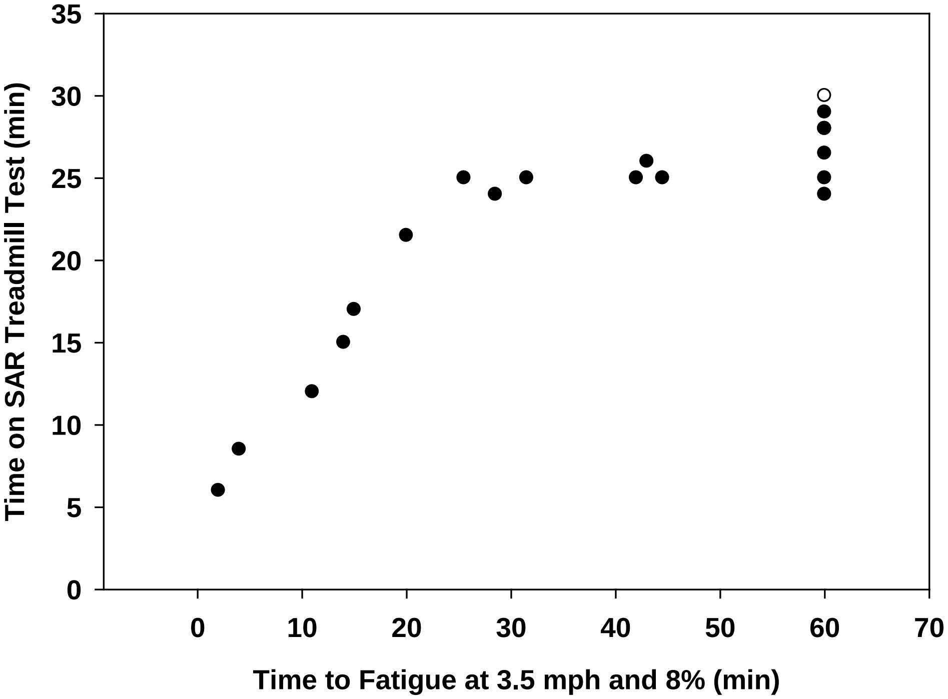

Figure 5-1. Performance time on the SAR Treadmill test plotted against time-to-exhaustion under load for 22 subjects. Note that the time-to-exhaustion trial was terminated if the subject reached 60 minutes.

Minimal standards should discriminate between those applicants who are able to safely and effectively manage the physical stresses of SAR training and those who cannot. While the minimum standards should be accessible to legitimate applicants to the SAR trade, they must be rigorous enough to ensure safe, efficient and reliable completion of training exercises. Great care was taken throughout this project to identify the physical demands of the various aspects of the QL5A course and to acknowledge the demanding environmental conditions that increase the difficulty. When setting the performance level required for a passing score, we have adopted the position that such levels indicate the lowest level of fitness required to meet the demands as we understand them. Applicants are tested under near-perfect conditions while QL5A training is done under some of the worst possible conditions. Nevertheless, in the interest of complete fairness to the applicant, the matter of biological variability should be considered when applying the minimal standards. The estimated confidence intervals reported (Table 4-5) from the reliability sub-study could be used to justify a re-test should an applicant fail. The individual standard deviation on the Treadmill, Equipment Carry and Swim Tests were 39, 13 and 19 s, respectively. If, for example, an applicant were to fail a test by a margin within those confidence intervals (e.g., $\leq$ 39 s on the Treadmill Test), it is possible that on another day, the applicant could actually meet the standard. However, there is an equal probability that an applicant who achieves a passing score of less than 21:39 might fail on the next test.

The various methods used to arrive at minimum standards (screening) for the Treadmill, Equipment Carry and Swim tests are described below. In each case, the focus was to identify the minimally acceptable level of performance, which designated the transition from a failing score to a passing score. It should be noted that field observations, laboratory test results and scores on the new SAR tests, obtained from QL5A students were used as guidance towards the setting of minimal standards. However, reliance on the data from “successful” candidates alone could lead to artificially high minimal standards. Therefore, while the methods varied between the various tests, the underlying principle was based on the need to identify the lowest level of performance that was believed to be consistent with the ability to manage the physical demands of training.

The method for determining performance categories for the passing scores was consistent. Once the minimally acceptable score was identified, the range of performances from test results of QL5A students was considered. The best scores from the QL5A were identified as the ideal score, consistent with the top category of performance. The range between the top and the bottom scores (best score to the minimally acceptable score) was divided into 10 equal levels of performance. This method allows any test score to be assigned from 0 to 10 points. A failing score receives 0 points. A passing score consistent with the minimally acceptable level of performance receives 1 point, while a score consistent with the best score receives 10 points. This provides a simple method of identifying the relative fitness level on each test for selection purposes.

Our analysis of the physical demands of the QL5A course (Chapter 2) revealed that aspects of physical fitness embedded in each test (Treadmill - overall work capacity and aerobic fitness; Equipment Carry – strength and muscular endurance; Swim – water-based aerobic fitness with emphasis on lower-body propulsion) were all important. Therefore, it was decided that an applicant must meet the minimum expected level of performance (screening level) on each test. Furthermore, when rating scores for selection purposes, there was no compelling reason to weight performance on one test higher or lower than the others.

Screening and Selection Standards for the Treadmill Test

The minimal standard (screening) for the Treadmill test arose from our integration of the field observations with the laboratory studies of the physiological responses to load carriage. As already described, it was determined that SAR students must be able to complete repeated bouts of exercise of at least 15 minutes duration at a metabolic rate equivalent to 37 ml/kg/min while carrying relatively heavy loads (typically 25 kg). In the interest of developing a simple test that could be easily replicated under standardized conditions without sophisticated gas analysis equipment, the minimum standard for the treadmill test was based on demonstration of the ability to complete 15 minutes of work at the desired workload. The test protocol was designed with this minimum level of performance in mind. Following the standardized, progressive warm-up of 6 minutes duration, the test subject is required to complete 15 minutes of work where the metabolic rate is estimated to be 37 ml/kg/min. Therefore, if a test subject completes 21 minutes in total (6 minute warm-up + 15 minute “constant-work phase) that level of performance is consistent with a passing score.

The best scores on the Treadmill test achieved by the QL5A students (Courses 42 and 43) were approximately 32 minutes test duration which provided an indication of an optimal score for the population of interest, in this case, successful QL5A students. Test duration is recorded in minutes and seconds between the beginning of the standardized warm-up and the point where the test subject is unable to continue exercise. This total time is used to rate performance on the Treadmill Test as shown in Table 5-1.

Screening and Selection Standards for the Equipment Carry Test

Determination of the minimal acceptable score for the Equipment Carry test involved several steps. First, we calculated the mean (± SD) performance time from the scores of the QL5A students tested on the final protocol (Courses 42 and 43). Dividing the average test time by 15 provided an indication of the duration of each repetition of the 40 m course. We then calculated target times slightly faster than and progressively slower than the mean lap time where each target time was approximately one standard deviation apart from the next. The projected total test time could be calculated by reconstructing the 15 repetitions from the individual lap times. Six paces for both loaded and unloaded laps were calculated (approximately 20 – 40 s) that, when reconstructed, represented a range of test times from the mean of the QL5A students to much slower than any times observed. The analysis began with the assumption that the average of the QL5A group would be an acceptable performance time. Video records of an actor performing a loaded and an unloaded repetition at each pace were made. The records for each type of repetition (loaded and unloaded) were arranged in random order on a DVD which was then shown to 16 expert judges. The judges were qualified as experts by virtue of experience as instructors in the QL5A course. The judges offered expert opinion on each pace displayed on the DVD. After watching each video clip, the judge was asked to rate the pace as “acceptable” or “unacceptable” and state the reasons for their rating. The researchers believed that the instructors were the best judges of the pace associated with a minimally acceptable rate of work when performing the activities represented by the Equipment Carry Test (e.g., loading an aircraft or boat in preparation for SAR training activities).

