ARMY RESEARCH LABORATORY

Feasibility of MOS Task Analysis and Redesign to Reduce Physical Demands in the U.S. Army

Joseph J. Knapik
Rene J. de Pontbriand
William H. Harper
Richard A. Tauson
Jennifer C. Swoboda
N. William Doss

ARL-TR-1594 DECEMBER 1997

Approved for public release; distribution is unlimited.

Abstract

Heavy physical demands characterize a large number of U.S. Army military occupational specialties (MOSs). About 45% of the Army's 277 MOSs require at least occasional lifting of 100 pounds or more and frequent lifting of 50 pounds or more. In an effort to reduce these physical requirements, we developed and tested an Army-specific ergonomic task analysis and redesign procedure. Five MOSs were selected for this feasibility project: Food Service Specialist, Medical Specialist, Motor Transport Operator, Tracked Vehicle Mechanic, and Chemical Operations Specialist. Literature review, numerous pilot investigations, and professional experience produced a multiphase process involving (a) review of military publications describing specific occupational tasks, (b) a questionnaire and structured interview with five junior and five senior soldiers working in the MOS, and (c) filming of tasks identified in the first two phases. Contact with military schools responsible for the MOS, project managers (individuals responsible for specific pieces of equipment or projects), or military construction (agencies responsible for new buildings) was found useful in all phases of the process. Potential redesign solutions could also be identified at all phases with soldiers themselves an especially good source of ideas. The feasibility of the potential redesigns was discussed with the schools, project managers, or military construction personnel, and specific solutions were targeted for testing in a usability analysis. In one usability analysis, we identified and improved stretcher carrying methods by moving the stretcher load from the small muscle mass of the hands and forearms to the larger muscle mass of the shoulders and hips. Stretcher carriage time was extended 9.4-fold and soldiers' subjective impression of effort was reduced. These and other redesigns proven to reduce physical demands could be implemented through the appropriate agencies, usually the schools. Not all physically demanding tasks appear amenable to change, and most redesigns did not totally remove the physical burden from the soldier. However, the paradigm developed here allowed identification of the most demanding tasks, some potential redesigns, and targeted solutions with the greatest chance of reducing the soldiers' physical effort.

FOREWORD

This project developed through cooperation between the Department of the Army-Deputy Chief of Staff for Personnel (DA-DCSPER) and the Human Research and Engineering Directorate (HRED) of the U.S. Army Research Laboratory (ARL). On 27 January 1994, an initial meeting was held between members of the two groups to discuss requirements for lifting in various military occupational specialties (MOSs). The meeting focused on the fact that a large percentage of MOSs had strength requirements that exceeded the capabilities of a large percentage of female soldiers. On 24 February 1994, ARL submitted a preliminary proposal to examine MOS-related tasks that were physically demanding and look for ways to eliminate or manage these tasks.

Subsequent findings by the DA-DCSPER office revealed that a number of men could not meet the lifting requirements of their respective MOSs either. Because of the larger number of men in the Army (at that time, about 88% of personnel strength), the absolute number of men not able to meet the requirements was greater than the absolute number of women. In March 1995, DA-DCSPER requested a modified proposal, taking a gender-neutral approach. In May 1995, ARL submitted a full proposal to examine the feasibility of MOS task analysis and redesign to reduce the physical demands in the U.S. Army. In September 1995, DA-DCSPER accepted the proposal with modifications.

On 27 October 1995, Brigadier General Kerr and Colonel Green were briefed about the preliminary findings of the investigation. On 5 April 1996, the project was continued for a second year. This report covers work from September 1995 to April 1997, detailing the results of the feasibility project and providing a model for identifying and redesigning physically demanding tasks in specific MOSs.

On 6 August 1997, Lieutenant General Volrath, DCSPER, was briefed about the completed project. The briefing included an overview of the project, sample video of "very heavy" requirements tasks, and data for a critical redesign effort involving carrying of the medical stretcher. LTG Volrath agreed that there is strong justification for broadening this effort to include other MOSs and offered to present the project to the Army Chief of Staff. An ensuing briefing of the MOS Redesign for Force XXI Working Group, under Colonel Lee, Assistant Secretary of the Army (Manpower and Reserve Affairs) (ASA [M&RA]), gained support for the redesign approach. The group includes representatives from DCSPER, Deputy Chief of Staff for

Operations (DCSOPS), Army Research Institute, U.S. Army Research Institute of Environmental Medicine (USARIEM), Medical Research and Materiel Command (MRMC), U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM), Physical Fitness School, Training and Doctrine Command (TRADOC), Personnel Command (PERSCOM), as well as ARL. That group is working on a strategy to focus these efforts on the most critical MOSs.

ACKNOWLEDGMENTS

It is a difficult task acknowledging all the individuals and organizations that participated in this investigation and provided the information that made this project a reality. It was the soldiers whom we interviewed and filmed to whom we want to provide our special thanks. In addition, many other active duty soldiers, retired soldiers, and Army civilians volunteered their time to talk with us freely and frankly, thus providing us with a much more comprehensive report.

Our special thanks go to the following for providing opportunities to interview soldiers and film them in action: Major Malecha, Staff Sergeant Cheryl Miller, Sergeant First Class Richard Edwards of the 180th Transportation Battalion, Fort Hood, Texas; Captain Grove of the 13th Corps Support Command (COSCOM), Fort Hood, Texas; Captains O'Neil and Gaworski of the 1st COSCOM, Fort Bragg, North Carolina; Master Sergeant Newcomb of the 46th Support Group, Fort Bragg, North Carolina; Captain Albert Vigna of the Aberdeen Test Center, Aberdeen Proving Ground (APG), Maryland; Sergeants First Class Clinton Walker and Christopher Forde, and Major Coffelt of the Chemical School, Fort McClellan, Alabama; Sergeant First Class Chasten, Captain McBride, Major Tyra, Captain Haugh, and Mr. Wright of the Ordnance School, APG; Lieutenant Colonel Peggy Trimble and Sergeant First Class Cole of the Regional Training Center-Medical, Fort Indiantown Gap, Pennsylvania; and Sergeant First Class Sulpulvida of Kirk U.S. Army Hospital, APG.

