Optimizing Operational Physical Fitness

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ABSTRACT

With the conclusion of the RSGs 4, 8, and 17, as well as the Workshop on Optimizing the Performance of Women in the Armed Forces of NATO, there remained open questions concerning mission-related testing and training. The Research and Technical Organization (RTO) recognizes the need to address these issues in light of the wide range of missions (coordinating humanitarian relief, coordinating emergency and relief operations in the event of a disaster, both nature and man-made, civil emergency measures, addressing instability caused by regional and ethnic conflicts, defence again terrorism and countering other threats to modern society) and increased deployment of NATO personnel on operations since 1997 (NATO in the 21st Century @ http:www.nato.int/docu/21-cent/html). The revised spectrum of NATO missions requires a new approach to operational physical fitness. Specifically, a new necessity to define, assess, evaluate and optimize physical capability by setting appropriate criteria and methodology was identified by an exploratory team that met in Spain in 2002. As a result of the exploratory meeting, Task Group 019 on Optimizing Operational Physical Fitness was established to determine the requirement for physical fitness for military personnel in order to prepare military personnel for physical task requirements, to prevent physical overburdening, and to reduce injuries. The efforts of RTG-019 Optimizing Operational Physical Fitness will represent the international agreement for evidence based findings which may provide the basis for policy decision. The efforts of RTG-019 continue, and as such, the information contained in this report represents the efforts of the group to date.

1.0 BACKGROUND

To date, three Research Study Groups (RSGs 4, 8 and 17) and one workshop pertaining to physical fitness have been sponsored and completed under Panel 8. With the conclusion of RSGs 4, 8, and 17, as well as the Workshop on Optimizing the Performance of Women in the Armed Forces of NATO, there remained open questions concerning mission-related testing and training. The Research and Technical Organization (RTO) recognizes the need to address these issues in light of the wide range of missions (coordinating humanitarian relief, coordinating emergency and relief operations in the event of a disaster, both nature and man-made, civil emergency measures, addressing instability caused by regional and ethnic conflicts, defence again terrorism and countering other threats to modern society) and increased deployment of NATO personnel on operations

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since 1997 (NATO in the 21st Century @ http:www.nato.int/docu/21-cent/html). The revised spectrum of NATO missions requires a new approach to operational physical fitness. Specifically, a new necessity to define, assess, evaluate and optimize physical capability by setting appropriate criteria and methodology was identified by an exploratory team that met in Spain in 2002. As a result of the exploratory meeting, Task Group 019 on Optimizing Operational Physical Fitness was established determine the requirement for physical fitness for military personnel in order to prepare military personnel for physical task requirements, to prevent physical overburdening, and to reduce injuries.

1.1 RSG 4

RSG 4 on Physical Fitness with Special reference to Military Forces was established in 1975, and focused on identifying the military requirement for physical fitness, the measurement and training of peak anaerobic (alactic) power/strength, anaerobic and aerobic power, the importance of physical fitness as it pertains to sustain military operations (sleep deprivation, time zone change, environmental influences, ergogenic aids, and sustained cognitive performance), medical aspects of physical training (age, gender, overuse and traumatic injuries, coronary heart disease, risk factors and screening, heat and cold injuries, fitness and G tolerance, exercise and health), and test of physical fitness and body composition. The final report summarizing the work of RSG 4 was published in August of 1986 (AC/243 (Panel VIII) D/125).

1.2 RSG 8

RSG 8 on Nutritional Aspects of Military Feeding (Military Nutrition) was established and focused on nutrition and optimum physical performance (muscle glycogen, glycogen strategies, micronutrients and performance, caloric restriction, environmental factors), nutrition and coronary heart disease (CHD) risk factors in the military population (lipid metabolism, and CHD, influences of diet), body composition and its relation to health and physical performance of military personnel, rations of selection NATO countries (composition of survival, emergency, and combat rations and their influence on performance), nutrition education and weight control programmes, and nutritional strategies to enhance military performance. The final report summarizing the work of RSG 8 was published in December of 1989 (AC/243 (Panel 8/RSG 8) D/9).

1.3 RSG 17

RSG 17 was formed to study critical biomedical issues relevant to physical fitness training in NATO military forces. RSG on the Biomedical Aspects of Military Training elaborated on the training issues left over from the RSG 4 work. Specifically, RSG 17 focused on the physiology of physical training (responses to training, description of training programs for aerobic fitness, muscular strength, muscular endurance, and other fitness related factors like flexibility and body composition), principles of physical training (overload, specificity and reversibility principles, training variables of intensity, frequency and duration, training guidelines and training evaluation), trainability of military populations (adaptations to training, influencing factors, military application, training effects, and response of women), practical guidelines for development military physical training programs, injuries related to physical training (incident rates, risk factors, costs of injuries, prevention strategies, policy and management considerations), and models of physical training responses. The groups report (AC/243 (Panel 8)TR/16, 0875-94) summarized the knowledge that had been consolidated through the NATO membership and which concerned physical fitness for the military role.

1.4 WORKSHOP ON OPTIMIZING THE PERFORMANCE OF WOMEN IN THE ARMED FORCES OF NATO

During the period of 13-16 October 1995, a NATO DRG Panel 8 Workshop on Optimizing the Performance of Women in the Armed Forces of NATO was held in London, U.K. The pre-stated aim of the meeting was to establish contacts between military policy planners and the scientific programmes of different nations, which would promote collaboration and avoid duplication in research work. Topics covered in the Workshop included many of the issues relating to the integration and performance of women in Sea, Land and Air Forces, with emphasis being placed on practical experiences (attitudes towards integration, plans for future integration), anthropometry and physical fitness (differences between genders and some of the effects that these difference have on clothing, personal military equipment and workstation design), gender and physical selection standards (Nations progress reports pertaining to the introduction of fair, scientifically based and legally defensible job-related standards), gender differences in the heat and cold, cognitive differences, women in teams (mixed gender teams or all female teams in comparison to the traditional all male teams), and policy and social issues (health care, pregnancy, sexual harassment). One of the major outcomes of this Workshop was the production of draft position statements and recommendations for future research (AC/243 (Panel 8) TP/13).

2.0 IDENTIFICATION OF COMMON MILITARY TASKS

In order to optimize the physical capacity of soldiers by setting appropriate criteria and evaluation methodologies, physically demanding tasks representative of recent and current NATO Missions (humanitarian, peace-keeping, conflict resolution, counter-terrorism, etc) were identified by members of HFM-080/RTG-019. Members of RTG-019 identified and provided descriptions of common tasks used in their respective countries through the review of mission essential tasks lists, types of missions undertaken, and other pertinent military documents. HFM-080/RTG-019 members agreed that the common physically demanding tasks of marching, digging, manual materials handling, and special missions (fighting in built up areas, close quarter battle) would be described in terms of:

- (i) Intensity and duration;
- (ii) The physiological requirements;
- (iii) Testing to predict performance; and
- (iv) Training to improve performance.

In addition, RTG-019 members agreed that the following factors influencing performance would be briefly summarized (factor description and effects on performance) and contained in one Chapter of the Final Report:

- (i) Sustained Operations;
- (ii) Temperature (Cold);
- (iii) Temperature (Heat);
- (iv) Nutrition;
- (v) Altitude;
- (vi) Clothing;
- (vii) Teamwork;
- (viii) Age;
- (ix) Gender;
- (x) Hydration;
- (xi) Genetics; and
- (xii) Anthropometry.

3.0 MARCHING

This chapter will focus on the physiological demands of marching, factors impacting marching performance (weight carried, distance of march, speed of march etc), validation studies that describe the physiological requirements of marching, testing to predict marching performance, and training to improve and maximize marching performance (benefits/risk model, description of optimal frequency, speed, load, periodization of training, and best combination of general fitness training and task specific training). To date, 86 articles on marching have been found and are in the process of being reviewed. To this end, limited information is contained in this report as the work on this chapter continues.

3.1 DESCRIPTION

Although warfare continues to become increasingly automated and mechanized, many military occupations and missions still require soldiers to march. The US Army Field Manual (21-18) states that foot marches are the movement of troops and equipment mainly by foot with limited support by vehicles, and that they are characterized by combat readiness, ease of control, adaptability to terrain, slow rate of movement, and increased personnel fatigue. A successful foot march is when troops arrive at their destination at the prescribed time, and are physically able to execute their mission. Combat load is defined as the minimum mission-essential equipment required for soldiers to fight and survive immediate combat operations. The load is essentially the load carried by soldiers in forward subunits or the load that accompanies soldiers other than fighting loads. Fighting load is the load a soldier carries while fighting on the battlefield (< 22 kg). The Approach March Load is the load that a soldier carries while he/she approaches the battlefield and the load may be up to 33 kg. The Emergency Approach March Load is when terrain is impassable by vehicles, and greater loads are carried (55 – 65 kg) (U.S. Army Field Manual 21-18 Foot Marches'90).