Linear regression was used to calculate the transition point between acceptable and unacceptable times for both loaded and unloaded repetitions of the 40 m Equipment Carry course. This analysis revealed that the minimal acceptable time for the loaded component was 27.6 s per lap, and that the minimal acceptable time for the unloaded component was 24.2 s per lap. Calculation of the minimal acceptable total test time, based on 8 loaded and 7 unloaded laps led to a minimal standard for passing the Equipment Carry Test of 390 s.

The best scores observed from testing QL5A students (Courses 42 and 43) were in the range of 250 s which provided direction on optimal performance. Test duration is recorded in seconds and the total time is used to rate performance as shown in Table 5-1.

Screening and Selection Standards for the Swim Test

Several factors were considered when developing the minimal standard for the swim test. First, we frequently observed demanding surface swim or dive exercise with equipment that lasted between 15 and 20 minutes. Second, one of the expectations during dive training at FDU-P is swimming approximately 850 of open water, dressed in wet suit and using fins. Because this swim is in open-water, sea-state may increase difficulty and navigation skills influence the total distance swum (often more than 850 m). Nevertheless, the expected time for this swim is less than 20 minutes (personal communication, dive instructors). Third, feedback from students, instructors and operators suggested that during training and actual rescues, it is often necessary to make at least 50 m of progress on the surface in open water encumbered by personal dive and emergency equipment. This is often done in a challenging sea-state where swimming is done against some combination of wind, wave and current. Importantly, the operators emphasized the need to complete the swim with enough physical reserve to provide medical aid and/or complete the rescue. In other words, swimming 50 m in very difficult conditions must not require a maximal effort. Simple calculations reveal that swimming 750 m in a pool (quiet water) in 20 minutes is equivalent to making 130 m of progress against a 1 knot current.

The best scores on the Swim Test achieved by the QL5A students (Courses 42 and 43) were approximately 11 minutes which provided an indication of an optimal score on this test. Test duration is recorded in minutes and seconds. This total time is used to rate performance on the Swim Test as shown in Table 5-1.

Table 5-1. Performance ratings for test times on the Treadmill, Equipment Carry and Swim Tests.

Treadmill		**Equipment Carry**		**Swim**	
Time	**Points**	**Time**	**Points**	**Time**	**Points**
≥32:15	10	<255	10	≤11:00	10
31:00 – 32:14	9	256 - 270	9	11:01 – 12:00	9
29:45 – 30:59	8	271 - 285	8	12:01 – 13:00	8
28:30 – 29:44	7	286 - 300	7	13:01 – 14:00	7
27:15 – 28:29	6	301 - 315	6	14:01 – 15:00	6
26:00 – 27:14	5	316 - 330	5	15:01 – 16:00	5
24:45 – 26:59	4	331 - 345	4	16:01 – 17:00	4
23:30 – 24:44	3	346 - 360	3	17:01 – 18:00	3
22:15 – 23:29	2	361 - 375	2	18:01 – 19:00	2
21:00 – 22:14	1	376 - 390	1	19:01 – 20:00	1
<21:00	0	>390	0	>20:00	0

Summary

The distinction between the minimal standard for screening (pass or fail) and rating performance for the purposes of selection should be emphasized. The *screening* standard is, in each case, reflective of the minimal level of fitness required to meet the requirements of the QL5A course. Given the arduous nature of the course and the somewhat unpredictable influence of environmental conditions on physical capacity, it seems likely that those candidates whose performance is at the minimal level would have little or no reserve to handle unforeseen challenges. Therefore, the current practice of candidate selection based on higher levels of fitness appears justified. The determination of *selection* standards was guided by acknowledging the fitness levels of successful candidates and in this case, the use of population norms is justified.

Adverse Impact

The concept of adverse impact implies that individuals sharing certain characteristics (e.g., age, gender, size) may be systematically disadvantaged by a standard. It is well known that physical capacity usually diminishes with age, however the vast majority of applicants to the QL5A course are relatively young. The average age of the members of Courses 41, 42 and 43 and the candidates tested at Pre-selection in Edmonton in January 2010 and 2011 was 30 ± 5 years. The oldest student encountered during this project was 40 years of age at the beginning of his QL5A course. A recent study by Nelson et al (2010) reported that the expected decline in VO_{2peak} in men 40-49 compared to men 30-39 years was less than 6%. Therefore, considering the relatively small age range in the target population, it seems unlikely that the minimal standards would present systematic barriers to “older” applicants that could not be offset by physical training. It should also be noted that it is well known that the SAR-Tech trade is very physically demanding (http://www.forces.ca/en/job/searchandrescuetechnician) and presumably applicants are well advised to undertake extensive physical training prior to application.

The tests were designed to impose “absolute” loads (e.g., pack, weights) that are representative of the kind of loads commonly encountered throughout the QL5A course. It might be suspected that smaller individuals would be disadvantaged by this approach however analysis of test results from Courses 42 and 43 as well as candidates tested at Pre-selection in Edmonton in 2010 and 2011 reveal no such trend. Figures 5-2 and 5-3 show scatterplots of body mass plotted against Treadmill and Equipment Carry scores, for 92 and 81 subjects, respectively. Linear regression analysis revealed that body weight predicts approximately 9% of the variance in performance on the Treadmill Test and less than 1% of the variance in performance on the Equipment Carry Test. In other words, body mass cannot be considered as a significant factor in test performance. This analysis was not conducted for the Swim Test because swimming is not a weight-bearing activity.

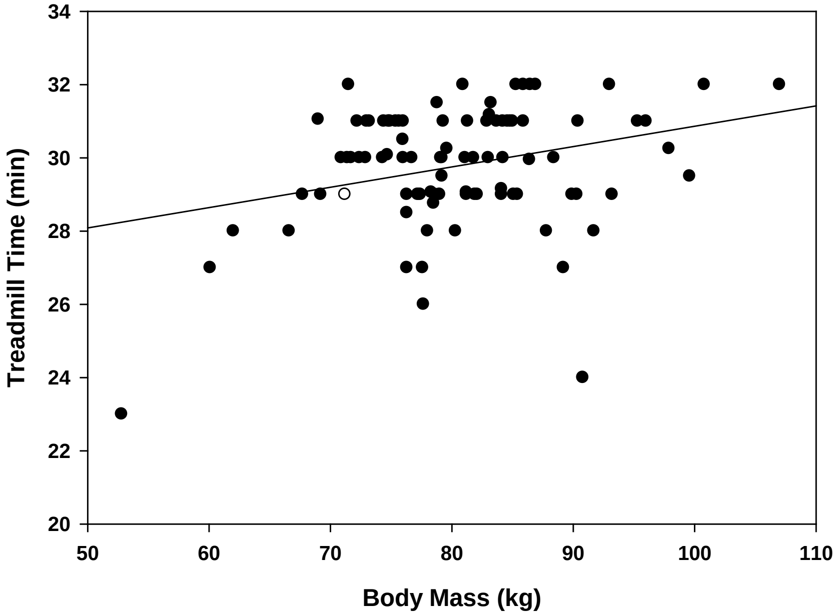

Figure 5-2. Regression plot of body mass and Treadmill Test time (N=92, r^2 = 0.09, ns)