Our thanks also go to the following individuals who shared their expertise and provided us with information which would have been impossible to obtain elsewhere: Mr. Richard McMahon and Mr. David Harrah of the Human Research and Engineering Directorate of the U.S. Army Research Laboratory, APG (Weapons Branch, Edgewood Research, Development, and Engineering Center [ERDEC] Field Element); Master Sergeant Hall of Training Developments, Transportation School, Fort Eustis, Virginia; Sergeant First Class Collins of the Ordnance Product Development Team, Combined Arms Support Command, Fort Lee, Virginia; Warrant Officer 1 Lorraine Mann, Sergeants First Class DeJesus and Fishburne of the Installation Food Service, APG; Lieutenant Colonel Bluth, Ms. Ellen Waraksa, Chief Warrant Officer 5 Galloway, and Mr. Stauton from the Quartermaster School, Fort Lee, Virginia; Mr. David Carney of the Soldier Systems Command, Natick Research Development and Engineering Center; Ms. Belinda Rameriz, Lieutenants Colonel Sadler, Larry Johnson, and Valerie Rice, and Sergeant First Class Craig of the Army Medical Department Center and School, Fort Sam Houston, Texas.

CONTENTS

FIGURE

TABLES

EXECUTIVE SUMMARY

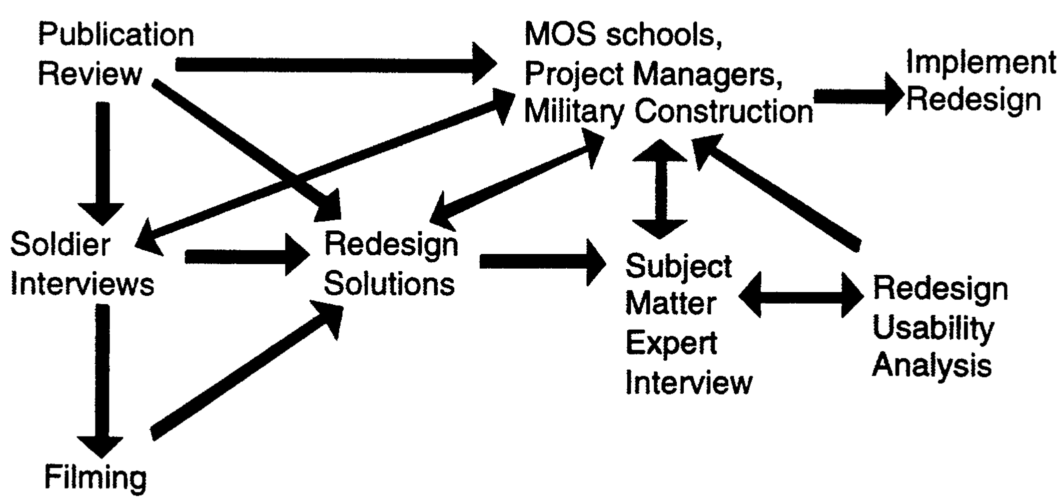
Heavy physical requirements characterize a large number of military occupational specialties (MOSs). More than 124 of the U.S. Army's 277 MOSs (45%) are classified as "very heavy" by the Department of Labor (DOL) standards. This is the most demanding DOL classification and is reserved for jobs that require occasional lifting of 100 pounds or more and frequent lifting of 50 pounds or more. Reducing physical requirements would improve health and safety, conserve soldier strength and endurance for other battlefield tasks, and optimize personnel utilization. This report describes a feasibility project focusing on identifying methods to reduce physical demands through an Army-specific ergonomic task analysis and redesign.

We selected five MOSs for this feasibility project, based on their DOL strength classification and availability of troops locally: 92G (Food Service Specialist), 91B (Medical Specialist), 88M (Motor Transport Operator), 63H (Tracked Vehicle Mechanic), and 54B (Chemical Operations Specialist). The initial project design involved three steps: (a) review of publications describing occupational tasks, (b) interviews with soldiers working in the MOS, and (c) filming the tasks. After reviewing many publications and databases (Army training and evaluation programs [ARTEPs], programs of instruction [POIs], Army Safety Center, etc.), we found that soldier training publications (STPs) and data from the Army occupational survey were the two most useful sources. We initiated, tested, modified, developed, and finalized a structured soldier questionnaire and interview format. Filming was most usefully limited to the most physically demanding tasks identified in Phases 1 and 2.

During the course of the investigation, it became apparent that potential redesign solutions could be identified at all phases. The soldiers themselves were an especially good source of ideas. Further, schools responsible for the MOS, project managers, commanders, and noncommissioned officers (NCOs) were often (though not always) aware of the physical demands of specific tasks and were working on or had otherwise considered potential solutions. The schools were found to be the best single source of information about current efforts (if any) to reduce soldier physical demands. It was also essential in specific cases (e.g., those tasks involving equipment) to contact project managers and in some cases, individuals involved with military construction.

We found it most useful to target physically demanding tasks not being currently worked by the schools or project managers for which reasonable solutions could be found and tested. As an example of this, carrying patients on litters was consistently identified by medics as one of the most physically demanding tasks they performed. We identified and improved methods to carry litters using the ergonomic principle of moving the load from the small muscle mass of the hands and forearms to the larger muscle masses of the shoulders and hips. This distributes the load mass over a larger area of muscle tissue, thus reducing the load per unit of muscle. Using equipment designed in our laboratory, and testing under controlled conditions, we extended litter carriage time by 9.4-fold and decreased the soldiers' subjective impression of effort. A system was designed that was adaptable to the pistol belt on soldiers' load-carrying equipment for the integrated individual fighting system; it was also adaptable to the new system designed for medics (i.e., the improved medic vest).

A model was established using lessons learned from this feasibility project and this is shown in the following diagram (Figure 1 in main body of report). The initial project design was retained, but several modifications were made. After the initial publication review, the school, project managers (PMs), and others associated with the MOS are contacted. The purpose of the project is made clear and feedback is solicited. Interviews with soldiers in the MOS are conducted and a second contact is made with the schools, PMs, and others. The tasks identified as the most demanding are filmed. Potential redesign solutions are sought at all steps. After completion of the list of tasks and potential redesigns, the schools are contacted again and the feasibility of the potential solutions determined with subject matter experts (SMEs) at the schools. Specific solutions are targeted and tested in a usability analysis. Those redesigns proven to reduce physical demands are implemented through the appropriate agencies.



Model for identifying and redesigning physically demanding tasks in the U.S. Army.

This model is a general one, and the approach for identifying, redesigning, and implementing solutions must be flexible. The model should be conceived as a starting point and a guideline. Additional tasks may need to be performed. For example, agencies other than the schools or PMs may be working on methods to reduce physical demands, and these must also be contacted to avoid duplication of effort. Part of the reason there is currently no organized redesign effort is that the problem cuts across several disciplines and the missions of several agencies. It might be possible to establish and maintain a network of agency representatives whose charge it is to inform others of known potential problems, potential solution strategies, and potential implementation methods.