3.2 PHYSIOLOGICAL REQUIREMENTS

Table 1: Physiological Requirements of Marching

Validation Study	Author
16 km march, speed 5.33 km.hr, in full fighting order (24.5 kg) – time of 2 hrs 26 min	Lee (1992) - CA
Incremental maximal test, speed 6-7 km/hr, load 25 – 62.5 kg (step 12.5 kg per 10 min)	Van Dijk (1996) - NL
12.8 km load carrying performance (load 25, 20, 15kg)	Rayson (1997) - UK
10 km load carrying performance (18, 27, 36 kg)	Harper (1997) - US

4.0 DIGGING – CHAPTER LEADER: MR. RENE NEVOLA, UK

Digging trenches, shell-scrapes, fox holes, filling sand-bags, and shovelling debris are common military tasks during land-based military operations. Survivability is a term that has been used throughout the Armed Forces of NATO to describe the fundamental aspects of protecting military personnel, weapons and material from enemy and detection systems. Digging has been universally identified as a fundamental skill that is required by tasks which enhance military survivability (ATP-52(A) 1997). A number of tasks have been proposed within the context of survivability (NATO 2001) which require manual digging, and these include the preparation and construction of field fortifications, camouflage, concealment and deception, and the clearance of fields of fire. Digging was found to be the eighth most frequently conducted task of all the physically demanding tasks within the US Army. Further, eighteen different military occupational specialities (MOS) identified digging as a critical task in the effective performance of their role (Sharp et al., 1998). In Canada, entrenchment digging is one of the six common military tasks that all soldiers can be expected to perform in an emergency regardless of rank, gender, age or military occupation (Deakin et al., 2000). Three of the 14 core operational tasks defined as a Bona Fide Occupational Requirement (BFOR) for Royal Air Force (RAF) combined incident teams involved digging or shovelling actions (Nevola et al, 2003b). During a project to develop criterion-based physical fitness standards, digging was identified as one of four critical tasks required by land-based personnel within the Netherlands military services (MOMRP 1999).

4.1 TASK DESCRIPTION

Digging tasks that are common to the military role are summarized in Table 2.

Table 2: Digging Tasks Common to the Military Role

Military Task Name	Task Specification	Occupational role	Equipment	Source/Reference
Database of 18 digging tasks, representing 18 MOS	1.0x 1.0.183,0 ft trenches to emplace piping –	US Army Specialists MOS 57E	N/A	Sharp et al., 1998
Standard 4 man trench	12 x 2 4.5 ft	1st Royal Norfold Regiment, British Infantry	Pick and Entrenching tool	Gould 1957
Digging pilot holes to lay explosive for excavation	Digging a 30 to 48 x 1.5 inch hole	Royal Engineers (British Army)	Hand-held auger	Briosi, 1980; Strickland, 1995
2 man battle trench	1.5 m (h) x 0.75 m (w) x 3.45 m (l) with elbow rests of 0.45m (w) x 0.3 m (h)	Royal Engineers (British Army)	Shovel, pick axe, sand-bags, and trench materials	Briosi, 1980; Military Engineering 1993

4 man battle trench	1.5 (h) x 0.75 m (w) x 7.75m (l) with elbo rests of 0.45 m (w) x 0.3 m (h) Dig five anchor wire channels 0.3 m (h) x 0.3 m (l) Fill 36 6o 110 sandbags for protective cover and place 0.45 m earth above the shelter	Royal Engineers (British Army)	Shovel, pick axe, sand-bags, and trench materials	Military Engineering 1993; Military Engineering 1996.
Fox hole	1.80 (l) x 0.60 (w) x 0.45 (h) m crushed gravel	US Army Canadian Forces	Entrenching tool	 Deakin et al., 2000
Shell Scrape	2.0 (l) x 1.0 (w) x 0.4 (h) m sand	UK Armed Forces – dismounted land	Entrenching tool	Nevola et al., 2003a
Shell Scrape	1.9 (l) x 0.6 (w) x 0.5 (h) m sandy soft clay	Canadian Forces	Entrenching tool	Deakin et al., 2000
Sand-bag Sangar	2.5 (l) x 1.0 (w) x 1.2 (h) m sand	UK Armed Forces – dismounted land	Pick axe, shovel, entrenching tool	Nevola et al., 2003b
Augering	1.3m (h) x 0.24m (w)	Royal Engineers and Specialist Infantry trades (UK)	Auger	Stickland, 1995
Rapid protection trench	0.6 m (h) dig with 0.6 m (h) wall of sandbags to afford a combined h of 1.2m protection	UK Armed Forces – dismounted land	Pick axe and entrenching tool	Strickland, 1995

4.2 PHYSIOLOGICAL DEMAND

4.2.1 Some of the prime factors that have been known to influence shovelling tasks demand include: (i) shovelling rate; (ii) blade load; (iii) throw height; (iv) properties of the material being dug; (v) throw distance;

and (vi) posture (or technique). Unfortunately, only a few of these features have been investigated under controlled condition. Consequently, the results that have been reported in the available literature have been inconclusive.

4.2.2 Deakin et al., (2000) assessed the aerobic demand (KB1-C Portable Metabolic Measurement System) incurred by 5 male soldiers (mean age of 28 years) who each dug a shell scrape (0.6m wide x 1.9 m long x 0.5 m deep). The terrain was fairly sandy with some areas of soft clay and a few small trees, and the outline for the shell scrape was marked ready to be dug. A mean VO_2 of 30.2 $ml \cdot kg^{-1} \cdot min^{-1}$ was reported, with the five soldiers working at 58.6% VO_2 max (mean data). During the same study, the mean aerobic demand of an entrenchment dig simulation (1.8 m x 0.6 m x 0.45m) was reported to be 30.6 $ml \cdot kg^{-1} \cdot min^{-1}$ for 16 male soldiers (representing 64.2% VO_2 max), and 23.9 $ml \cdot kg^{-1} \cdot min^{-1}$ for female soldiers (representing 66.4% VO_2 max).

4.2.3 A sand-bagging task (shovelling sand into sand bags which weight 26 to 28 kg each when full) within the British Army was first assessed using heart rate monitors and Oxylog portable expired gas analysers by Rayson et al., (1994). They reported a mean VO_2 of 30.7 $ml \cdot kg^{-1} \cdot min^{-1}$ (range = 22.0 to 34.7 $ml \cdot kg^{-1} \cdot min^{-1}$) for participants at steady state, who shovelled dry, medium-grain sand into bags which held by a colleague at waist height, and completed at an undefined self-selected pace. These data were obtained from 4 male experienced and trained British soldiers who were subsequently using the sang-bags to construct a sand-bag sangar. These data included the physical demands of lifting the filled sand-bags to a maximum height of 1.8 m.

4.2.4 Nevola et al., (2003a) assessed the aerobic demands of digging a shell scrape in wet sand (2.0 m in length x 0.8 m wide x 0.3 m deep) at simulated operational tempo (shovelling rate of 20 $scoops \cdot min^{-1}$). The mean data to estimate VO_2 (from relative heart rate reserve in relationship with VO_2 max) were reported as 23.3 (sd = ± 8.4) $ml \cdot kg^{-1} \cdot min^{-1}$. the task was completed in 14.0 minutes.

4.2.5 As part of project to develop evidence-based operationally-related physical fitness standards for Royal Air Force (RAF) personnel, Nevola et al., (2003b) used the Cosmed $K4b^2$ portable, breath-by-breath analyser to assess the aerobic demand of a standardized sand-bagging task. Military experts from the British Army and the RAF defined the specification for this task. Wet sand was shovelled into a bag that was held at waist height and which weighed 28 kg when filled. When 20 bags had been filled with sand, they were carried by hand (two bags at a time) a distance of 50m. The entire task was completed in 32 minutes. The mean VO_2 of the task was reported to be 19.5 $ml \cdot kg^{-1} \cdot min^{-1}$ ((sd = ± 8.8). Unfortunately, the mean data that were reported included the aerobic demand of carrying the sand-bags.