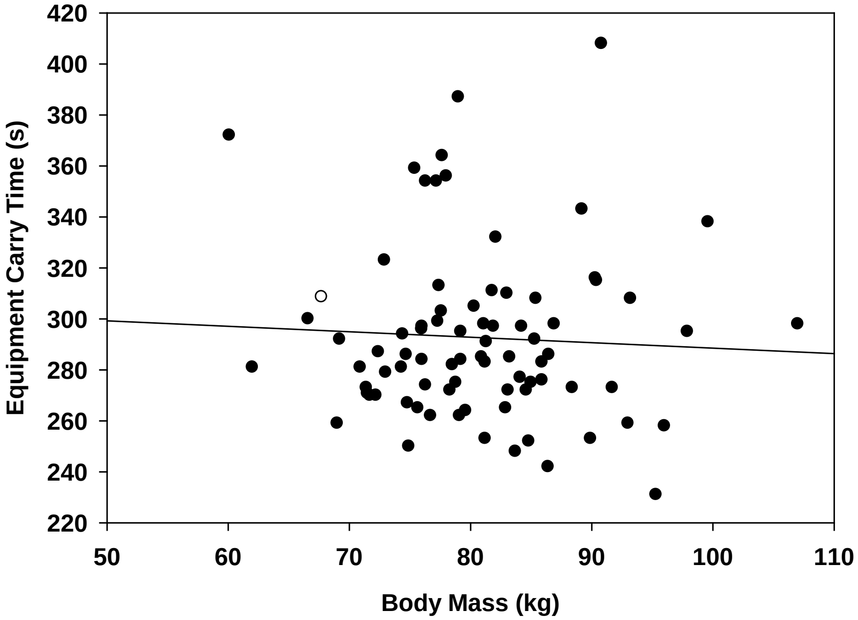

Figure 5-3. Regression plot of body mass and Equipment Carry Test time (N=81, r^2=0.003, ns)

In contrast, fitness is a much stronger predictor of test performance. This is important because the test outcome is meant to be determined by fitness, not other factors such as size. In a separate analysis of data from load carriage studies in our laboratory, test results from 22 young healthy, physically active subjects show a strong correlation (r = 0.83) between VO_{2peak} and Treadmill Test time. In this experiment, each subject completed a graded exercise test to exhaustion on a treadmill while carrying the same pack used in the SAR-Tech Treadmill test. The main outcome was the measurement of peak oxygen uptake. On a separate day, each subject completed the SAR-Tech Treadmill test where the main outcome was elapsed time. The results are shown in Figure 5-4 below:

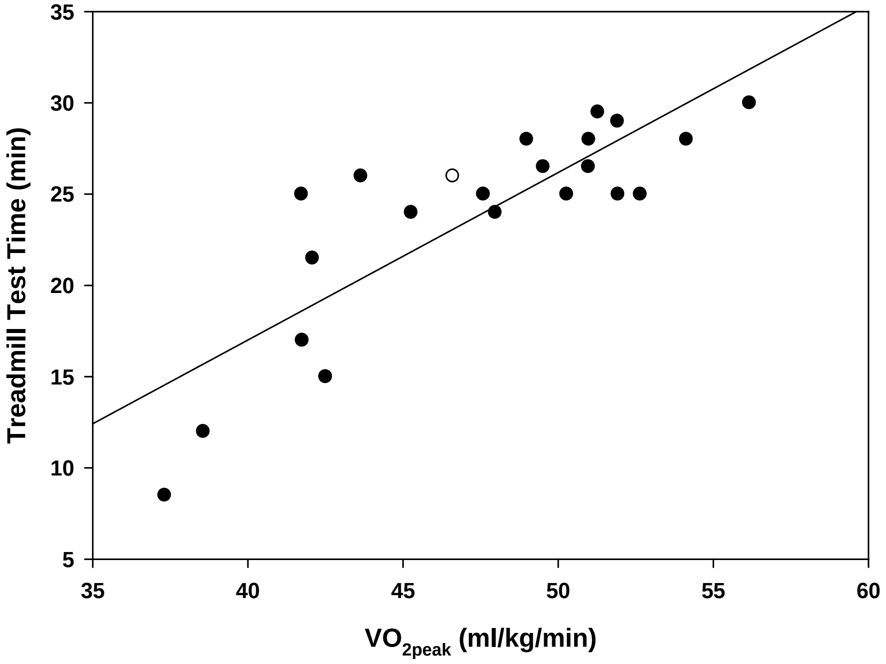

Figure 5-4. Regression plot of VO_{2peak} and Treadmill Test time (N=22; $r^2 = 0.69$, $p<.05$)

Interestingly, linear regression analysis of body mass and Treadmill Time with the same 22 subjects revealed no significant relationship and the r^2 value was actually less than shown in Figure 5-2 where the data came from testing students and applicants to the QL5A course.

There is simply not enough data from testing legitimate female applicants to the QL5A course to draw any conclusions regarding adverse impact due to gender. Most females are smaller than most males and typically have a lower fraction of muscle compared to total body mass. As well, it is acknowledged that women generally have smaller lungs and hearts as well as lower blood volume and hemoglobin levels (Shephard and Bonneau, 2002). Consequently, when fitness scores for men and women are categorized, a lower score is required for a woman to be placed into the same fitness category. For example, the mid-points of the "Good" aerobic fitness category for males and females of 30-39 years (based on VO_{2max}) are 46 and 41 ml/kg/min, respectively (McArdle et al, 2001, p.163).

To date, only two female applicants have completed the test protocol (Pre-selection 2010). Both females were relatively small in size (body mass was 53 and 60 kg). Both candidates passed the Treadmill and Swim Tests. One candidate passed the Equipment Carry Test while the other was unable to complete that test due to a pre-existing wrist injury which prevented her from carrying the weights. Both candidates passed the Swim Test. Clearly the standards are accessible to women, however at this time it is not possible to speculate further. It would be prudent to analyze test results from female applicants as it becomes available to evaluate the potential for adverse impact due to gender.

In summary, despite the fact that two of the tests involve carrying absolute loads, there appears to be no adverse impact due to body mass. The justification for the absolute loads is firmly grounded in the documented demands of the QL5A course and the SAR trade. The size range for the recommended test equipment (e.g., packs and fins) can accommodate differences in torso length and foot size, so other aspects of body size (e.g., height) should not be factors in test performance. Based on available data, the relatively narrow age range of applicants to the QL5A course suggests that deterioration of fitness due to ageing alone should not influence the accessibility of the standards or prevent "older" applicants from being competitive with "younger" applicants. While the standards are accessible to women, there remains the potential concern that test results from a "fit woman" may be less competitive than results from a "fit man". Further analysis of test data from actual applicants will be required to explore this possibility.

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Chapter 6
Summary and Recommendations

The purpose of this project was to develop new physical fitness tests and standards for entry to the QL5A course based at CFSSAR. The project was completed in several phases which included a literature review (Appendix A), physical demands analysis of the QL5A course (Chapter 2), development of new tests with emphasis on establishing acceptable validity and reliability (Chapter 4), establishment of standards for both screening and selection (Chapter 5), and, finally, numerous demonstrations of the logistical feasibility of test administration. For the purposes of this report, the outcome of this research is referred to as the "SAR-Tech Selection Test"

The researchers encountered a considerable mix of opinion from the SAR trade on the value of the old test. Notwithstanding the apparent simplicity and logistical convenience of the old test, any further use of this tool cannot be justified. There is little doubt that completion of all the physical challenges within the target time requires a very good fitness level, however the critical concern is the lack of any rational connection between that "performance" and the actual physical demands of the QL5A course. One of the most obvious shortcomings in test design is that all the elements in the old test require the candidate to work against his/her own body mass. Running, chin-ups and push-ups are examples of activities where strength-to-mass ratio is a significant factor in performance. However, it is very important to recognize that virtually all the "work", with the exception of PT, observed during our systematic analysis of the QL5A course involved effort against "absolute" resistance (e.g., dive gear, parachutes, medical kits). At the risk of oversimplification, if the task requires moving equipment from point A to point B, then a test that mirrors the physical demand of that requirement is far more valid than a test that involves lifting one's own body mass. Therefore, one of the first decisions made in this project was in favor of a "task simulation" approach to testing rather than perpetuating the myth that excellence in non-specific fitness component evaluations predicts success in work against absolute loads.