Not all physically demanding tasks are amenable to change using current technology, and many potential solutions do not totally remove the physical burden from the soldier. However, by using the model just described, potential solutions can be identified and those with the greatest chance of reducing the soldiers' physical effort can be targeted and worked on. We advocate this approach, which is based on standard ergonomic assessment tools and can provide a common language to a complex multidisciplinary problem. Such efforts may improve soldier health and safety, conserve fighting strength, and optimize personnel utilization.

FEASIBILITY OF MOS TASK ANALYSIS AND REDESIGN TO REDUCE PHYSICAL DEMANDS IN THE U.S. ARMY

INTRODUCTION

The U.S. Army currently has 277 military occupational specialties (MOSs), and each has its own particular set of mental, skill, and physical requirements (U.S. Army, 1994). As in industry, some specialties may require high mathematical aptitudes, while others demand more manual dexterity, and still others, long-term training in selected skills. However, it is the extreme physical demands that often distinguish Army occupations from those in the civilian sector. There are many reasons for this, some having to do with the demands of the battlefield and the operating environment. For example, a field artillery round may weigh 100 or 130 pounds because it needs sufficient mass and explosive power to achieve its tactical objective; the weight is based on mission demand, not on human lifting capability. In cases when there are infrequently performed tasks or sudden emergencies, there may not be adequate personnel and the work may fall on the few soldiers who are available. Also, it is not unusual for an individual who cannot perform the physically demanding parts of a particular MOS to be reassigned to less demanding tasks, thus further increasing the workload on the remaining personnel, and the operating environment cannot be ignored. Tasks that are easily performed in garrison on hard surfaces are made difficult in the field because the surface may be uneven, rocky, loose, muddy, snow covered, and overall unpredictable; tasks such as tank track repair, portable bridge emplacement, casualty extraction, and mobile kitchen setup become burdensome and difficult.

More than 124 (45%) of all MOSs are classified as "very heavy" by the Department of Labor (DOL) standards. This is the highest strength classification of the DOL and is reserved for jobs that require occasional lifting of 100 pounds or more and frequent lifting of 50 pounds or more (DOL, 1991). MOSs with very heavy lifting requirements comprise a large proportion of the total Army manpower, accounting for a large percentage of enlisted slots. Performance of tasks with heavy lifting requirements can be negatively impacted by personnel availability since these requirements can often exclude a large number of otherwise fully capable individuals from entering or being retained in these MOSs. An indication of the potential severity of the problem is the fact that pre-enlistment testing demonstrates that approximately 14% of the volunteer military age male population are not capable of the DOL "very heavy" lifting standard to the height of a standard military truck, and only a very small percentage of the military age female population are capable of such lifting (Sharp, Wright, & Vogel, 1985).

Rationale for Lowering Physical Demands

The battlefield requires great effort and sacrifice not found in most other human endeavors; it is known to be exceptionally demanding. However, even with the Army's unique set of circumstances, there are strong reasons to reconsider its physical requirements. Such reasons must be made explicit, since this area competes for resources with a variety of other critical programs, from technology development to weapons purchases.

A principal reason for lowering physical demands is safety and health concerns. Physically demanding tasks are dangerous. It is known that injuries are directly related to the amount of exposure to heavy physical demands (Jones, Cowan, & Knapik, 1994; Koplan, Powell, Sikes, Shirley, & Campbell, 1982). For example, heavy loads are prone to being dropped, to shifting unexpectedly, and to being improperly lifted, carried, and emplaced. They can critically injure the lower back, joints, and limbs, incapacitating individuals (Jensen, 1988), and can consequently jeopardize readiness and mission success. Lowering physical requirements would reduce these potential risks and enhance battlefield effectiveness.

Equally critical is the need for performance sustainment. Some Department of Defense (DoD) restructuring changes call for reduced artillery crew sizes, for example, going from a six- to a four-person squad (USAFAS, 1984). The reduced squad might be expected to support the same rate of fire, the same number of moves per day, and the same number of rearm-refuel missions as it did in its previous configuration. One way to sustain a given workload level with fewer people is to reduce "heavy lift" task requirements (i.e., anaerobic, quickly fatiguing) to "low lift" task requirements (i.e., aerobic, longer term fatiguing).

A benefit related to sustainment is performance maintenance. The increasing influx of new technologies (e.g., the 45-mph tank, digitized battlefields, command and control while moving, etc.) has the effect of increasing operational tempo for everyone--more must be done in a given period of time, such as three vehicle refuelings in the same time it formerly took to perform two. Lowering soldier physical requirements is one way to allow soldiers to keep pace with increased activity.

Reduced demands are also key to more complete personnel utilization. Some individuals do not have the strength and stamina to perform specific tasks in some MOSs. Lowering physical requirements will allow a greater proportion of the total available manpower to perform all necessary tasks. An associated benefit relates to interoperability with our coalition partners. To the extent that DoD downsizing and strategic change requires greater interaction with and reliance upon joint coalition missions, the potential for success of those missions is enhanced if, again, the load can be shared with international counterparts. This can be accomplished if U.S. Army tasks, materiel, and equipment are designed to lower boundaries of physical size and strength.

Approaches for Addressing Physical Demands

Approaches for addressing heavy physical demands in the U.S. Army include personnel placement, physical training, and task redesign. Personnel placement may not be adequate to handle all necessary tasks. Appropriate individuals (those with greater physical capacity) may not be available at the times they are needed since the pool of these individuals is limited. Further, there is no guarantee that these individuals can handle particular tasks properly under the stress of battlefield conditions, even if they are fully capable during normal conditions (Holmes, 1985).

Physical training increases individual capacity to meet physical requirements and provides benefits even away from the job, such as increased health, longevity, and productivity (Bly, Jones, & Richardson, 1986; Lakka, et al., 1994; Paffenbarger, Hyde, Wing, & Hsieh, 1986; Sternfeld, 1992). Indeed, the major military response to the physical demands of military life has been to maintain highly conditioned soldiers through regular physical fitness training. Well-designed physical training programs have been shown to improve the physical capability of soldiers (Knapik & Gerber, 1996; Knapik & Sharp, 1997; Sharp, Harman, Boutilier, Bovee, & Kraemer, 1993). However, improvements resulting from physical training are circumscribed by the amount of time that can be dedicated to this type of training, the potential for injury (Jones, et al., 1994), and the inherent biological limits to improvements (Bouchard, Malina, & Perusse, 1997; Prud'Homme, Bouchard, Leblanc, Landry, & Fontaine, 1984; Wenger & Bell, 1986).