4.2.6 Davis et al., (1986) reported that the US Marine Corps MOS 0311 conducted a digging task with an entrenching tool at a VO_2 of 22.5 $ml \cdot kg^{-1} \cdot min^{-1}$. They also reported Rating of Perceived Exertion (RPE) data for US Marines who had experience digging with an entrenching tool on jungle operations (RPE = 13), cold climate operations (RPE = 17), and desert operations (RPE = 13). Digging with a conventional shovel was similarly rated to the entrenching tool for RPE in jungle and cold climate operations, but was reported to be greater when digging on operational duty in the desert (RPE = 16).

4.2.7 Sharp et al., (1998) compiled a database of digging tasks that were conducted by MOS within the US Army. The reported shovel loads ranged from a minimum of 4.5 kg (for 6 tasks) to a maximum of 14.9 kg (for 1 task) with a mean of 8.3 kg (sd = ± 7.5).

4.3 TESTING TO PREDICT PERFORMANCE

4.3.1 Minimum Physical Fitness Standards (MPFS 2000) was developed as a single standard for Canadian Forces personnel regardless of age, gender or service. A compensatory model was created for the implementation of the single standard and it was based on achieving a minimum composite score based on 6 fitness tests identified as significant predictors of physical performance on 6 common military tasks (CMT), of which one is the entrenchment dig (Deakin et al., 2000). Deakin et al., (2000) performed separate principal component analyses with varimax rotations on their CMTs and fitness test data for their male versus female subjects (soldiers). It was observed that the pattern of test variable loadings was the same for men and women, which provided evidence of similar correlation patterns among the tests between men and women despite differences in performance levels. This finding was interpreted by Deakin et al., (2000), as further justification for the development of a single minimum physical fitness standard for men and women. In this study, the performance of 623 Canadian Forces personnel (416 men and 207 women) on an entrenchment dig common military task was assessed. The mean performance time for female soldiers (n = 207) was 11:11 ± 4:12 (min/sec) with a range of performance times from 5:52 to 28:45 (min/sec). The mean performance time for male soldiers (n= 416) was 5:45 ± 1:41 (min/sec) with a range of performance times from 3:22 to 14:40. Significant Pearson correlation coefficients ($p < 0.001$; transformed data) between fitness test and entrenchment dig task performance are depicted in Table 2.

Table 3: Significant Pearson Correlation Coefficients – Fitness Tests and Digging Task Performance

Variable	Correlation with Digging Task Performance	
	Female Soldiers (n = 207)	**Male Soldiers (n = 416)**
VO_2 max (20 MSR) (ml·kg^{-1}·min^{-1})	-0.46	-0.44
VO_2 max (Step Test) (ml·kg^{-1}·min^{-1})	-0.32	-0.21
Sit ups (Number completed in one minute)	-0.28	-0.33
Push ups (Number completed continuously)	-0.23	-.033
Combined Handgrip (kg)	-0.26	-0.20
Vertical Jump (cm)	-0.45	
Back Dynamometer (kg)	-0.36	-0.23
Leg Dynamometer (kg)	-0.23	
Upper Body Strength Device (kg)		-0.21
Chin up (Number completed continuously)		-0.26

4.3.2 Nevola et al., (2003b) designed Representative Service Tasks (RST) (content based) that could be used to establish evidence-based physical fitness standards for RAP personnel. One of the four RSTs targeted digging/shovelling performance and involved shovelling 0.5 m3 of sand (this volume equated to that required to fill 20 sand-bags or an individual's expected quota within a team of four personnel when digging a sand-bag sangar or trench). Subsequent to this study, the RST digging task was modified twice. The second modification to the digging task resulted in shovelling dry gravel through the centre of a hole (0.2 m diameter) which stood at the 1.0 m point in a 1.2 m vertical barrier that separated two containers of equal dimension (1.15 m long x 0.87 m wide x 0.25 m deep). Fourteen participants (11 men and 3 women) performed this modified digging RST on 3 occasions within a 5 day period. It was observed that there was a statistical bias between test performance ($p < 0.001$) with an average of 13.4% improvement between test 1 and test 2 (- = 0.006). However, the improvement in performance time between test 2 and test 3 (7.8%, p + 0.073) did not reach statistical significance. Analysis of heart rate collected during the tests found no difference in mean heart rate between tests ($p = 0.67$). Rayson et al., (2004) suggested that the improvement in test times was attributed to a skill learning effect and was not related to any differences in physical effort or strain between tests.

4.3.3 Visser et al., (1996) developed separate equations for male soldiers ($n = 137$) and females soldiers ($n = 61$) to predict performance of a (criterion) digging task for the Royal Netherland Army. The results of tests to assess maximum aerobic power (cyclo-ergometry), static leg extension strength, fat fee mass, and 12-minute run distance afforded the highest correlation with the criterion digging task for men (r2 = 0.30). However, the combination of test data that afforded the best correlation with the criterion digging task for women (r2 = 0.45) were fat free mass, estimated maximum aerobic power (arm ergometry), elbow flexion, isometric strength, and estimated maximum aerobic power (cyclo-ergometry).

4.3.4 Lee (1992) obtained performance data from 99 male soldiers in the Canadian Army who conducted a series of physical fitness tests and a simulated entrenchment digging task. Stepwise multiple linear regression analysis was used to design an equation to predict digging task performance for these soldiers from a combination of "best predictor variables" within the battery of fitness tests. Lee (1992) reported a correlation of $r^2 = 0.39$ when data from test to assess maximal leg power output, maximum leg power output, maximum aerobic power, arm power decline, arm peak power and leg power decline were used to predict digging task time. Chahal (1993) conducted analysis of body composition, muscle strength, and muscle endurance data from 116 soldiers in the Canadian Army. Analysis afforded a test-retest reliability for the slit trench digging task of $r^2 = 0.86$. During this study, an equation to predict trench digging task performance used a combination of results from leg extension strength, and tests of dynamic shoulder extension endurance ($r^2 = 0.28$). Further development of the physical performance standards for the Canadian Army found that maximum aerobic power, static trunk flexion and leg peak power afforded the best prediction of slit trench digging task performance ($r^2 = 0.36$) (Singh et al., 1991).

4.4 TRAINING TO IMPROVE PERFORMANCE

4.4.1 MOMRP (1999) reported that an 8 to 18% improvement in digging performance with increased physical conditioning could be gained from task-based physical training.

4.4.2 Sharp et al. (1998) suggested that although it was less realistic, the material used in standardised digging tasks should not be influenced by changes in humidity or temperature and should present the same physical challenge to each test participant.

4.4.3 Developments in manual digging strategies have focused upon re-designing equipment to reduce the energy cost incurred by the individual performing the task. A number of design features that may influence the energy cost (or efficiency) of digging with a shovel (or shovelling) have been investigated. Such features include the weight of the shovel, handle type and length, lift angle. However only a few of these features have been investigated under controlled conditions. Consequently, the results that have been reported in the available literature have been inconclusive.

4.4.4 Stevenson and Brown (1923) studied trench digging tasks within the Army using imagery analysis (stroboscopic photography) and expired gas analysis. They found that shovelling performance was the most efficient in terms of the time to move a volume of material when soldiers worked at a rate of 19 to 21 scoops·min-1 with a throw height of <1.3 m. Best results (quickest time to dig the trench) were observed when soldiers digging the trenches first scraped loose material onto the shovel in preference to thrusting it into the target material.

4.4.5 Development in manual digging strategies have focused on re-designing equipment to reduce the energy cost incurred by individuals performing the task. A number of design features that may influence the energy cost (or efficiency) of digging with a shovel (or shovelling) have been investigated. Such features include: (i) the weight of the shovel; (ii) handle type and length; (iii) lift angle; and (iv) blade size, shape and thickness. However only a few of these features have been investigated under controlled conditions. Consequently the results that have been reported in the available literature have been inconclusive.

5.0 MANUAL MATERIAL HANDLING – CHAPTER LEADER: MS. MARILYN SHARP, US

5.1 DESCRIPTION OF MILITARY MANUAL MATERIAL HANDLING TASKS

5.1.1. Manual materials handling (MMH) can be defined as the movement of objects, vertically or horizontally, from one location to another using physical labour. This is accomplished through lifting, lifting and carrying, holding, pushing and pulling objects. The manual movement of materials is the most physically demanding aspect of most non-sedentary occupations, both military and civilian. Lifting (L) and lifting and carrying (L&C) constitute the most common physically demanding task performed by the Canadian, US and UK Armies (Rayson, 1998; Sharp, Patton, & Vogel, 1996). Heavy L-L&C has long been associated with occupational injury, particularly with lower back disorders (Chaffin, 1974; Chaffin, 1987; Gardner, Landsittel, & Nelson, 1999; Griffin, Troup, & Lloyd, 1984; Kraus, Schaffer, McArthur, & Peek-Asa, 1997; Marras, Davis, Kirking, & Bertsche, 1998; Snook, Campanelli, & Hart, 1978).