In designing the new tests, care was taken to select absolute loads that are representative of the loads lifted and carried during the QL5A course. The Treadmill

Test is completed while carrying a properly fitted pack (identical to the pack used on course) loaded to 25 kg, which is a representative weight for an overnight pack. The minimal standard (screening) is based on the requirement of the candidate to demonstrate the ability to work under load at a metabolic rate for a period of time that is consistent with the amount of effort typically required on course during a bout of hiking or back-country skiing. The Equipment Carry Test requires lifting and carrying weights (bilateral and unilateral carry) that are similar to many pieces of equipment (e.g., dive tanks, dive bags, parachutes, medical kits) that are regularly moved while on course. The screening standard reflects the minimal expectations of experienced instructors for “purposeful” movement when performing various tasks related to loading equipment in vehicles, aircraft or boats. Purposeful movement is characterized by getting the job done in a safe and effective manner in the context of efficient use of training time and simulation of emergency response situations during training. The Swim Test utilizes fins which change the emphasis on propulsion from the upper body to the lower body musculature. This is a more appropriate reflection of the kind of water-based work that occurs during the QL5A course. Excluding PT, all water-based work on course involved equipment. The minimum standard reflects reasonable competency in the water and the ability to make progress in open water in the face of challenging conditions of sea-state (e.g., wind, wave, tide, current).

In each case, the selection standards are based on demonstrated physical capacities of successful QL5A students. Selection based on fitness level is justified by the belief that superior levels of fitness translate to greater physiological reserve and greater ability to resist fatigue during challenging training periods. There is no doubt that the QL5A course is very physically demanding and while search and rescue training may be thought of as learning basic skills (e.g., scuba diving) it is important to remember that those skills are then incorporated into rescue simulations. The physical challenge and risk involved in those simulations cannot be underestimated. Exiting an aircraft with full equipment to land in a confined area, or diving into an overturned vessel is serious business whether during an actual rescue or during SAR training. Execution of search and rescue skills under challenging environmental conditions requires a unique blend of physical, technical and cognitive abilities. There is no question that greater physical capacity and resistance to fatigue are desirable attributes to complement the necessary technical and cognitive skills. Importantly, the physical attributes are often employed to get the SAR-Tech student to the scene (e.g., hiking, skiing, swimming) in a timely manner in order to provide medical aid or effect a rescue. If the SAR student is exhausted upon arrival, the physical, technical and cognitive challenges of rescue or medical aid are exacerbated.

We make the following recommendations regarding adoption, implementation and evaluation of the SAR-Tech Selection Test.

- The SAR-Tech Selection Test should be adopted as a complete package. It would be inappropriate to alter the testing protocol without further research. Adding or deleting tests, changing the order of the tests, the rest periods, or the test equipment is not advised.
- The SAR-Tech Selection Test was designed for the purposes of SCREENING as well as SELECTION. The minimum standard for each test defines the level of performance required to pass that test. An applicant who meets or exceeds the minimum required level of performance on all tests should obtain an overall PASS.
- Individuals who meet or exceed the minimum standards should be considered physically fit to undertake the SAR-Tech QL5A course. However, there should be further follow-up to regulate safe and effective work during the course. It is important to remember that physical fitness is not stable and is subject to change over time. Therefore, the practice of administering the test at the point of application, prior to the Pre-Selection process, at the commencement of the QL5A course, and possibly during the course, should be continued.
- Individuals who fail to meet the standards outlined in this report should be considered physically unfit to meet the physical challenges of the QL5A course. The standards are based on our best understanding of the minimum requirements of for safe and effective completion of SAR training.
- Individuals who fail to meet the minimum standards should be fully debriefed and offered remedial physical training programs, followed by opportunities for retesting.

- Individuals who fail to meet the minimum standards by the margins identified as Confidence Intervals (Table 4-5) may be allowed a retest because their score may reflect the expected variation due to biological variability.
- Other than a retest granted for the reason above, opportunities for retesting should normally be allowed after an appropriate period of time that allows for physical training (e.g., three months).
- One of the deliverables from the research group was an information package and training program to assist potential candidates with effective preparation for the test. It is recommended that this information be made accessible to all prospective applicants and that PSP staff at CF bases be available to provide professional assistance guide this preparation.

Appendix A
Review of Literature

Literature Review

Introduction

There is very little information available on the occupational physical demands of the Canadian Forces Search and Rescue Technicians (SAR-Techs) or any other international search and rescue occupation. The only document relating specifically to the Canadian Forces SAR-Techs was put forth by Deakin *et al.* in 1999. It has been generally assumed the SAR-Tech trade is physically demanding and requires a high level of fitness. However, there is little published research to support this. One purpose of this literature review is to identify the physical demands of the SAR-Techs and formulate a basic understanding of these demands. To accomplish this, the authors will investigate wildland firefighting, mountain climbing, paramedic and emergency response workers, as well as other occupations which relate to the Search and Rescue profession. A second purpose of this review will be to analyze performance and fitness testing in various military organizations regarding the needs required for the development of job-related fitness tests and standards.

Physiological Demands of SARTechs and Related Occupations

Deakin et al. (1999) reviewed SAR-Tech mission and training reports from 1991-1995, and characterized the responses as marine emergencies (51.6 %), land based emergencies (18.1%), emergencies involving air rescue (15.4%), and unclassified (14.9%). They concluded the majority of missions were completed in less than one hour, with other lasting up to four hours. The Ergonomics Research Group (ERG) also developed an expert panel of eleven (11) SAR-Techs that generated a list of the most physically demanding and most frequently performed tasks. This list is summarized in Table A-1.

Based on the relationships identified between the SAR-Tech's most Physically Demanding Tasks and Frequently Performed Tasks, physiological research should focus on the following areas:

1. Climbing/hiking over various terrain with load carriage,
2. Lifting/carrying equipment and/or victims,
3. Wearing full equipment for extended periods of time,

4. Diving with a compressed air breathing apparatus (CABA),
5. Parachute jumping.

Table A-1. A list developed by an expert panel of eleven SAR-Techs identifying physically demanding and frequently performed tasks done by SAR-Techs.

Physically Demanding Tasks		Frequently Performed Tasks
Night full equipment jumps		Re-pack parachutes
Mountain climbing and rescue	→	Climb/hike over various terrain
Hiking to crash site	↗	Search
Surface swim		Boat hoist
Extracting/carrying victims	↘	Fly
Lifting of equipment	→	Load/unload aircraft
Flying in full equipment (fixed wing)	→	Wear heavy equipment over time
Flying in full equipment (rotary wing)	↗	Stokes hoist
Night CABA dive	→	CABA dive
Day full equipment jumps	→	Day training parachute jumps

Adapted from Deakin et al.1999.: Table 2. Most physically demanding and most frequently performed tasks by the expert panel.

→ Denotes relationship between Physically Demanding and Frequently Performed Tasks. CABA, compressed air breathing apparatus.

Climbing/hiking over various terrain with load carriage

SAR-Tech hiking and mountain climbing activities are regularly performed with external loads (such as backpacks) or what is referred to as load carriage. It is well documented that energy cost increases in a systematic manner with increases in load carriage, velocity of exercise, and/or surface grade (Knapik et al. 1996). Presumably during a victim rescue, SAR-Techs function at a self-paced speed. The exercise intensity at which individuals self-pace during load carriage is highly dependent on load mass and the individual's aerobic fitness (Myles and Saunders 1979). Myles and Saunders (1979) investigated subjects exercising with load carriage equal to 10% and 40% of body weight carried on their back. The heavier load carriage placed significantly more strain on the cardiopulmonary system, with significant increases in heart rate, ventilation, frequency of breathing, and rating of perceived exertion. When the subjects were allowed to self-pace, they compensated for the heavier load carriage by decreasing walking speed. Presumably, individuals with an increased level of fitness can either self-pace at a higher speed or maintain a physiological reserve buffer, both which would be beneficial to performance.