Task redesign has some advantages not afforded by other approaches. Appropriate task redesign can actually lower physical requirements. Lowering physical demands allows soldiers to conserve their strength and endurance, thus extending their performance and conserving energy for emergency situations such as those typically encountered during battlefield conditions (Keegan, 1976). Further, once the task has been made less difficult to perform, everyone benefits without further involvement. The Army does not have to engage in repeated, specific training for all individuals coming into the MOS.

Purpose of Report

The purpose of this report is to document the results of a pilot project designed to identify methods to reduce the physical demands of specific tasks through an Army-specific ergonomic task analysis and redesign procedure. We report the results of our literature search, initial approach to the problem, and modifications of the initial approach in the light of new data. We present a model that allows systematic identification and possible redesign of physically difficult tasks. The ultimate goal of this project is to reduce the soldier's physical effort.

BACKGROUND LITERATURE REVIEW

This section reviews four distinct areas from which ideas for the present investigation were obtained. These included (a) task analysis and redesign, (b) job analysis, (c) physical demands analysis, and (d) posture analysis. We reviewed widely because of the broad nature of this project. Within the review, we have cited when appropriate literature has been used to develop the methods and techniques we chose.

We used the U.S. Department of Labor definitions for elements, tasks, positions, and jobs as follows: "An Element is the smallest step into which it is practical to subdivide any work activity without analyzing separate motions, movements, and mental processes involved. A Task is one or more elements and is one of the distinct activities that constitutes logical and necessary steps in the performance of work by the worker. A task is created whenever human effort, physical or mental, is exerted to accomplish a specific purpose. A Position is a collection of tasks constituting the total work assignment of a single worker. There are as many positions as there are workers in the country. A Job is a group of positions within an establishment which are identical with respect to their major or significant tasks and are sufficiently alike to justify their being covered by a single analysis" (DOL, 1991).

Task Analysis and Redesign

Task analysis is a well-established technique in industrial engineering that focuses on the time and motions an employee uses to complete this work. The goal is to improve efficiency and working conditions in the production of goods and services. The technique stems from the early pioneering works of Frederick Taylor and Frank Gilbreth who were industrial workers themselves. Frederick Taylor was employed at a steel company and progressed from lathe operator, to gang boss, to foreman, and finally to chief engineer. At Bethlehem Steel Works, he studied shoveling of ore by manipulating the size of the scoop and noting the tonnage moved in a day. He found that with a shovel full of about 10 kg, tonnage per day was maximized; larger or smaller shovels produced less tonnage per day. He also found that the light ash produced from ovens could be easily moved with very large shovels. He developed shovels of sizes that took advantage of these findings. In addition to equipment modification, Taylor examined other aspects of performance including selection and training of workers and paying bonuses for work exceeding set criteria. He demonstrated that shoveling work formerly performed by 400 to 600 men could be done by 140 at the same efficiency (Copley, 1923). Taylor developed what he called "Principles of Scientific Management" which involved the facts that (a) the best workers should be selected for the job and trained properly, (b) cooperation should be developed between management and labor, and (c) a division of work should exist between labor and management with each doing the work best suited to that job (Taylor, 1929).

In 1885, Frank Gilbreth was a 17-year-old bricklayer who later became a building contractor. He did considerable work with brick layers. He noticed that each brick layer had his own way of laying bricks, and he decided to find a method that was most efficient. He developed a scaffolding that could be easily raised and held bricks at a height that minimized the bending the craftsmen had to perform. He had less expensive laborers sort and stack the bricks conveniently for the brick layers. He arranged the work site so the craftsmen could pick up the bricks with one hand and a trowel full of mortar with the other, thus considerably increasing the efficiency of the operation (Gilbreth, 1911). In studies conducted primarily at the New England Butt Company, he developed a technique he called "micromotion studies" which segregated industrial jobs into a series of 17 elemental motions that Gilbreth believed to be common to all manual work (Gilbreth, 1912).

Building on the work of Gilbreth, Barnes (1980) cites nine other motion analysis systems developed between 1924 and 1952. These systems are used to guide industrial efficiency efforts. In the basic procedure, an engineer views a job and breaks it into tasks and the tasks into elements. He or she then records the movements and time necessary to complete specific elements. Barnes (1980) developed specific checklists and principles to guide redesign efforts after these data had been collected. One checklist provides guidance for redesign efforts for each of Gilbreth's 17 elemental motions. A second list provides 22 guidelines designed to improve efficiency and reduce fatigue in manual effort. These "Principles of Motion Economy" are listed in Appendix A. While these were intended primarily for industrial work, some of the principles were found useful in the present project.

Another set of useful considerations were those of Corlett (1983). He provided principles for the arrangement of workplaces. These principles are directed primarily at reducing stressful working postures, but they can be applied to any task redesign. The principles are arranged in order of importance so that if two or more conflict, the higher principle takes precedence. The principles are listed in Appendix B.

Flanagan (1954) describes a method called the "Critical Incident Technique." The philosophy underlying this technique is that task requirements determining the difference between success and failure are those that are most critical to the successful performance of a job. Workers will recall serious errors, accidents, emergencies, or even a better way of performing a task that can assist in redesign efforts. The technique involves soliciting memorable events from qualified workers. Individuals or groups can be interviewed. In the interview, the general purpose is stated, and specific questions are then asked relating to memorable experiences. Such a question may be, "Think of the last time you recall an accident or near accident as a result of unloading crates from trucks on your loading dock," or "Think of the last time you recall something that was done that allowed crates to be taken off the trucks more efficiently." After a sufficient number of individuals are interviewed, incidents are placed into post hoc categories. Inferences are then drawn from methods to improve tasks; Flanagan offers no specific recommendations for task improvements. We found during interviews with soldiers that critical incident techniques would allow soldiers to remember information that was useful for identifying demanding tasks.

A very simple technique for rating the physical demands of individual tasks is the Index of Perceived Exertion (IPE) (Hogan & Fleishman, 1979; Hogan, Ogden, Gebhart, & Fleishman, 1980). This is a modified Borg Scale (Borg, 1970) using only 7 points instead of the 15 on the original Borg Scale. Hogan and Fleishman (1979) asked personnel specialists and untrained college volunteers to rate 30 occupational and 41 recreational tasks on the IPE scale. These tasks had known metabolic costs. The correlations for the personnel specialists between the IPE ratings and the metabolic costs were 0.81 and 0.83 for the occupational and recreational tasks, respectively. For the untrained volunteers, the correlations were 0.80 and 0.70 for men and women, respectively, on the occupational tasks; correlations were 0.80 and 0.75 for men and women, respectively, on the recreational tasks. In another study (Hogan, et al., 1980), subjects performed 24 manual material handling tasks and then rated them on the IPE scale. A work index was calculated by the investigators based on the mass, distance lifted, and distance carried. The correlation between the work index and the IPE was 0.88, with a reliability among raters of 0.83. These two studies suggest that group ratings of IPE are valid and reliable indices of both metabolic and ergonomic requirements of occupational and recreational tasks. We used the IPE in a portion of our project but found it did not provide information beyond that which could be provided by direct soldier interviews or from observations of tasks that were filmed. However, the IPE could provide a quantitative construct validity measure, which may be useful in a large study with many investigators.