5.1.2 L-L&C tasks vary greatly and have the potential to stress any of the body's three energy systems. L-L&C tasks can be purely strength demanding, stressing the ATP-CP system, as in the case of a single heavy lift. Short duration L-L&C tasks, such as lifting and carrying a heavy object for 30-seconds, stress the lactic acid system. L-L&C tasks which are repetitive in nature, and last more than a few minutes are aerobically demanding, as in the case of palletizing boxes. Although MMH tasks include pushing and pulling objects, the focus of this chapter will be on non-mechanized lifting and lifting and carrying objects, as these types of tasks are the most commonly performed by soldiers. The important task variables for lifting and lifting and carrying tasks are the load lifted/carried, the height from and to which the object is lifted, the frequency with which the object is lifted, the distance an object is carried, team size (whether the task is performed by an individual or a team of soldiers), and the dimensions and characteristics of the object moved.

5.2 RECOMMENDED LIMITS OR STANDARDS SET FOR L-L&C TASKS

5.2.1 There are industrial load limits (Germany, Greece, Austria, Finland) or ergonomics guidelines (USA, UK, Netherlands) for many NATO countries (Mital, Nicholson, & Ayoub, 1993). The best known guideline in the United States is the National Institute for Occupational Safety and Health Work Practices Guideline (Waters, Putz-Anderson, Garg, & Fine, 1993). The equation provided in the guideline can be used to evaluate the safety of a lifting task and takes numerous task variables into account (lift starting and ending height, load, frequency, reach, handles, task symmetry, etc). It is a useful equation to determine the effect of changes in task variables. The NIOSH equation was evaluated and modified by Hidalgo et al (1997) to develop a comprehensive lifting model. Two new lifting indices were developed: The Relative Lifting Safety Index, which is used to evaluate a lifting task for a group of workers, and the Personal Lifting Safety Index, which is used to evaluate the relative safety of a lifting task for an individual worker. These indices consider factors in addition to those considered by the NIOSH lifting index, particularly heat stress, body weight, gender and age. Some of the load modifiers were adjusted to include more recent data.

5.2.2 The US Army sets limits on the loads to be lifted by soldiers during the design of new equipment in Military Standard 1472F(1989). The standard sets an absolute maximum load of 39.5 kg to be lifted by one male soldier using two hands from the floor to a waist high surface. This load is decreased if women will be handling the object (20 kg), if the object is to be lifted to a greater height (25.4 kg), if the object is lifted repetitively, and if the object is not compact or extends more than 30 cm away from the body. The limit for lifting from the floor, carrying an object 10 m or less, and replacing the object on the floor is 37.2 kg for men and 19 kg for women. Again, these allowable loads are decreased for repetitive tasks, loads lifted to greater than waist height, and unwieldy objects.

5.3 PHYSICAL CHARACTERISTICS OF OBJECTS HANDLED BY MILITARY PERSONNEL

5.3.1 Physical characteristics of the objects handled vary greatly in size, shape, existence or location of handles, and fluidity. Mital & Ayoub(1981) recommends objects lifted be compact, stable, not extend more than 50 cm away from the body, and that the distance between the hands be kept to a minimum. Handles have been shown to increase maximal lifting capacity by 4%-30% (Mital et al., 1993). US Army Military Standard 1472F (1989) identifies the optimal object for lifting as *"an object with uniform mass distribution and a compact size not exceeding 46 cm high, 46 cm wide and 30 cm deep (away from the lifter)", pg 139.* It also assumes the object will have handles, and they will be located at half the object height and 15 cm deep. Not all objects lifted by military personnel meet these specifications. In his review of UK Army MMH tasks, Rayson (1998) reports that while most objects had good hand coupling, *"A number of examples of large and variable shaped objects were measured which included various missiles, generators and scanners, camouflage nets etc., which compelled unusual methods of handling. Other objects were either asymmetrical in load distribution (generators, missiles, drawbars etc.) or had unstable loads (camouflage nets, fuel cans, food pots etc.) thereby reducing performance."*

5.3.2 Most of the research in the literature on L-L&C capabilities examined box lifting capacity. While it is convenient for research purposes to study box lifting performance, or Olympic weight bar lifting, it should be noted that these investigations represent an artificial environment and reflect the maximum performance possible. The measured L-L&C capabilities must be adjusted downward when handling sub-optimal configuration objects, such as sand bags, liquids (Karwowski & Yates, 1986), camouflage netting (Patton, Vogel, Damokosh, & Mello, 1989) or injured soldiers(Rice, Sharp, & Tharion, 1996a; Rice, Sharp, & Tharion, 1996b).

5.4 PHYSIOLOGICAL REQUIREMENTS

5.4.1 There are a number of factors which determine the physiological demands of a repetitive L-L&C task. These include the body position one must assume, the lifting technique used, the physical characteristics of the load (most importantly the mass), the starting height of the lift, the vertical travel distance, the frequency of lifting, and the number of repetitions to be performed. In addition, environmental factors such as temperature and humidity, as well as clothing worn, can influence the physiological demands of a L-L&C task.

5.4.2 Lifting technique will greatly influence the energy expended, particularly during a prolonged repetitive lifting or lifting and carrying task (Asfour, Ayoub, Genaidy, & Khalil, 1986; Unger & Gallagher, 1990; Garg & Herrin, 1979; Garg & Saxena, 1985; Kumar, 1984; Welbergen, Kemper, Knibbe, Toussaint, & Clysen, 1991; Hagen, Harms-Ringdahl, & Hallen, 1994). Although a bent knee, straight back lifting technique is often recommended for safety, this technique is rarely used during repetitive lifting. This form may be maintained during an occasional heavy lift, and is particularly useful when the load fits between the knees (Mital et al., 1993). However, squat lifting technique elicits a higher energy cost due to the work of moving one's body weight up and down. For repetitive lifting, a freestyle or semi-stooped lift is typically self-selected as the most energy efficient.

5.4.3 The heavier the load lifted, the greater the work done, and the greater the metabolic requirement to complete the task (Asfour et al., 1986; Asfour, Tritar, & Genaidy, 1991; Garg, Rodgers, & Yates, 1992; Jorgensen & Poulsen, 1974; Legg & Pateman, 1984; Petrofsky & Lind, 1978b; Sharp, Harman, Vogel, Knapik, & Legg, 1988a). The starting height of the lift, in conjunction with the lifting technique will determine the degree to which the body center of gravity must be lowered to complete the lift. If the same load is lifted a vertical distance of 0.5 m starting from the floor or from knuckle height, the knuckle height lift will involve less movement of the body center of gravity, and will therefore incur a lower metabolic cost. All other factors being equal, the greater the vertical travel distance, the greater the work done, and the greater the metabolic cost of a L-L&C task. Increases in the frequency of lifting produce increases in the metabolic cost of repetitive lifting (Intaranont, Ayoub, Bobo, & Smith, 1986; Miller, Farlow, & Seltzer, 1977; Petrofsky et al., 1978b). These increases are tend to be linear at lower percentages of maximal oxygen uptake (<50%). As the object size increases, so does the energy cost for repetitive L-L&C (Mital & Ayoub, 1981).

5.4.4 The total energy cost is related to the rate of work, the number of repetitions and the total duration of L-L&C tasks. The longer the task duration, the lower the energy expenditure can be maintained. These are not well defined for most soldiering tasks. For example, during a re-supply, soldiers move materials until the weapon or transport vehicle is full. This may take anywhere from a few minutes to several hours. If the vehicle has been recently re-supplied, fewer supplies will be needed and the task will be accomplished more rapidly. In peacetime, re-supply can be a self-paced activity. If soldiers are being fired on, they must accomplish the task as rapidly as possible. All these factors influence the metabolic requirements of the task. There are a number of predictive equations to determine the energy cost of L-L&C tasks (Ayoub, Mital, Asfour, & Bethea, 1980; Garg, Chaffin, & Herrin, 1978; Garg et al., 1985; Garg et al., 1992; Mital, 1985; Taboun & Dutta, 1984; Taboun & Dutta, 1989; Randle, Legg, & Stubbs, 1989)

Table 4: Prediction equations for energy expenditure

Type	**Energy Expenditure Equation (kcal/min)**	**Reference**
Stoop Lift	E=0.0109 BW + (0.0012 BW + 0.0052 L + 0.0028 S*L) f	Garg (1976)*
Squat Lift	E=0.0109 BW + (0.0019 BW + 0.0081 L + 0.0023 S*L) f	Garg (1976)*
Arm Lift	E=0.0109 BW + (0.0002 BW + 0.0103 L - 0.0017 S*L) f	Garg (1976)*

* BW = body weight (lbs), L= load weight (lbs), S=Sex (female=0, male=1), f=frequency (lifts/min)

5.4.5 There are a number of reports in the literature indicating the energy cost of soldiers performing various simulated L-L&C tasks (Bilzon, Scarpello, Smith, Ravenhill, & Rayson, 2001; Legg et al., 1984; Nicholson & Legg, 1986; Patton, Murphy, Bidwell, Mello, & Harp, 1995; Rice et al., 1996a; Rayson, 1998; Sharp, Harman, Boutilier, Bovee, & Kraemer, 1993; Sharp, Knapik, & Schopper, 1994; Sharp, Rice, Nindl, Mello, & Bills, 1998). Rayson (Rayson, 1998) measured the cardiovascular requirements of UK soldiers performing actual L-L&C tasks (not simulated tasks) of longer duration. Soldiers worked at 55-88% of their maximum heart rate, with 59% of the tasks in the 70-79% maximum heart rate range. The rate of oxygen uptake ranged between 1.16 and 2.92 $l \cdot min^{-1}$, with 80% of the tasks falling within the 1.5-2.5 $l \cdot min^{-1}$ range.