In an investigation by Patton et al. (1991), performance over a distance of twelve (12) km was assessed at speeds and load carriage typically utilized by recreational hikers and infantry soldiers. Energy cost was measured at different treadmill speeds (1.10 $m{\cdot}s^{-1}$, 1.35 $m{\cdot}s^{-1}$, and 1.60 $m{\cdot}s^{-1}$) and different load carriages (unloaded, 31.5 kg, and 49.5 kg) over the fixed distance. The unloaded condition, regardless of speed, produced no changes in oxygen consumption (VO_2). However, the load carriage conditions produced significant increases (10 to 18%) in VO_2, with the 49.4 kg load eliciting a significantly higher VO_2 than the 31.5 kg load for all speeds. In a similar study which investigated a shorter sustained treadmill exercise bout (5 km), it was found oxygen uptake, heart rate and pulmonary ventilation increased linearly with load carriage (Borghols et al. 1978). Each kilogram of extra load carriage increased absolute oxygen consumption by 33.5 $ml{\cdot}min^{-1}$, heart rate by 1.1 $beats{\cdot}min^{-1}$ and pulmonary ventilation by 0.6 $l{\cdot}min^{-1}$. Therefore, an 80 kg SAR-Tech hiking or climbing at an unloaded VO_2 of 25 $ml{\cdot}\ kg^{-1}$ min^{-1} would have their rate of oxygen consumption increase to 35 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ and 42 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ when hiking with a 20 or 40 kg pack, respectively.

The studies described above were performed on a treadmill. However, terrain can have a considerable effect on pace and energy expenditure. Ruby et al. (2003) investigated the physiological responses of Wildland Firefighters to a maximal hike along a 660.5 m dirt trail with a grade increase of 20.75%. Expired gas samples were measured while the firefighters performed the task with no load carriage or a 16 kg load carriage. Average pace without load carriage was a 1.21 m· min^{-1} while the pace with load carriage was a significantly slower 0.93 m· min^{-1}($P < 0.05$). Despite a considerably slower pace than previously studied (Patton et al. 1991; Borghols et al. 1978), average relative oxygen consumption was ~80% of peak VO_2 (36.8 ml· kg^{-1}·min^{-1}) when carrying the 16 kg load carriage. Completion time was significantly correlated ($P < 0.05$) with the subject's relative peak VO_2 ($r = 0.87$), once again suggesting that aerobic fitness is important to hiking/climbing with load carriage.

Although, the Patton et al. (1991) investigation was related to recreational hikers and infantry soldiers, it is unclear how these results will relate to the speeds and distances covered by SAR-Techs. Deakin et al. (1999) reported average oxygen consumption values between 26.45 and 34.08 ml·kg^{-1}·min^{-1} for the following four tasks: (1) 400 m Toboggan Pull over snow (34.08 ml· kg^{-1}·min^{-1}); (2) 100 m Toboggan Pull over varied terrain (30.15 ml·kg^{-1}·min^{-1}); (3) Long-Distance uphill hike with personal pack (27.75 ml· kg^{-1}·min^{-1}); (4) 300 m Snowshoe Hike (27.55 ml·kg^{-1}·min^{-1}); and 100 m Stokes/Lit-O-Splint Carry (26.45 ml·kg^{-1}·min^{-1}). These data seem to be consistent with the average VO_2 values reported in literature describing the energy expenditure required to perform sustained locomotion with load carriage over uneven terrain.

If it is considered the data from Ruby et al. (2003) and Deakin et al. (1999) represent the upper limit expected by SAR-Techs performing hiking/climbing activities with load carriage, then the minimum level of aerobic fitness of a SAR-Tech would need to be high enough to sustain a work rate equivalent to ~35 ml·kg^{-1}·min^{-1}. The predictor of sustainable work rates is the work intensity relative to anaerobic threshold (AT). Some effort has been made to publish reference values describing normative responses to incremental exercise tests (Neder et al. 2001; Habedank et al. 1998; Inbar et al. 1993). The data from Habedank et al. (1998) reports an average AT for the 101 healthy volunteers studied (age 16 – 75) to be ~57.5% of VO_{2max}. Inbar et al. (1993) with a population of 98, report an average anaerobic threshold of 58% of VO_{2max}, without any differentiation between the active and sedentary populations within the subject pool. It is expected, based on the traditional fitness level of a SAR-Tech, the average SAR-Tech would reach AT around 70% of VO_{2max}. Therefore, to sustain climbing/hiking activities requiring ~35 ml·kg^{-1} min^{-1} would require a SAR-Tech to have an aerobic fitness level equivalent to or greater than 45 ml·kg^{-1}·min^{-1}.

Lifting/Carrying equipment and/or victims

There is limited literature on the physiological demands for lifting and/or carrying objects. Many investigations have documented the effects of resistance exercise on muscle physiology (Benson et al. 2006; Adams et al. 1998; Always et al. 1989; Booth et al. 1998; Durand et al. 2003), as well as the efficacy of resistance training designed to elicit specific physiological adaptations (Tran et al. 2006; Behm et al. 2002; Byrd et al. 2005; Carpinelli and Otto 1998; Hass et al. 2000; Munn et al. 2005; Wastcott et al. 2001). However, very little effort has been given to quantify the resistance moved or carried by a particular occupation, or to describe the level of fitness one needs to sustain such work. Some research has been done to describe the general fitness of populations who are required to lift and carry. However, because it is difficult to quantify each task documented in these studies relative to body weight, height and gender, direct comparison to the SAR-Tech profession is difficult.

Table A-2 presents a compilation of data from several studies which have attempted to quantify the fitness of individuals performing lifting/carrying tasks related to their occupation. The review of literature includes combat soldiers (Panichkul et al. 2007; Sekulic and Miletic 2006; Sharp et al. 2002; Richmond et al. 2008; Williams and Evans 2007), firefighting with self contained breathing apparatus (Sothmann et al. 2004), and ambulance personnel involved in lifting/carrying stretchers (Barnekow-Bergkvist et al. 2004). Many of the tests are physically demanding and related to the occupation being investigated. A two-person stretcher carry (96.9 kg) up-and-down 51 steps was evaluated by: (1) the time heart rate (HR) was > 70% HR_{peak} as well as, (2) peak lactate accumulation. Heart rate was shown to remain > 70% HR_{peak} for ~2.4 minutes, with lactate accumulation reaching 5.3 $mmol \cdot l^{1}$ indicating a physically demanding task (Barnekow-Bergkvist et al. 2004). Extracting/carrying victims was previously identified as a Physically Demanding Task by the SAR-Techs (Deakin et al. 1999), and was related to the Frequently Performed Task of loading/unloading aircraft (Table A-1).

Table A-2. Compilation of research studies quantifying lifting/carrying tasks related to occupational duties.

Reference	Occupation	n	Age (yrs)	Weight (kg)	Height (cm)	VO_{2max} ($ml \cdot kg^{-1} min^{-1}$)	Repetitive lift and carry # of reps x mass (kg) x d	Single lift
Williams and Evans 2007	British Army	21	27	79	176	48.4	34 x 22 x 10	63.2 kg
Barnekow-Bergkvist et al. 2004	EMS	55	35.7	84.4	180.3	43.3	---	1420 N
Sharp et al. 2002	U.S. Army	2117	20.4	74.2	175,3	50.7	---	1266.5 N
Sothmann et al. 2004	Fire fighting	138	36	84	172	---	---	---
Richmond et al. 2008	Royal Air Force	58	31.1	80.4	180	----	18 x 20 x 30	38.4 kg

EMS, emergency medical services

Wearing full equipment for extended periods of time

Like most of the identified issues surrounding SAR-Techs, there is a void in the literature related to wearing full equipment for extended period. One research area that will assist in understanding this issue is research with obese populations. External adipose tissue represents an additional mass that is carried on the body and produces a physiological disadvantage, much the same as the equipment worn by the SAR-Techs.