NIOSH Equations for Manual Lifting

Since many military tasks involve manual lifting, we explored possible uses of the National Institute for Occupational Safety and Health (NIOSH) guidelines for manual lifting (NIOSH, 1981). NIOSH defined manual lifting as the act of grasping and raising an object of definable size without mechanical aids. To identify, quantify, and document the physical stresses associated with a particular job, NIOSH suggests a job physical stress evaluation. Jobs are ranked on the basis of incidence and severity of musculoskeletal disorders, and those with the highest incidence are studied first. Analysts are selected who have experience with work measurement and familiarity with the work done in a particular plant. Experienced workers who routinely perform the jobs undergoing study are examined while they perform the work at a normal pace. Data from the analysis are collected on a physical stress job analysis sheet which includes the following: (a) object weight - mass of the object determined by direct weighing (if this varies from time to time, the average and maximum weights are noted); (b) hand location - measured at the starting point (origin) and ending point (destination) of the lift in terms of the horizontal (H) and vertical (V) position (H is measured from the midpoint of the line joining the ankles to the midpoint where the where the hands grasp the object in the lifting position; V is measured as the distance from the floor to the point where the hands grasp the object; if the values vary from task to task, the job must be separated into elements and each element evaluated separately); (c) task frequency - average lifts per minute (a separate frequency is entered for each task); (d) period - total time engaged in lifting and need only be noted as more than 1 hour or less than 1 hour for this procedure. Once these data have been collected, the action limit (AL) and maximum permissible limit (MPL) can be calculated. These limits only applied to smooth, two-handed symmetric lifting in the sagittal plane using a load of 30 inches or less in width with good couplings (hand holds) and favorable ambient conditions. The equations are

$$AL=40*(15/H)*(1-.004*|V-75|)*(0.7+7.5/D)*(1-F/Fmax)$$

$$MPL=3*AL$$

in which AL = action limit (kg),
H = horizontal location forward of the midpoint between ankles at origin of lift (cm),

V = vertical location at origin of lift (cm),
D = vertical travel distance between origin and destination (cm),
F = average frequency of lift (lifts/min),
Fmax = maximum frequency that can be sustained (V>75cm standing for 1 hour = 18, 8 hours = 15; V75cm stooped for 1 hour = 15, 8 hours = 12).

Simplified versions of the 1981 equation have been successfully used for worker educational purposes (Buse, 1990).

In 1991, NIOSH (Waters, Putz-Anderson, Garg, & Fine, 1993) eliminated the concepts of AL and MPL and developed the concept of the recommended weight limit (RWL). The RWL represents a load that nearly all healthy workers can perform over a period as long as 8 hours without increased risk of developing low back pain. An equation to estimate the RWL was established, based on a review of the literature and expert opinion using well-specified biomechanical, physiological, and psychophysical criteria. The biomechanical criterion was based on a load mass that resulted in a maximum vertebral disc compressive force of 350 kg; the physiological criterion was physical activity requiring 2.2 to 4.7 kcals/min; the psychophysical criterion was a load mass acceptable to 75% of female workers and 99% of male workers. The equation was designed to allow an evaluation of asymmetric lifting, lifting of objects with unfavorable hand couplings, and a wider range of work durations and lifting frequencies. The equation is

$$RWL=23*(25/H)*(1-(0.003*|V-75|)*(0.82+(4.5/D)*(1-(0.0032*A)*F*C$$

in which H = horizontal distance of the hands from the midpoint between the ankles, measured at the origin and destination of the lift (cm),
V = vertical distance of the hands from the floor, measured at the origin and destination of the lift (cm),
D = vertical travel distance between origin and destination of the lift (cm),
A = angle of asymmetry-angular displacement of the load from the sagittal plane measured at the origin and destination of the lift (degrees),
F = frequency multiplier (see Appendix C), given work duration, lifting frequency, and vertical distance (V),
C = coupling multiplier (see Appendix D), given vertical distance and an estimate of the quality of the coupling.

The NIOSH equations are designed to workers of all ages in the United States (V. Putz-Anderson, personal communication, 1996). The military population is comprised mainly of young, healthy individuals (Defense, USA, 1992). Revisions in the NIOSH equations would be required to accommodate this population. Thus, the equations were considered only minimally in this investigation.

Job Analysis and Physical Demands Analysis

Job analysis and physical demand analysis do not consider just a single task but all tasks in a job. They provide additional ways of examining tasks and some useful information for our efforts.

Physical Demands Analysis

Physical demands analysis (PDA) is a type of job analysis that attempts to define the actual physical requirements of the job and their contribution to completing the primary objective of the job. It is a subcategory of job analysis because job analysis is a broader term that encompasses many different ways of collecting and evaluating data about a job (Lytel & Botterbusch, 1981). PDA stems from the work of the War Manpower Commission. During World War II, this group attempted to match the physical abilities of the worker with the physical requirements of the job (Fraser, 1992), probably because a number of disabled soldiers were returning to civilian occupations. Hanman (1945; 1946) provides a review of some prior attempts in this area. Hanman (1945; 1946) also reports on a project which resulted in the development a list of some 30 physical factors (e.g., lifting, carrying, handling, stooping, twisting, etc.) and 30 environmental factors (e.g., temperature, toxicity, noise, height, cramped quarters, etc.) that attempted to objectively define a job. In a study of this technique, two analysts were trained to use the list over a 1-week period; then they independently analyzed 25 industrial jobs. The correlation between the two sets of analysis was 0.90. In another study, data from the analysis were presented to physicians to assist in medical screening of applicants. The applicant returned to a placement officer who then knew which jobs the applicant was physically qualified for. In a 6-week period, 110 workers were placed and none left for physical reasons. In the 6 weeks and 6 months before this study, 10% and 17%, respectively, of the workers left for physical reasons. Further attempts to refine this scale resulted in a new format in which the amount of time during each day that the physical capacity was required was also included (Lytel & Botterbusch, 1981).