Due to the difficulty of identifying the required lifting rate, the aerobically demanding L-L&C tasks were self-paced during the metabolic measurements. The intensity of exercise of soldiers is often determined by the situation. For this reason, it is difficult to accurately characterize the typical cardiovascular strain of soldiers during MMH tasks because an acceptable level of intensity and duration of task performance has not been defined.

5.4.6 Physiological limits for repetitive L-L&C tasks. The recommended upper limits for prolonged performance of aerobically-demanding, repetitive L-L&C tasks typically ranges from 28% up to 35% cycle ergometer VO_2max for an 8 hour day (Asfour, Genaidy, Khalil, & Muthuswamy, 1986; Jorgensen, 1985; Legg et al., 1984; Lind & Petrofsky, 1978b; Petrofsky & Lind, 1978a). Garg (Garg et al., 1992) recommends that the exercise intensity of repetitive L-L&C tasks not exceed 50% VO_2max (treadmill or cycle ergometer) for one hour, 40% VO_2max for 2 hours or 30% VO_2max for 8 hours to avoid fatigue.

5.5 TESTS TO PREDICT PERFORMANCE

5.5.1 There are several approaches to testing for L-L&C performance. The maximum performance capability of the individual, such as a 1RM can be examined, or a minimal performance standard can be set and soldiers tested to determine if they are capable of meeting that standard. Several of the NATO allies have conducted job analyses of physically demanding soldiering occupations and have developed CMTs representing the most common lifting or lifting and carrying tasks. Many of these tests were designed as the first step to develop pre-assignment screening tests to place service members into physically appropriate jobs. Knapik et al (Knapik et al., 2004) has recently published a thorough review of the pre-assignment screening tests used by many of the NATO Forces. The types of tests pertaining to L-L&C used in the literature, as well as the tests used by the NATO Forces will be briefly reviewed here.

5.5.2 Tests of lifting strength are typically a one-repetition maximum lift (1RM) of a box to a given height. In most military applications, it is the height of the standard supply transport vehicle, such as the Army 2-1/2 ton truck (Sharp et al., 1980; Rayson, Holliman, & Bell, 1994; Sharp et al., 1980; Harman et al., 1997). Alternatively, the lift height can be based on body landmarks, such as floor to knuckle height or floor to shoulder height (Beckett & Hodgdon, 1987). Physical fitness measurements found to be predictive of 1RM lifting strength include fat free mass (Sharp et al., 1980; Teves, Wright, & Vogel, 1985; Beckett et al., 1987; Rayson, Holliman, & Belyavin, 2000), isometric 38 cm upright pull (Teves et al., 1985; Sharp et al., 1980) , isometric back extension strength (Rayson et al., 2000), incremental lift machine (Teves et al., 1985; Beckett et al., 1987; Rayson et al., 2000), vertical jump, broad jump and push-ups (Beckett et al., 1987; Hodgdon & Beckett, 1998).

5.5.3 Tests designed to measure repetitive lifting capacity include tests of repetitive lifting maximal oxygen uptake (Jorgensen et al., 1974; Williams, Petrofsky, & Lind, 1982; Sharp et al., 1988a; Lind & Petrofsky, 1978a), timed maximal effort tests (Sharp, Bovee, Boutilier, Harman, & Kraemer, 1989; Harman et al., 1997; Bilzon, Scarpello, Bilzon, & Allsopp, 2002; Sharp et al., 1993), tests of maximum acceptable load (Legg & Myles, 1981; Legg et al., 1984; Nicholson et al., 1986; Sharp & Legg, 1988b; Snook & Ciriello, 1991; Ciriello, Snook, Blick, & Wilkinson, 1990), timed completion of a set amount of work (Wenger, 2001) or a set work rate to exhaustion (Williams, Rayson, & Jones, 1999). Most repetitive lifting tests are labor intensive, as the boxes that are lifted need to be lowered, either using an automated system (pneumatic shelf or rollers) or manually.

Power output from a repetitive lifting task can be calculated using the following equation (Sharp et al., 1988b):

$$P = \frac{F\left(W_B T_B + W_L T_L\right)}{t}$$

where

P=power (watts)

F=total number of lifts

WB=box weight (newtons)

TB=vertical box travel (meters)

WL=lifter's body weight (newtons)

TL=vertical travel of lifter's center of mass (meters)

t=total lift time (seconds)

5.5.4 Tests of repetitive lifting maximal oxygen uptake are progressive in nature, either increasing the load lifted, the rate of lifting, or both, until the maximum rate of oxygen consumption has been reached(Khalil, Genaidy, Asfour, & Vinciguerra, 1985; Sharp et al., 1988a; Nindl, Sharp, Mello, Rice, & Patton, 1995; Lind et al., 1978a; Petrofsky et al., 1978b; Williams et al., 1982). Metabolic measurement equipment is needed to conduct the tests, and they are not commonly used to evaluate L-L&C performance.

5.5.5 A maximal-effort, timed repetitive lifting test was used to simulate the re-supply of a 155mm self-propelled howitzer (Sharp et al., 1993). The final test score was the maximum number of 41 kg boxes lifted to a 132 cm high shelf in a 10 min period. Similar protocols with varying weights (20.9-41.0 kg) and varying lengths of time (5-10 min) have been used to examine the repetitive lifting capacity of men and women before and after physical training programs (Kraemer et al., 2001; Harman et al., 1997; Knapik & Gerber, 1996; Sharp et al., 1993). These tests have been shown to have high test-retest reliability with a stable score obtained after two trials (Sharp et al., 1988a; Pandorf et al., 2003).

5.5.6 Tests of the maximum acceptable load or lifting rate involve a subjective measure of the exercise intensity an individual is willing to work at under a defined set of conditions. For example, an individual may be asked to determine the MAWL for an 8 hour work day when lifting a box from the floor to a 70 cm high table at the rate of 3 times per minute. The person is given a box that is either too heavy or too light and asked to perform the defined task for a 20 min period. The individual then adds or subtracts weight from the box until it is judged acceptable. The load is adjusted by the individual so that he/she does not become overtired, overheated or out of breath. Snook and colleagues have developed an extensive data set for a wide variety of L-L&C tasks with loads determined to be acceptable to various percentages of the population of US workers (Ciriello et al., 1990; Snook, Irvine, & Bass, 1970; Snook & Ciriello, 1974; Snook et al., 1991). While these tests provide useful information for setting limits and equipment design guidelines, they can also be used to measure of performance before and after a training program (Sharp et al., 1988b).

5.5.7 The Dutch Army repetitive lifting test involves lifting loaded boxes from the floor to 145 cm at the rate of 6 lifts/min for 90-second periods. The initial box load is 12 kg. The load is increased by 4 kg during a 30 sec rest period at the end of each 90 sec lifting period. The maximum load is 56 kg. This load is administered two times if the volunteer is successful. The maximum number of lifts completed, while maintaining the lifting pace is the final score (possible range=0-117 lifts). The average man (n=137) lifted the

52 kg box five times for a total of 95 lifts. The average woman (n=59) lifted the 32 kg box two times for a total of 47 lifts (van der Doelen et al., 1996).