Research investigating the influence of accumulated fat around the ribs, diaphragm, and abdomen, on chest wall compliance (Naimark and Cherniack 1960) and reductions in lung volumes (Zerah et al. 1993; Weiner et al. 1998) has shown a close relationship with obesity and increased total oxygen consumption at rest (Zavala and Printen 1984; Refsum et al. 1990). The high percentage of oxygen consumption has been related to an increased work of breathing by the respiratory muscles (Kress et al. 1999). Naimark and Cherniack (1960) showed that due to the reduction in chest wall compliance, the respiratory muscles of obese individuals are performing twice as much work as individuals without external loads (normal BMI). Obesity appears to reduce functional residual capacity (FRC), total lung capacity (TLC), and vital capacity (VC) at rest, associated with the balance of elastic recoil of the chest wall, diaphragm and lungs (Zerah et al. 1993).

Obesity has therefore been shown to influence lung function by imposing an external load on the chest wall and by placing the respiratory muscles at a disadvantage, described as respiratory muscle inefficiency (Weiner et al. 1998). When obesity is reversed with surgery, lung volumes have been shown to increase, along with increased respiratory muscle performance (Weiner et al. 1998). In addition, Burki et al. (1984) reported obese individuals must increase their minute ventilation in order to meet the demands of the increased work of breathing. To date, no metabolic or ventilatory data has been collected on the SAR-Techs at rest when wearing heavy equipment to determine if similar physiological changes are occurring.

Significant pulmonary ventilation and perfusion defects have also been reported in obese patients (Holley et al. 1967). The reduction in lung volume with obesity has been shown to impair ventilation to the lower lung zones resulting in low ventilation to perfusion (V/Q) ratio (Holley et al. 1967). V/Q mismatch may lead to arterial hypoxemia as the PO_2 of the blood exiting the lower lung zones will remain similar to mixed venous blood. Both the increased work of breathing, combined with the potential for arterial hypoxemia would likely contribute to the description of wearing heavy equipment for long period of time as being physically demanding and strenuous. Further investigation into these issues would provide insight into the unique physical and physiological effects SAR-Techs incur when wearing heavy equipment.

Diving with a compressed air breathing apparatus (CABA)

Most of the research investigating CABA diving has focused on the potential risks of decompression sickness and clinically observed risk factors associated with underwater diving with a self-contained underwater breathing apparatus (SCUBA). In 2005, the University of Victoria Occupational Testing Group (OTG) released a report investigating the physical and physiological demands of dive tasks performed by the Canadian Forces Dive Personnel (Docherty et al. 2005). To date, this is the only know report which systematically investigated the physiological demand of diving tasks. Data were collected on Clearance (n = 28), Ship's Team (n = 41), Port Inspection (n = 27), and Combat (n = 12) divers. Divers tasks analyzed were: (1) carrying and loading equipment, (2) dressing and preparing to dive, (3) diver casualty, (4) surface swimming, (5) underwater swimming, (6) working unsupported, (7) swimming in current, and (8) swimming with equipment. Average age, bodyweight, height were 28.7 yr, 82.5 kg, and 180.0 cm, respectively. Maximal heart rate (obtained via 400 m running sprint and 200 m surface swim) was compared to heart rate recorded during each task and reported as a percentage of maximal heart rate (%MHR). Table A-3 provides a summary of the data.

Based on these results, it is apparent that underwater diving is not the only physically strenuous task involved in the diving evolution. Pre/post dive tasks, measured by Docherty et al. (2005), involved carrying equipment (personal dive gear, 13-15 kg; dive weights, 11-16 kg; and gas cylinders, 37 kg) 100 to 200 m. In many cases, the equipment was carried over several trips. Dives did not exceed a depth of 30m and average work time ranged from 12-30 min. Divers spent up to 13 min swimming on the surface to reach the dive site, shuttle equipment, and swim to safety. Diver casualty (rescuing another diver in distress) was analyzed for land and water components during a casualty simulation. The water component consisted of finding the diver in the water and transporting them to medical assistance out of the water (81% MHR). The land component consisted of the diver casualty being carried by stretcher a standard distance on land (90% MHR, 1.3 min, and 41 $ml\cdot kg^{-1}\cdot min^{-1}$). Table A-3 data demonstrates all phases measured during the diving phase resulted in very heavy to extremely heavy work intensities and confirms the description of diving with CABA as being 'physically demanding' (Docherty et al. 2005).

Table A-3. Physiological data reported on Canadian Forces Diving Personnel completing various task simulations and training routines.

Task	%MHR	VO2 ($l\ min^{-1}$)	VO2 ($ml\ kg^{-1}\ min^{-1}$)	Work Intensity Rating
Pre/Post	76	2.36	28.7	Extremely Heavy
Diving (30 m)	72.3	---	---	Very Heavy Work
Surface Swim	76.7	---	---	Extremely Heavy Work
Diver Casualty	81.0	---	---	Extremely Heavy

%MHR, maximal heart rate; Work Intensity Rating, light to extremely heavy.

Investigating the effect of work while diving, Bell and Wright (1979) had subjects perform leg and arm exercise at a depth of 1.5m and measured heart rate (116-151 bpm) with predicted oxygen consumption (between 1.22 – 1.76 $l \cdot min^{-1}$). These heart rates corresponded with the heart rates obtained during various other normal underwater tasks (Docherty et al. 2005). Togawa et al. (2006) also evaluated work with SCUBA diving. Putting on the equipment and preparing for the dive elicited a heart rate ~60% MHR, and a 20 m, fin-swimming produced a heart rate of ~62% MHR. Maximal heart rate was derived on land and may be an underestimate of the work intensity underwater. However, the added compression underwater may improve venous return and therefore reduce heart rate response to exercise. These investigations indicate diving with a CABA is physically strenuous and requires both aerobic fitness in order to sustain an elevated cardiovascular stress, as well as muscular strength and endurance prior to, during, and at the end of each dive (Togawa et al. 2006).

Until recently (Jones et al. 2007) the ability to measure oxygen consumption directly from exercising divers has been limited by the regulator worn during SCUBA diving. Only a few researchers have attempted to collect pulmonary ventilation and oxygen consumption underwater (Loomis et al. 1972; Pendergast et al. 1996; Almeling et al. 2006). Previously, metabolic rate and work intensity were predicted based on heart rate then correlated to land based tests of peak oxygen consumption (Togawa et al. 2006; Mano et al. 1985). With the new advancement by Jones et al. (2007), energy expenditure and work intensity can now be accurately measured during simulated work tasks underwater. Future research with the SAR-Techs should incorporate the recent advancements by Jones et al. (2007) and report on the physical demands (collection of pulmonary ventilation and oxygen consumption) during simulated SAR and CABA tasks.

It has been speculated that breathing compressed air at depth will result in an increase in the density of such gas (Brubakk and Neuman, 2003), increasing the work of breathing relative to a comparable workload at sea level. Water temperature may also influence the metabolic cost associated with cold water diving. Oxygen consumption has been shown to increase by 25.3% (700 ml min^{-1}) when water temperature decreases from 33°C to 18°C (McArdle et al. 1976). With only heart rate data and predicted oxygen consumption values, it is difficult to formulate precise conclusions of the SAR-Tech's work load during the diving process. It is apparent however, that diving with a CABA is physically strenuous and requires an average to above average fitness level.