Lytel and Botterbusch (1981) developed a complex and comprehensive technique designed primarily for placing the handicapped into jobs they could perform. The method involves (a) identification of need for the analysis, (b) identification of the target population, (c) development of contacts in appropriate sectors to gain access (clubs, businesses, boards of directors, etc.), (d) an initial meeting to brief employers and tour the facility, and (e) interview and observation. The core of the analysis is the latter and the interview and observation proceed together with the general process relying heavily on the Department of Labor Handbook (DOL, 1972). A series of forms is used to characterize the job. These include the following: (a) environmental and social conditions, (b) job tasks (with percent of time and criticality), (c) task analysis form. The Task Analysis Form includes (a) most common postures, (b) height and weight of manipulated objects, (c) handling objects, (d) speech and hearing, (e) driving and control placement, (f) infrequent actions, (g) visual demands placement, (h) measurement and manipulation, (i) mobility, (j) strength, (k) duration of walking, standing and sitting, (l) extended or heavy physical demands, (m) need for driving, (n) physical barriers. The forms are checklists, but space is provided so comments can be made on each item.

Job Analysis

The work on physical demands analysis (especially the work of Hanman (1945; 1946) eventually led to a wider approach in which all job requirements were considered. The U.S. Department of Labor developed an approach for cataloging nationwide employment information (Lytel & Botterbusch, 1981). Jobs were classified in terms of (a) the worker's relationship to data, people and things (worker functions), (b) the methodology and techniques employed (work fields), (c) machines, tools, equipment and work aids used, (d) materials, products, subject matter, or services that result, and (e) worker attributes that contribute to successful job performance (worker characteristics). Most useful for the current analysis is a component of the worker characteristics called "Physical Demands and Environmental Conditions." This is a systematic way of describing the physical activities that are required on the job (DOL, 1991).

Another job analysis technique is called the "Arbeitswessenschaftliches Erhebungsverfahren der Tatigkeitsanalyse" or AET method (Rohmert, 1985; Rohmert & Laundau, 1983). AET translates to "ergonomic survey method for job analysis" (Wagner, 1985). This system focuses on jobs in which the worker is involved in a production process or renders a service (Fraser, 1992). It is based on a theoretical model that sees man existing in a particular environment and exerting an influence on working objects to obtain specific results through the use of materials, energy, and information (Rohmert & Laundau, 1983). The system involves (a) preliminary discussions with management and labor, (b) information sessions with supervisors and workers, (c) observation at the work site, (d) interviews with workers, and (e) coding of the results. Observation forms the primary tool, but interview is used to determine job characteristics not apparent by observation. The coding is done using a complex series of questionnaires containing 216 items. The questionnaires are structured in three major parts involving (a) work system analysis (143 items), (b) task analysis (31 items), and (c) job demands analysis (40 items).

Another technique reported by Wagner (1985) is called the job profile. It is designed for work that is repetitive, with short cycles and medium accuracy. Of most interest here is the factor C (physical load) which has six criteria. The first two criteria are the most common posture and the most awkward posture. The values are weighted according to the time in each posture during the work cycle. Work-time effect combines posture with the force-duration values and provides a numerical value for the least favorable force-posture combination.

Job Analysis by Trait

A number of job analysis techniques examine "traits" or aptitudes that are necessary for the effective performance of a job (Lopez, Kesselman, & Lopez, 1981; McCormick, Jeanneret, & Mecham, 1972). The Abilities Requirement Approach of Fleishman and colleagues (Fleishman & Quaintance, 1984) places more emphasis on the physical requirements of the job than other techniques do. The general objective of the Abilities Requirements Approach is to describe the least number of independent ability categories that are useful and meaningful in describing performance of the widest variety of tasks. The methodology for determining ability categories involves presenting individuals with a broad array of physical tasks for which quantitative performance measures can be obtained. Correlational and factor analytical techniques are used to group tasks into "ability constructs" that have a hypothetical common performance requirement.

A series of studies (Fleishman, 1964; Fleishman, 1978; Fleishman & Quaintance, 1984; Hogan, 1991; Myers, Gebhart, Crump, & Fleishman, 1993) has identified physical abilities as (a) static strength (exert maximal strength against a fairly immovable object), (b) dynamic strength (exert muscular force repeatedly or continuously over time), (c) explosive strength (spend a maximum of energy in one or a series of bursts), (d) trunk strength (exert muscular force of the trunk muscles repeatedly or continuously over time), (e) stamina or cardiorespiratory endurance (ability to sustain physical effort involving the cardiovascular system), (f) gross body coordination (ability to perform movements that simultaneously involve the entire body), (g) gross body equilibrium (ability to maintain or regain body balance, especially when equilibrium is threatened or temporarily lost), (h) extent flexibility (ability to extend or stretch the body), and (i) dynamic flexibility (ability to move trunk and limbs quickly and through a wide range of motion).

Myers, Gebhart, and Fleishman (1980) used a modified version of the Abilities Requirements Approach to classify the physical demands of infantry, combat engineers, tank crewmen, and military police. The modified rating scales included measures of criticality (seriousness of inadequate performance), delay tolerance (how much time can elapse between when the task is recognized and when it is completed), and learning difficulty. Documents examined by these investigators to help identify physical ability requirements included enlisted career management fields and military occupational specialties (U.S. Army, 1994), dictionary of occupational titles, soldier's manuals, skill qualification tests, and military occupational data banks. The military occupational data banks were the most useful for identifying physically demanding tasks.

Posture

In general, posture can be defined as the orientation of the body in space (Haslegrave, 1994). "Good" posture can be defined as a body orientation that minimizes muscular tension (Pleasant, 1984). There appear to be working postures that are less desirable because they may cause discomfort, musculoskeletal problems, and rapid fatigue. These postures include prolonged periods with arms overhead, arms extended (especially the upper arm), forward bending of the trunk, and excessive head tilts. If these body postures can be modified by appropriate redesign, it may reduce injuries and increase the time that soldiers can perform specific activities. This section briefly examines the relationship of posture and task demands, reviews the evidence indicating that some postures are less favorable than others, and describes available methods of analyzing postures.

Posture and Task Demands

Postures adopted during physical activity are determined to a great extent by the demands of the task. Head and neck posture will be determined by visual demands, hand and arm posture will be determined by manipulative and strength demands, and trunk posture will be determined by the need to maintain stability, minimize muscle fatigue, and allow for the effective use of the arms and hands (Haslegrave, 1994). These demands may not be independent and a compromise among them may be necessary. For example, for a precision task like repair of an engine electrical component that requires visual and manipulative demands, individuals might accept a fatiguing trunk posture to accomplish the task.