5.5.8 Carrying and repetitive carrying tests incorporate walking while holding an object. These tasks are the most commonly performed physically demanding tasks conducted by the US Navy (Robertson, 1992), and the Armies of both the US (Sharp et al., 1996) and the UK (Rayson, 1998). Reported tests include maximal effort timed tests (Harman et al., 1997; Beckett et al., 1987; Beckett et al., 1987), continuous carrying tests (Genaidy, Mital, & Bafna, 1989; Rice et al., 1996a) and maximum acceptable load determinations (Sharp et al., 1995). The reported loads for bi-manual carrying (one object in each hand) ranged from two-10 kg jerry cans to two-35 kg cans (total load 20-70 kg). Twenty kg sandbags and 34 kg boxes have been used for carrying one object with both hands. The U.S. Navy utilized a box carry with distance carried as the measure of performance. Soldiers carried a 34 kg box with handles along a 51.4 m up and back course for two-five minute periods. The box was placed on a table, and Soldiers walked the distance without a box. The final score was the distance covered during the two-five minute exercise periods(Hodgdon et al., 1998). The British included a repetitive lift and carry test and a continuous carry to exhaustion (Rayson, 1998). For the repetitive lift and carry test, 3 box loads, either 10, 22 or 44 kg, were lifted, carried 10m, and lifted onto a platform at a rates of 6, 3 or 1 shuttles per min, respectively. The load and rate standard was based on the requirements of the Soldier's assigned job. All Soldiers tested were able to complete the required lift and carry task for their assigned job. For the continuous carry, Soldiers walk up and down a 30 m course at a rate of 1.5 m/sec while carrying 2-20 kg jerry cans. The best predictors included handgrip strength, hydrodynamic lifting strength and fat-free mass (Rayson et al., 1994).

5.5.9 The Dutch Army repetitive carrying task is the only progressive test. Two-15 kg cans are carried 90 meters twice (180 m total) at a speed of 5.3 km/hr (3.3 mph). The cans are then replaced with cans that are 4 kg heavier until the Soldier cannot maintain the pace, or until the maximum load of 35 kg is reached. The average male Soldier (n=135) completed the segment with the 27 kg cans and failed during the 31 kg cans. The average female Soldier completed the 19 kg load and failed during the 23 kg load. The final score is the total distance walked. Performance on this carrying task was best predicted by measures of upper body aerobic capacity, strength and body size (Visser et al., 1996).

5.6 PREDICTION OF COMMON MILITARY TASK PERFORMANCE

5.6.1 One of the most comprehensive and well documented efforts was undertaken by the British Army(Rayson, 1998; Rayson et al., 2000; Rayson, Pynn, Rothwell, & Nevill, 2000; Rayson, Holliman, Nevola, & Birch, 1996a; Rayson et al., 1994; Rayson & Holliman, 1995; Rayson, Holliman, Nevola, & Birch, 1996b; Rayson, Wilkinson, & Blacker, 2002). They conducted a detailed job analysis of all entry-level Army occupations and identified four Representative Military Tasks (RMTs) that were common to most military occupations and critical to soldier performance(Rayson, 1998). Three of the tasks involved L-L&C. These were a 1RM lift of an ammunition box, a continuous carry of 2-20 kg water jugs (jerry cans), and a repetitive lift and carry of an ammunition box. Based on the actual array of job demands, all Army jobs were assigned to one of three levels of difficulty within each task. The difficulty of the task was altered using different loads and lift heights. Each employment group, or job specialty, was assigned to the appropriate difficulty level for each task. Soldiers from various specialties were then tested on the RMTs and on a comprehensive battery of physical fitness and anthropometric measurements (Rayson et al., 2000). These data were used to develop a series of models to predict the RMTs (Rayson et al., 1995). The predictive models were cross-validated in a separate study using a group of initial-entry trainees (Rayson et al., 1996a). 1RM box lifting was best predicted by fat-free mass and muscle strength measures. The continuous carrying models used muscular endurance and anthropometric measures. The repetitive L&C models included muscular strength, muscular endurance, and anthropometric measures. The 1RM lifting models worked well, but the continuous carry and repetitive lift and carry models did not accurately predict success on the criterion tasks.

Table 5: Performance tests of representative military tasks from Rayson et al (2000)

Task Level	Single Lift of Ammunition Box (Measure: Max load up to 75 kg)	Carry (Measure: Time to exhaustion)	Repetitive Lift and 10 m Carry of Ammunition Box (Measure: Time to exhaustion up to 60 min)	Road March of 12.8 km (Measure; Time to complete)
1	To 1.70 m	Jerry cans, 20 kg each, one carried in each hand, 1.5 m/sec	44 kg, ground to 1.45 m, 1/min	25 kg load
2	To 1.45 m		22 kg, ground to 1.45 m, 3/min	20 kg load
3			10 kg, ground to 1.45 m, 6/min	15 kg load

5.6.2 The US Air Force designed an intial entry pre-enlistment screening test to assign recruits to jobs for which they were physically qualified(Ayoub, Jiang, Smith, Selan, & McDaniel, 1987; McDaniel, Skandis, & Madole, 1983). A job analysis was conducted for all of the Air Force specialties. The physically demanding tasks were identified and quantified. A series of predictor tests were used to model the lifting and lifting and carrying tasks of Air Force personnel. The test item selected for pre-assignment screening was the Incremental Lift Machine (ILM) to 183 cm. This lifting height is a common lifting height for loading aircraft. All job descriptions were assigned a rating for the ILM load that must be lifted for an individual to qualify. The load was based on the average demands of the job, rather than the maximum demands, because it was assumed an Airman could request help in lifting during the heaviest lifts. A report by the US General Accounting Office was critical of the accuracy of the system(1996), but Dr McDaniel reports that this placement system is working well (personal communication, Dr. Joseph McDaniel, Dec 2004).

5.6.3 The ILM weight stack machine lifting test was also used by the US Army. A three phase study was conducted (Teves et al., 1985) in which a group of new recruits was tested on entry to Basic Combat Training (BCT) (Phase 1), during the last week of BCT (Phase 2), and near the end of Advanced Individual Training (AIT) (Phase 3). The only CMT was a 1RM box lift to 132 cm. The physical fitness measures selected to predict 1RM box lift included isometric hand grip, isometric 38-cm upright pull, an ILM to 2 heights (152 cm and 183 cm), a bicycle test of predicted VO2max (Astrand-Rhyming test) or a step test of predicted VO2max, and a skinfold estimate of body composition. The Air Force ILM test was to 183 cm, however, the Army used a lifting height of 152 cm to represent lifting a box with handles 20 cm high to the height of a 2-1/2 ton truck (Teves et al., 1985). The 1RM box lift was measured at the end of BCT and a multiple regression analysis was conducted to predict the CMT from the measures of physical fitness. Fat-free mass and ILM produced multiple regression correlation coefficients (r2) of 0.33, 0.11 and 0.47 for men, women, and combined genders, respectively. The standard error of the estimate was too large for the gender combined equation to be recommended for further use.

5.6.4 Using the physical fitness data collected by Teves et al (1985), and the same Phase 3 volunteers, a modelling study was conducted concurrently by Myers et al (1984). The following additional criterion measures were made: 1RM box lift, a prolonged carry, pushing, and applying torque (turning a wrench). The criterion tasks and the physical fitness predictors were measured at the end of AIT. A combined score was calculated to represent performance on the four criterion tasks. The ILM was found to be the best predictor of the combined score (Myers, Gebhardt, Crump, & Fleishman, 1984). Pre-assignment ILM standards were set for soldiers, but it was not mandatory to lift to standard in order to qualify for a specific military occupational specialty. In a two year follow on study, the US Army was unable to establish the efficacy of the program and dropped the screening test in the early 1990s (VanNostrand, Thompson, & Captain, 1985).

5.6.5 The Canadian Forces have identified three L-L&C common military tasks: Land casualty evacuation, sea casualty evacuation and a sandbag carry (Stevenson et al., 1992). These tasks were standardized for evaluation purposes to develop tasks that could be tested on one soldier. The land evacuation involves one person carrying the front end of a litter, with wheels on the back for .75 km. The litter was loaded to 40 kg (representing ½ of an 80 kg man). The sea evacuation task was conducted in fire fighting protective clothing and consisted of three parts. An 80 kg litter was moved 12.5 m, then a 40 kg litter was pushed up and down a ship staircase and finally, the 80 kg litter was carried back to the starting position. The sandbag carry task required the movement of 20 kg sandbags a distance of 50 m as many times as possible in 10 min. The passing score for these CMTs was the 75th percentile, or the score at which 75% of the tested population would pass the test. The distribution was corrected for differences in the number of men and women. The EXPRES physical fitness test (sit-ups, push-ups, combined maximal grip strength and step test prediction of VO2max) was used to predict performance on the criterion tasks. While the EXPRES tests were significantly correlated with the CMTs, they were not strong predictors. The 5th percentile on each fitness test for the population of subjects who achieved the 75th percentile on all criterion tasks became the passing score. These standards for theEXPRES test are considered to be the minimal level of physical fitness needed to successfully perform the CMTs. The soldier readiness tests, fitness checks and training procedures are all age and gender free(Stevenson et al., 1994; Stevenson et al., 1992; Stevenson et al., 1995).