Parachute Jumping

A small number of investigations have attempted to measure physiological factors associated with parachute jumping, and heart rate data from these investigations is displayed in Table A-4. In an investigation by Schedlowski and Tewes (1992), a comparison of non-experienced and experienced parachute jumpers was completed to assess heart rate and respiration rate during different stages of a jump (from preparation through to landing). Non-experienced data is important as it may be an indication of the physiological stress on new recruits to the SAR-Tech program. In both groups peak arousal occurred just before parachute deployment (experienced: 153 beats·min^{-1}, 21 breaths·min^{-1}; novice: 171 beats·min^{-1}, 42 breaths·min^{-1}) with arousal being elevated again just before landing (experienced: 142 beats·min^{-1}, 30 breaths·min^{-1}; novice: 146 beats·min^{-1}, 31 breaths·min^{-1}). Surprisingly, exiting the aircraft was less strenuous then parachute deployment or landing (experienced: 132 beats·min^{-1}, 31 breaths·min^{-1}; novice: 138 beats·min^{-1}, 31 breaths·min^{-1}). Again, heart rates are significantly increased for all subjects during parachute jumps with non-experienced subjects having even greater elevation. This is supported by Breivik et al (1997) who reported that the number of jumps was the only good predictor of heart rate in expert jumpers at exit from the plane confirming that experience reduced the physiological strain of parachute jumping.

Table A-4. Heart rate response of experienced parachute jumpers during different phases of a jump.

Study	N	Exit	Freefall	Parachute Deployment	Landing
	Mean Heart Rate Values				
Fenz and Epstein 1967	10	98	---	---	104
Shane and Slide 1968	29	139	165	178	162
Reid et al. 1971	3	125	135	124	137
Deroanne et al. 1975	11	152	165	135	148
Schedlowski and Tewes 1992	18	132	153	144	134
Wittels et al. 1994	11	---	152	---	---
MEAN	14	129	154	145	137

Adapted from Schedlowski and Tewes (1992) Mean heart rate reported by five studies for experienced and inexperienced parachute jumpers at four different points in time.

Wittels et al. (1994) investigated the relationship between aerobic fitness and sympatho-adrenal response to stress (heart rate and catecholamines). Heart rate and the noradrenaline: adrenaline ratio (NA/A) were evaluated immediately after subjects completed a “guerilla slide” (sliding down a rope with an exposure to a fall of 8 m) and parachute diving at night. The NA/A confirmed the two tasks were emotionally stressful. However, there was no relationship between aerobic fitness and heart rate response to parachute jumping at night. The authors did comment on one of the subjects with significantly more parachute jumping experience then the others. This particular individual showed a significantly reduced heart rate response to parachute jumping; suggesting that experience and the potential psychological coping mechanisms reduced the physiological strain on the individual. Fenz and Epstein (1967) also support this observation, suggesting that repeat exposures to parachute jumping increased the inhibitory reaction to suppress excessive arousal.

Performance and Fitness Testing for Military Organizations

A number of Fitness Standards exist for military personnel, but there is limited data on standards for Search and Rescue technicians. Table A-5 displays a number of military fitness tests used to evaluate physical readiness. Physical readiness is defined in summary report of the *Research Workshop on Physical Fitness Standards and Measurements within the Military Services* (1999) as: (1) performance of common tasks, and (2) performance of emergency tasks.

Based on the physiological review of occupational tasks similar to the SAR-Tech trade, it is evident SAR-Techs likely require a relatively high level of aerobic fitness (VO_{2max}~45 $ml \cdot kg^{-1}\ min^{-1}$) as well as a sufficient amount of muscular strength and endurance to perform lifting and carrying activities. The following discussion will review different physical fitness tests currently performed by other militaries (internationally and nationally) and tests not currently performed but which may facilitate the SAR-Tech trade.

Table A-5. Compilation of fitness standards and tests used by Canadian Forces personnel and other international military operations to test physical readiness.

Population	Aerobic	Loaded March	Repetitive lift	Digging	Carrying	Single Lift	Upper Body Strength	Abdominal Strength	Flexibility	Leg Strength
Royal Netherlands Army	---	X	X	X	X		---	---	---	---
Canadian Forces Army	---	X	Ammunition box lift	Maximal dig	X		---	---	---	---
U.S. Army	Aerobic fitness	---	---	---	---		Push-ups (2-min)	Sit-ups (2 min)	---	---
U.S. Air Force	2 mile run	---	---	---	---		Chest press	Machine	Sit and reach	Leg press
U.S. Marine Corps	Sub-max cycle erg	---	---	---	---		Dead hang pull-up	Sit-ups (2 min)	---	---
U.S. Navy	3 mile run	---	---	---	---		Push-ups (2 min)	Curl-ups (2 min)	Toe touch	---
British Army	---	X	X	---	X	X	---	---	---	---

UK Armed Forces	1.5 mile run	---	Jerry can carry	---	---	Weight lifted to 1.45 m	Body weight lift Press-ups	Sit-ups	---	---
Air National Guard Fitness Program	3-min step test	---	---	---	---	---	Push-ups	Sit-ups	Sit and reach	---
CND Forces Parachute Fitness test	1 mile run	---	---	---	---	---	Chin-ups	Sit-ups	---	---
Royal Military College	20 meter shuttle run	---	---	---	---	---	Push-ups	Sit-ups	---	Standing long jump
CND Forces Special Operations	1.5 mile run	---	---	---	---	---	Push-ups Pull-ups 1 RM bench	Sit-ups	---	---
U.S Army Rangers	5-mile run 2-mile run Buddy run (3 miles)	16 mile (45 lbs)	---	---	---	---	Push-ups Chin-ups	Sit-ups	---	---

CF SAR-Tech **(< 16 min)**	1.5 mile run 450 m shuttle run 675 m swim	---	---	---	---	---	Push-ups Chin-ups	Sit-ups	---	---

Note: X symbolizes that the task is completed in some form, only when possible is a description of task provided. Aerobic testing is timed (distance covered in maximal time).

Aerobic fitness testing

The gold standard for measurement of aerobic fitness is the direct measure of maximal rate of oxygen consumption (Vanhees et al. 2005; Sutton, 1992). Direct measurement requires trained personnel and sophisticated equipment, and can be time consuming. This type of test is less appropriate for testing large numbers of personnel, or when the testing location is variant or lacking in required equipment. Table A-5 displays predictive tests often used to test military and SAR personnel.

Predictive tests can involve walking or running for a given time (Cooper et al. 1968), progressive multistage tests where speed is increased every minute (Stickland et al. 2003; Leger and Lambert 1982; Ramsbottom et al. 1988), or the extrapolation of submaximal heart rate to predicted maximal heart rates (Maritz et al. 1961). Tests which use predictive extrapolations from submaximal intensities are favored because the subject does not have to exercise to exhaustion in order to predict aerobic capacity. A flaw with such tests is they use predicted values for maximal heart rate and such equations have recently been criticized (Tanaka et al. 2001).

Grant et al. (1995) (Table A-6) compared results from a Cooper walk run test, a multistage shuttle run test, and a submaximal cycle test with the direct measurement of maximal oxygen uptake. The Cooper walk run test, which involves walking/running for 12 min and estimates VO_{2max} from the distance covered, was found to have the highest correlation coefficient ($r = 0.92$) with the multistage shuttle run had a slightly lower coefficient ($r = 0.86$). Based on the literature review, with the exception of the 6-minute run, most predictive tests shown have a relatively high correlation to directly measured maximal oxygen consumption.

Table A-6. Correlation coefficient values comparing predictive aerobic fitness tests to the gold standard, incremental stress test with direct measurement of whole body oxygen consumption.