Whole body postures are often adopted to maximize strength capabilities. Different muscle groups can be brought into play by altering position. Body mass can be used to increase force. Momentum can be used to compensate for lack of strength. Increasing friction between the body and supporting surface (e.g., shoe and floor) may enhance useful force production (Haslegrave, 1994; Kroemer, 1969; Kroemer & Robinson, 1971).

Evidence Suggesting Unfavorable Body Postures

There are studies that suggest that some body postures may place excessive demands on the musculoskeletal system. These postures appear to result in rapid fatigue, musculoskeletal symptoms, and subjective impressions of pain, soreness, discomfort, and stiffness. Studies supporting the concept that some postures may be unfavorable are reviewed next.

Hands Over the Head

Individuals employed in work requiring considerable overhead activity reported more objective clinical signs and symptoms in the shoulders than those not employed in jobs requiring overhead activity (Sakakibara, Miyao, Kondo, & Yamada, 1995; Torner, Zetterman, Anden, Hansson, & Lindell, 1991). For example, one study examined farmers bagging pears, which required repetitive arm elevation 75% of the time, and the same farmers bagging apples, which required repetitive arm elevations only 41% of the time. Stiffness, pain, and tenderness in the neck and shoulder region were greater when farmers bag pears than when they bag apples (Sakakibara, et al., 1995). Static overhead welding and static overhead holding of fixed masses resulted in a greater shift in the electromyograph (EMG) power spectra of shoulder muscles (medial deltoid, supraspinatus, and trapezius) from higher to lower frequencies (indicating fatigue) than activity with the arms near chest level or at waist level (Herberts, Kadefors, & Broman, 1980; Kadefors, Petersen, & Herberts, 1976). Isometric contractions or holding fixed masses with elevated arms increased intramuscular pressure (Jarvholm, Palmerud, Karlsson, Herberts, & Kadefors, 1991) and impeded blood flow leading to rapid fatigue (Lind & McNicol, 1967; 1968).

Arms Extended Away From the Body

Individuals reporting to an occupational health clinic for acute shoulder-neck pain maintained longer duration and higher frequency of job activities requiring shoulder abduction or shoulder forward flexion compared to a matched control group working in the same plant (Bjelle, Hagberg, & Michaelson, 1981). As shoulder abduction angle increased, both subjective muscle discomfort and shifts in the EMG power spectra toward lower frequencies (indicative of fatigue), progressively increased (Chaffin, 1973). The greater the horizontal or vertical distance of the hand away from the body, the more rapid was the fatigue as measured by a shift in the EMG power spectra or increase in EMG activity (Chaffin, 1973; Sigholm, Herbert, Almstrom, & Kadefors, 1984). When the arms were closer to the body, individuals were active for longer periods of time than when arms were placed farther away from the body (Corlett, Madeley, & Manenica, 1979).

Forward Bending of Trunk

Forward bending of the trunk (decreasing the trunk angle) resulted in subjective discomfort in the thighs, buttocks, and back that was highly related to the estimated torque at the hip joint (Boussenna, Corlett, & Pheasant, 1982). Longer activity times were associated with more upright postures: activity times generally decreased as individuals bent farther forward (Corlett, et al., 1979).

Head Tilt

Chaffin (1973) showed that head tilt motions less than 15° from the normal upright position resulted in no appreciable fatigue (shift in the EMG power spectra). However, as the head tilt increased beyond 15°, fatigue progressively increased.

Posture Analysis

A number of job analysis techniques already mentioned include some form of posture analysis as part of their procedure (DOL, 1991; Hanman, 1945; Lytel & Botterbusch, 1981; Rohmert & Laundau, 1983). There are other systems that focus solely on this technique and these are described next.

Perhaps the first attempt to characterize posture was that of Priel (1974) who proposed a system called the "Posturegram." Postures were described by specifying the angle of each limb on a scale of 0 to 9, based on its position in relation to a reference figure. Three standard planes (sagittal, frontal, and horizontal) were used to record the estimated angle of rotation of the limbs. Sketches and a brief verbal description could also be included on a standard form used to record information.

Karhu and colleagues (Karhu, Harkonen, Sorvali, & Vepsalainen, 1981; Karhu, Kansi, & Kuorinka, 1977) described the Ovako Working Posture Analyzing System (OWAS). This system involved the use of figures that represent various body positions. There were four back positions, three upper limb positions, and seven lower limb positions. Each position had a number and the posture of a person could be described by a three-digit code, one for each of the three body parts (back, upper limbs, lower limbs). Reliability was estimated from the percentage of agreement between two workers (69%) and two work-study engineers (93%) taken on 52 tasks and 36,240 observations. In a direct application to task redesign, Karhu and coworkers (Karhu, et al., 1981) looked at workers in a steel plant who were laying bricks for an electric arc furnace. The craftsmen did the work from an undesirable bent back position 43% of the time. A ring was developed that allowed the bricks to be placed with the worker in the upright position and the bent posture exposure time was reduced to 22%.

A useful modification of the OWAS was developed by Lee and Chiou (1995), specifically for studying nursing personnel. They developed a seven-digit code that covered the following: five forearm positions, five upper arm positions, seven trunk positions, six lower arm positions, seven hand positions (with hand motions), seven tasks, and three load conditions (the latter are modifications of DOL strength classifications) (DOL, 1991). Ten nursing students viewed 8,629 nursing postures from 1.5 hours' filming of 64 nurses. The students achieved an average agreement of 88% with no systematic bias; this suggested the method could be used by untrained observers. Another modification of this system was developed to study perchery workers (Scott & Lamb, 1996).

Another posture analysis technique is called postural targeting (Corlett, et al., 1979). A two-dimensional body figure with 10 concentric circles was used for recording. The concentric circles represented the head, trunk, two shoulders-upper arms, two hands, two upper legs, and two lower legs. The concentric circles were used to show deviation from the standard anatomical position in the vertical (away from the centroid) and horizontal position (concentric to the centroid). A list of words was also present at the arm and leg circles to represent what the individual was actually doing. Ten observers who were trained for 1 hour then recorded six postures immediately and 3 weeks later; test-retest reliability ranged from 0.67 to 0.88, with an average of 0.79. The method was time consuming and not well adapted to on-the-spot recording except for head and trunk; recoding took 15 to 30 seconds. Film analysis where postures could be reviewed appeared to be a better option.