5.6.6 The Canadian Land Forces Command Army Fitness Manual (Wenger, 2001) lists two L-L&C CMTs. The casualty evacuation task is a fireman lift and carry of an equally sized soldier for 100m in less than 60 sec. The ammunition box lift requires the soldier to lift 20.9 kg boxes from the floor to 1.3 m, 48 times in under 5 minutes. Canadian soldiers are not routinely tested on these CMTs, due to the amount of equipment needed. The Army Fitness Manual provides a Fitness Check to assess an individual's fitness level and ability to perform the CMTs. The standards include four levels of performance on measures of aerobic capacity (2400 m run, 5 km run), strength (bench press, squat, sit-ups) and power and speed (long jump, two jump and 40m sprint). Detailed training instructions are provided to assist the soldier in achieving the standard.

5.6.7 The Royal Netherlands Army designed two L-L&C CMT tests: a repetitive lift (van der Doelen, van Dijk, Visser, & Veenstra, 1996) and a carry(Visser, van Dijk, van der Doelen, & Veenstra, 1996). Each test is progressive in nature with the goal of obtaining a maximum measure of performance. The Repetitive Lifting Task involved lifting a box from the floor to 145 cm one time/10 sec for 9 repetitions. The initial weight in the box was 12 kg and the weight was increased in 4 kg increments. Thirty sec of rest was given between each load increase. This sequence was repeated until the soldier could not keep up with the pace. The performance measure was the number of repetitions. The Carry Task involved a progressive, interrupted jerry can carry of 90 m at a pace of 5.4 km/h. The initial load was 15 kg was increased by 4 kg each trip with 1 min rest between trips. The task ended when the soldier could not maintain the pace and the performance measure was the distance covered. The tests were performed by a group of Soldiers who also performed a series of laboratory and field measures of physical capacity. The more traditional physical capacity tests were used to predict performance on the occupational tasks, and these traditional tests were used to place Royal Netherlands Army recruits into jobs compatible with their capability.

5.7 TRAINING FOR MANUAL MATERIALS HANDLING

5.7.1 Increasing fitness in soldiers is an important part of protecting them from injury, while improving their occupational performance. 90% of physically limiting tasks of Army MOSs include lifting or lifting and carrying (Sharp et al., 1980), and all manual materials handling tasks rely on muscular strength and endurance. By increasing muscular strength and endurance of soldiers, they will do the same tasks at a lower percentage of their capacity, reducing fatigue and therefore risk of injury. Cardiorespiratory endurance training can also be beneficial for materials handling tasks, such as manually lifting boxes for several minutes or hours (Knapik & Sharp, 1998b). The benefits of proper training for soldiers include health, longevity and reduced medical costs, benefiting both the soldier and the military.

5.7.2 Physical training is defined as muscular activity designed to enhance the physical capacity of the individual by improving one or more of the components of physical fitness (Knapik et al., 1998b). The three most important fitness components include muscular strength, muscular endurance and cardiorespiratory endurance (aerobic capacity). Muscular strength is the ability of a muscle group to exert maximal force in a single voluntary contraction. Muscular endurance is the ability of a muscle group to perform short-term, high-power physical activity. Cardiorespiratory endurance depends on the functioning of the circulatory and respiratory systems.

5.7.3 Performance gains in manual materials handling depend on three physical improvements through training: psychomotor learning, improved muscle activation, and cardiovascular changes (Knapik et al., 1998b). Psychomotor learning will result from improved neural coordination. Muscle activation and hypertrophy are achieved through increased strength. Cardiovascular changes are the result of adaptations of the circulatory and respiratory systems through endurance training.

5.7.4 Training to improve manual materials handling performance can be grouped by the type of training. Task specific training includes training by actually doing movements similar to the actual task, but organized as progressive resistance training. General or traditional training includes doing aerobic and weight training for general fitness. Where task-specific training would utilized equipment similar to military situations, such as ammunition boxes and truck beds, traditional training would use weight training equipment found in most gyms. In order to be effective, both training protocols would need to include progressive resistance training (PRT). PRT is accepted as the most effective way to improve performance in sports (Sharp et al., 1993). Progression is an increase in the frequency, intensity or time of the exercise as fitness improves.

5.7.5 Progression in task-specific training is an important way to increase occupational performance. Progression can be accomplished in manual materials handling by increasing the load (weight lifted), the rate (times per minute) of lift, or the frequency (training days per week). Increasing the rate of lifting can increase aerobic gains, while increasing the total number of repetitions will improve muscular gains. Task-specific training has the advantage of a shorter training period because very specific neural adaptations are rapidly acquired. The downside to the quicker improvements is that the gains are limited to the muscle groups and movements trained, and will not affect other types of physical labour. Task-specific training is usually less accessible to large groups of soldiers because it requires a specific training environment with specialized equipment. The need for specialized equipment and non-traditional exercises could result in a more dangerous or less controlled training environment compared to more traditional training. Task-specific training should be used for soldiers who have a repetitive and predictable task where loads and movements can be defined. This type of training is also useful for any materials handling tasks that require a higher skill level because strength and skills can be achieved through specificity of training.

5.7.6 Psychophysical training is a form of task-specific training, where the individual sets the exercise intensity and makes adjustments based on their perception of discomfort. It improved job performance of inexperienced lifters (1 hr repetitive lifting capacity test), but did not increase general physical fitness. (Sharp et al., 1988b) Psychophysical training was also very task-specific, improving lifting capacity for similar equipment used in training, but not for less familiar situations. Muscular endurance training may be more important for repetitive lifting situations than maximal lifting strength in psychophysical training. (Sharp et al., 1988b) In an effort to minimize the amount of psychophysical effects of training, Knapik (1997) used a general training program, but commented that there were some psychophysical effects simply by conducting the pre-training materials handling testing.

Table 6: Summary of task-specific training and improvements in materials handling

Author	Year	N	Sex	Population	Weeks	Testing	Description	% Improvement
Asfour et al.	1984	7	M	Students	6	1RM box lift	0-76 cm	41%
							76-127 cm	99%
							0-127cm	55%
						Vo2max	Cycle Ergometer	24%
Sharp and Legg	1988	8	M	Soldiers	4	Box Lift	1RM 0-132cm	7%
							Psychophysical Mass	26%
							VO2max (direct)	6%
Genaidy et al.	1989	11	M	Civilians	2.5	Lift and Carry	Endurance time to fatigue	102%
Genaidy et al.	1990b	15	M	Civilians	6	Lift, carry, push and pull	1RM	a. & b. 32%
							20 kg, 8 lifts/min endurance	Time/HR a. 57/10% b. 172/7%
Genaidy et al.	1990a	27	M	Students	4	Lift and Lower	Endurance time to fatigue	Sym: 248%, Asym: 46%
							Frequency of handling	Sym: 44%, Asym: 34%
Genaidy et al.	1991	20	M	Students	6	Lift, carry, push and pull	Endurance time to fatigue	a. 557%, b. 1350%
							Heart rate	a. 18%, b. 9%
Genaidy et al.	1994	23/5	M/F	Workers	6	Lift, carry, push and pull	1RM	58-84%
							Endurance time to fatigue	117-127%
							Total Cycles	107-183%

5.7.7 General training takes a longer training period to produce improvements in materials handling, because the increase in performance is attributed to both neural adaptations and muscle hypertrophy. General training is not limited to the specific tasks trained, and therefore will improve performance on a wider variety of tasks than specific training. Traditional training is usually safer than task-specific training and most training facilities have traditional training equipment, designed with safety in mind. General training can improve whole body fitness and should be used in situations where occupational tasks vary. The increase in overall fitness associated with more traditional training can also be effective in preventing muscular imbalances and overuse injuries. Generalized training is better for military, police, and fire fighting where there is no set routine, but require heavy physical labor. (Knapik et al., 1998b). 12 weeks of general training can significantly improve performance. Most of the performance gains come from upper body training in women, since the gender difference in materials handling abilities stem mostly from the difference in upper body strength between male and female soldiers.(Nindl et al., 1998)

5.7.8 When a "carefully structured progressive resistance training element" was added to British Army Basic Training, the increase in materials handling was much greater (12.4% vs 1-4%) then the original basic training regimen. Most of this training was general, but there were some specific skill training as well (Williams, Rayson, & Jones, 2002). For women, general training can improve materials handling performance, especially when the training is targeted at increasing upper body strength (Nindl et al., 1998). Table 7 shows a comparison of several training programs (Nindl et al., 1998; Kraemer et al., 2001). Maximal lifting capacity was not affected by aerobic endurance training, but improved with every type of progressive resistance training.