Reference	n	6-min Run	Cooper walk- run test	CND Aerobic Fitness Test	Multistage Shuttle Run	Submaximal 1-mile run	1.5 mile run	Submaximal Cycle
Grant et al. 1995	22	---	0.92	---	0.86	---	---	0.76
Weller et al. 1993	129	---	---	0.77	---	---	---	
George et al. 2000	156	---	---	---	---	---	---	0.88
van Mechelen et al. 1986	82	0.51	---	---	0.68	---	---	---
George et al. 1993	149	---	---	---	---	0.87	0.90	---
Hunt et al. 2000	83	---	---	---	---	0.88	---	---
Larsen et al. 2002	112	---	---	---	---	---	0.86-0.90	---
Stickland et al. 2003	122	---	---	---	0.66-0.77	---	---	---
Leger and Lambert 1982	91	---	---	---	0.84-0.92	---	---	---

The research displayed on Table A-6 was performed with strict protocols and controlled populations. However, several criticisms have been raised with predictive tests, mainly with regard to control. With predictive tests such as the shuttle run, a maximal effort is required in order to obtain accurate results. In addition, extrapolation equations require predicted maximal heart rates, which can be very unreliable on an individual basis. Furthermore, a correlation does not imply a causal relationship, which is a major limitation to the literature reviewed. Most of the research performed in this area has neglected to equate the accuracy/precision of such tests, and has opted to compare each test by correlation. Therefore, although the data may be correlated, a more precise statistical measurement would be differences between means.

Muscular strength and endurance testing

Acknowledging the work by Deakin et al. 1999, as well as the physiological review of tasks involved in search and rescue, it is apparent that muscular strength and endurance are required by SARTechs to perform their duties. In order to test muscular strength and endurance, the test battery should be valid and reliable. Important to reliability is minimal variance between different testers (inter-tester) and the same tester day to day (intra-tester). Therefore, with large numbers of individuals being tested at different locations by different testers, it is prudent for the test battery chosen to be easy to administer with minimal instruction.

Suni et al. (1996) investigated the inter-tester reliability for a series of muscular strength tests (modified push-ups; isometric sit-up, jump and reach, and one-leg squat). Forty-two (42) subjects were administered the test battery with an average time interval between test sessions of two (2) to eight (8) days. Inter-tester correlation coefficient ranged between 0.76 – 0.98. These authors concluded that if administered properly with adequately trained personnel, the reliability of the tests can be high; however, separating tests by more than one week may affect reliability. Baumgartner et al. (2002) also reported strong (0.95 -0.97) inter-tester reliability when having testers administer a test on correctly executed push-ups, strengthening the argument that field tests such as these can produce reliable results.

Validity of field tests is another issue to consider. Pate et al. (1993) compared commonly performed field tests for upper body strength (Pull-ups, Flexed arm hang, push-ups, and modified pull-ups) with laboratory equivalents test (Bench press, Lat pull down, and Arm curl). There were no significant correlations found with these measures until results were expressed relative to body weight. This would suggest the field tests were only moderately valid measures of weight-relative muscle strength. That problem with the lack of validity of these field tests is it would be unclear how such tests would differentiate one’s ability to performed search and rescue tasks. A lighter individual may score higher than a heavier individual in push-ups and pull-ups, but may not be able to perform the specific tasks of a SAR-Techs which often presents a standard resistance (such as carrying the 25.0 kg backpack).

A further question is the applicability of using laboratory gold-standard tests for testing populations with specific job-related needs. Reynolds et al. (2006) demonstrated that a five (5) RM for barbell bench press, and plate loaded leg press, accurately predicted maximal (1 RM) strength (0.95-.99). However, it is unclear how these laboratory tests or related field tests can predict physical readiness to perform job specific tasks as unique as those required for Search and Rescue. Rather than trying to fit commonly used tests into a specific population, a more valid approach would be to develop specific muscular strength and endurance tests which best represent the specific occupational demands of the job.

Lifting/Carrying tasks to measure muscular strength and endurance

As identified in the physiological demands section of the literature review, some effort has been made to test the muscular strength/endurance of occupationally specific tasks (Williams and Evans 2007; Barnekow-Bergkvist et al. 2004; Richmond et al. 2008). The test in these studies were meant to be relevant to the occupation being tested, and may not relate to SAR-Techs. However, the concept of specificity is relevant to all occupations including SAR-Techs. For example, the lifting a 22-kg ammunition box, carrying it 10 m, and placing it on a 1.45 m platform, can simulate the specific task of loading a standard military cargo vehicle (Williams and Evans 2007). Therefore, applying population norms to this task may help to identify the minimal standard needed to perform the intended occupation. In addition, specificity can be managed in different ways. A single maximal lift test is generally not applicable to occupational testing, as it is likely each occupation has an upper limit to the weight of equipment, etc. that is expected to be managed and moved by one member of the occupation. This upper limit is generally set to protect the safety of the members from injury during the performance of their day-to-day duties. However, lifting a large ammunition box beginning at 25 kg, with 5 kg increments, to a maximum of 40 kg is a more practical test if there exists a strong occupational rational for these resistances (Williams and Evans, 2007).

Before valid job-related fitness tests can be identified and developed, a solid understanding of the occupation is needed to identify and define the job-related tasks required for performance of the occupation. After these are identified, research must be performed to identify lower and upper levels of performance required and accepted. A combination of job shadowing, pilot work and population testing would be necessary to properly and scientifically identify these factors for a specific occupation. This process would best allow the development of valid and safe job-related tests, and would be the best process for developing bona-fide occupational requirements, tests and standards for the Search and Rescue Technician program.

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Appendix B

Stress and Fatigue Inventory

Stress and Fatigue Inventory

Name: ________________________________ **Date:** ___________ **Location:** _______________

Please complete the following items based upon your perceptions over the past 7 days. Use your 7-day average for each item.

A.	**Amount of Exercise:**			
		No	**Yes**	**Hours**
i)	Light aerobic (e.g., walking, jogging)			
ii)	Hard aerobic (e.g., running, climbing under load)			
iii)	Anaerobic (sprinting)			
iv)	Light to moderate lifting/hoisting			
v)	Moderate to heavy lifting/hoisting			
B.	**Travel:**			
		No	**Yes**	**Hours**
i)	Ground (car; bus)			
ii)	Air			
iii)	# time zones (local time: ______ am/pm)	1 2 3 4 5 >5		

C. **Health status**

none (minimal)	healing	some problem(s)	worse	unable to train or work

1. Muscle/joint pain

------+--------------+----------------+---------------+--------------+--------

2. Upper respiratory tract symptoms: (sore throat/cough etc.)

------+--------------+----------------+---------------+--------------+--------

3. Generalized fatigue

------+--------------+----------------+---------------+--------------+--------

D. **Personal:** (ups and downs occur but try to mark the pt. which best describes how you've been feeling over the past week)

very high	high	average	low	very low

1. My willingness to train and work hard:

------+--------------+----------------+---------------+---------------+--------

2. My ability to focus and control attention:

------+--------------+----------------+---------------+---------------+--------

3. My ability to tolerate annoyance and frustration:

------+--------------+----------------+---------------+---------------+--------

4. Confidence in my ability to handle training intensity:

------+--------------+----------------+---------------+---------------+--------

5. Confidence in looking forward to training and work:

------+--------------+----------------+---------------+---------------+--------

6. Satisfaction with present training course:

------+--------------+----------------+---------------+---------------+--------

7. Satisfaction with relations with other SARTech students:

------+--------------+----------------+---------------+---------------+--------

D. **Personal:** (continued)

very high	high	average	low	very low

8. Satisfaction with relations with instructors:

------+---------------+-----------------+----------------+----------------+--------

9. Satisfaction with relations with people outside the QL5A course (e.g., family, friends):

------+---------------+-----------------+----------------+----------------+--------

10. Satisfaction with financial situation:

------+---------------+-----------------+----------------+----------------+--------

11. Satisfaction with other aspects of my life:

------+---------------+-----------------+----------------+----------------+--------

E. If there were 1 or 2 events which had distinctly **positive** or **negative** effects on your training, please describe them.