Table 7: Comparison of training programs for female soldiers

Study	N	Weeks	Sessions	Program	Maximal Lift	Repetitive Lift
Nindl (1998)	46	12	36	Total Body PRT	15.10%	24.00%
				Upper Body PRT	14.00%	21.50%
Kraemer et al. (2001)	93	24	72	Total body strength/power PRT	26.70%	33.30%
				Total body strength/hypertrophy PRT	24.10%	33.30%
				Upper body strength/power PRT	12.10%	29.50%
				Upper body strength/hypertrophy PRT	19.30%	41.20%
				Plyometric/Partner PRT	16.70%	28.60%
				Aerobic Training	0%	28.60%

5.7.9 There is ample evidence that training can improve performance in manual materials handling (Asfour, Dutta, & Tabourn, 1984; Sharp et al., 1988b; Knapik et al., 1996; Nindl et al., 1998). Task specific training is best for jobs where there are few variables in the day to day work, whereas general training is better for jobs where materials handling can vary from day to day (Knapik et al., 1998b). An ideal training regimen for soldiers would include both traditional and task specific training. Most soldiering jobs require the basic fitness associated with general training because their tasks vary by situation, but the nature of their individual jobs may also require skills and specific fitness that can only be learned through task-specific training. This combination of training programs is effective in reducing the number of injuries and increasing the effectiveness of soldiers who are new to the job. One example of a training program already in place is the US Army Physical Fitness School's battle-focus concept task-specific training (Knapik et al., 1998b). This training instructs military leaders on how to optimize training by 1) identifying physically demanding tasks, 2) defining the elements of the task, and 3) developing creative methods of improving performance on each element. Also, adding progressive resistance training and skill specific training to the British Army BT showed much greater improvements in materials handling than in the original basic training program (Williams et al., 2002).

5.8 CONCLUSIONS AND RECOMMENDATIONS

5.8.1 The 1RM for dynamic two-person team lifting is 10-20% lower than the sum of individual 1RM lifts, but little further decrease is found with the addition of one or two more people. If a recommended load for an individual performing a task has been determined, the % sums from Table 1 can be used to estimate the load for two to four persons lifting as a team. It is essential that there is adequate team coordination, space, handholds, and an equal distribution of the load, when performing infrequent heavy team lifting tasks.

5.8.2 Repetitive team lifting and carrying MAWL tends to be equal to or greater than the sum of the individual MAWL for the same task. Therefore, doubling the individual MAWL provides a reasonable estimate of the load two-person teams will find acceptable for a repetitive MMH task. This is most appropriate for tasks that are symmetrical, and the same qualifiers apply as for 1RM lifting (i.e. adequate team coordination, space, footing, handholds, etc).

5.8.3 Where possible, individuals should be roughly matched for strength. When a large strength discrepancy exits between two persons performing a repetitive team lifting task, the weaker individual works at a higher relative intensity, predisposing that person to early fatigue and possibly injury. For 1RM lifting, the lower strength individual limits the maximum load that can be lifted.

6.0 SPECIAL MISSIONS – CHAPTER LEADER: PETER WITTELS, AU

6.1 REQUIREMENT

6.1.1 Specially trained soldiers are required for special missions in the army. Those soldiers are characterized by a demand of special tactical skills, special psychological skills as well as above-average skills of physical capacity. In describing those physical skills by means of sports motor components, characteristic sports motor profiles for the respective tasks of soldiers for special missions can be derived.

6.1.2 Evidence based physical selection criteria for soldiers for special missions have not been established yet. The development of profiles of sports motor requirements is of great importance. The derived sports motor requirement profiles serve as substructures for the development of selection criteria and selection procedures. Only through the knowledge of the physical requirements of soldiers for special missions individual and collective training recommendations can be established.

6.1.3 According to military experts in the Austrian army, close quarter battle can be defined as the battle in objects. The job specific scenarios are special reconnaissance in urban areas as well as direct action such as ambushing and liberating of captives and hostages. Common activities are weapon and gunnery training, identification of friend and foe (IFF), situation drills, training of a big range of different scenarios, tactics and close combat, and training in different specifications such as engineering or sniper training.

6.1.4 The job specific scenarios of mountaineering / mountaineering techniques are assault missions in alpine terrain behind enemy lines and advance to contact by crossing almost impassable terrain. Common activities are marching, climbing and skiing with heavy equipment. It is not the purpose of this work, to discuss the special problems of altitude in mountaineering. In this chapter we will restrict to alpine and mountaineering techniques, which can be used in any military environment.

6.1.5 Objectives of this chapter is to analyse the physical requirements for the tasks of soldiers for special missions, to examine whether the current physical training status of those soldiers agrees with the physical requirements by comparing the physical performance of Special Forces soldiers with the performance of other military groups, and to establish a model for minimal physical requirements for the mission demands of soldiers for special missions.

6.2 METHOD

In a first step the importance of different sports motor components for soldiers for special missions was assessed by means of an expert interview. In a second step, a test battery was established, to examine the sports motor components among three different military groups: Special Forces soldiers, the Professional Soldiers Company (both groups were soldiers for special mission) and as a third group Forces for International Operations that were currently serving in the Austrian army. And finally in a third step the bottom quartile of the physical performance of one of the groups of soldiers for special missions were computed and considered to be a suitable cut-off value for minimal requirements for soldiers for special missions.

6.3 RESULTS

The findings identify reaction speed as the key component for soldiers with special missions. Furthermore endurance, strength endurance and coordinative ability / adroitness are of special importance. The performances in the fields of aerobic and anaerobic endurance were significantly worse among soldiers for International Operations, compared to the groups of soldiers for special missions. Velocity and velocity/coordination, maximum strength and strength endurance were better among Special Forces soldiers compared to the other both groups. There was no difference in the anthropometric parameters in the different groups. As minimal requirements for soldiers for special missions a minimum of 10 minutes and 12 seconds for the 2,400 meter run and a minimum of 38 push ups and 23 sit ups are considered.

6.4 CONCLUSION

The requirements of soldiers for special missions are reflected in an elevated physical capacity. The findings identify reaction speed as the key component for soldiers with special missions. Furthermore endurance, strength endurance and coordinative ability / adroitness are of special importance. Based on the presented results we recommend for special missions a minimal requirement of 10 minutes 4 seconds for a 2,400 meter run, which equals a VO2max of about51 ml/min/kg, and a minimum of 38 push ups and 23 sit ups.

Additionally we recommend for maximum strength a minimum of 71 kg for bench press and 152 kg for leg press. For all other sports motor components, especially for reaction speed it is mandatory to establish a standardized test battery.

7.0 FACTORS INFLUENCING PERFORMANCE – CHAPTER LEADER: JIM HODGDON, US

7.1 APPROACH

- Factor description;
- Effect of factor on physical performance;
- Preventative Measures to Minimize Negative Effects

7.2 STRUCTURE

- 3 –5 pages to be dedicated to each factor;
- 5- 15 references to be used;
- near textbook information level.

7.3 EXTRINSIC FACTORS

Table 8: Sections

Factor	Contribution Author(s)	Status
Continuing Operations	Jim Hodgdon, US & Pat Gagnon, CA	In progress
Cold	Matti Mantysaari, Matti Santtila, Erkki Nordberg, FI	Draft submitted
Heat	Jim Hodgdon, US & Rene Nevola, UK	Draft submitted
Altitude	Lisa Goderdzishvilli, Georgia & Xavier Bigard, FR	Draft submitted
Nutrition	Xavier Bigard, FR	Draft submitted
Hydration	Xavier Bigard, FR	In progress
Clothing	Jim Hodgdon, US	In progress
Teamwork	Jim Hodgdon, US & Pat Gagnon, CA	In progress

7.4 INTRINSIC FACTORS

Table 9: Sections

Factor	Contribution Author(s)	Status
Age	Dieter Leyk, GE & James Bilzon, UK	In progress
Gender	Dieter Leyk, GE & James Bilzon, UK	In progress
Genetics	Xavier Bigard, FR	Draft submitted
Anthropometry	Dieter Leyk, GE & James Bilzon, UK	In progress

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