One computerized posture system was called ARBAN (the acronym is not explained) (Holzmann, 1982). The method involved (a) recording a task on videotape, (b) coding postures and loads at equally spaced film intervals, (c) computerizing the results, (d) evaluating the results. For coding, the body was divided into six function units including the head, two shoulders and arms, trunk, and two legs. Each functional unit was assumed to suffer stress because of four factors: (a) effort because of posture, (b) force attributable to dynamic muscle effort, (c) static muscle load, and (d) vibration and shock. For each functional unit, the magnitude of each of the four factors was estimated using a modified 12-point Borg scale (Borg, 1970). The results were displayed as graphs with the modified Borg scale on the vertical axis (this is called "ergonomic stress") and time on the horizontal axis.

Keyserling (1986) developed another computerized system for describing the postures of the trunk and shoulders. In this system, there are nine trunk positions and three shoulder positions, with each shoulder described independently. The lower extremities are only referred to with the general descriptors "stand," "sit," and "lie." The trunk is considered to deviate from the neutral upright posture if it is extended, flexed, bent, or twisted more than 20°; for the standing worker, these postures are considered risk factors for injury. The shoulder is considered to deviate from neutral if it is flexed or abducted more than 45°. Because posture changes so frequently, a video camera is used to record the subject. The tape is played back in real time once for each joint of interest. When the subject changed his posture, the analyst hit a computer key so the data were recorded and stored along with a time function (from the computer's internal clock). The report provides total time in each posture, average time in each posture, and the number of times the posture is assumed. Keyserling evaluated reliability after 20 hours of training, measured as rater agreement for the time in each posture. Differences ranged from 0.7% to 1.0% between raters and 0.0% to 0.3% for a single rater performing twice.

Study Objectives

The literature review provided us with ideas and approaches for achieving our objective, which was to examine the feasibility of identifying physically demanding tasks in specific U.S. Army MOSs, diagnostically analyzing those tasks, and discovering ways to redesign those tasks to reduce the physical demands. Specific ergonomic methods used in our investigation are cited next. This was a pilot project in that the investigators were asked to assess the availability of organizational and analytical methods as well as the overall utility of a potential redesign approach. As such, it represents an important first phase effort.

METHODS

For this investigation, five MOSs (with MOS number) were selected: Chemical Operations Specialist (54B), Tracked Vehicle Mechanic (63H), Motor Transport Operator (88M), Medical Specialist (91B), and Food Service Specialist (92G). Selection was based on the types of physical demands, work conditions represented, and availability of soldiers in the MOS with which to interact. Chemical Operations Specialists, Tracked Vehicle Mechanics, and Motor Transport Operators are classified as having "very heavy" strength requirements under DOL standards (DOL, 1991). Medical Specialists and Food Service Specialists are classified as moderately heavy and heavy, respectively, by the same criteria.

Initial Data Collection Procedures

As an initial approach, a three-step data collection process was derived, based on investigator experience and past work. The three steps were (a) publication review (DOL, 1972; Lytel & Botterbusch, 1981; Myers, et al., 1980), (b) soldier interviews (Adams, 1989; Flanagan, 1954; Myers, et al., 1980; Rohmert, 1985; Rohmert & Laundau, 1983), and (c) filming of physically demanding tasks (Corlett, et al., 1979; Holzmann, 1982; Keyserling, 1986). In the process of performing the investigation, additional steps were found useful and these are described later.

Publication Review

For the publications review, we located principal source documents and derived physical requirement information to determine tasks with high physical demands. Documents reviewed included the enlisted career management fields and military occupational specialties (U.S. Army, 1994), soldier's manual of common tasks (STP 21-1-SMCT), soldier training publications (STPs), Army training and evaluation programs (ARTEPs), programs of instruction (POIs), U.S. Army occupational survey program results, and summaries of accident reports from the U.S. Army Safety Center. An example of the form used to collect data from publications is in Appendix E.

Soldier Interview

For the soldier interviews, we developed and administered a structured questionnaire designed to solicit from the soldiers the most physically demanding tasks in the MOS, based on their knowledge and experience. Preliminary interviews were conducted with small groups of food service specialists and tracked vehicle mechanics. We also tested a large and a smaller group of 88Ms to determine (a) the group size necessary to identify physically demanding tasks and (b) the usefulness of Fleishman's physical performance factors (Fleishman & Quaintance, 1984) for describing why tasks were physically demanding. The form used for the structured interview procedure is shown in Appendix F. Additional groups of food service specialists and tracked vehicle mechanics were later interviewed using this form.

The structured interview began with introductions between the investigators and soldiers. The investigators discussed the purpose of the project using a standard set of introductory remarks. To begin the interview, soldiers were first asked what they thought were the most physically demanding tasks in their MOS. They were then asked to recount how these tasks were performed so that critical elements of each could be identified. Using critical incident techniques, soldiers were then asked about tasks that were dangerous to perform and to recall any emergencies or accidents they had encountered (Flanagan, 1954; Meister, 1985). In order to solicit potential redesign solutions, soldiers were asked if they knew of any ways to make the demanding tasks easier and if they had ever found a unique way to complete the physically demanding tasks. Tasks found in publications, which the investigators thought physically demanding but not mentioned by the soldiers, were then discussed.

Filming Tasks

After identifying physically demanding tasks in the two previous steps, we then went to the field, depots, schools, and other sites to observe and videotape the tasks being performed. During and after the filming, additional suggestions for redesigning the tasks were solicited from the soldiers performing the tasks.

Data Analysis

After the data were collected, analysis proceeded in three concurrent phases. In the first phase, specific problems that made the task physically demanding were identified. This information was most often provided by the soldier. A list of common problems that made tasks physically demanding was devised, based on publication reviews, SME interviews, examinations of the films, and suggestions from the literature (Haslegrave, 1994; Rohmert, 1985; Rohmert & Laundau, 1983; Wagner, 1985). These problems, along with an expandable list of codes, are shown in Appendix G. Common problems included (a) working space (e.g., restricted movement, hearing, or vision; working surface problems; poor lighting or work space organization); (b) load problems (e.g., excessive mass and load carriage distances); (c) posture and stability problems (e.g., asymmetric lifting, movement above shoulders or below knees); (d) user problems (i.e., problems that particular individuals could have with a task element that requires excessive strength, height, or reach); (e) other problems (e.g., problems with tools or materials). These categories were not mutually exclusive. There were problems that could overlap (e.g., lifting above the shoulder and requiring excessive strength), and examination of task elements could result in the identification of two or more problems within a particular task.

The second phase involved reviewing the potential redesigns that had been suggested by the soldiers or the investigators. A series of potential redesign solutions was developed, based on the work to date, and suggestions from the literature were used to expand these (Barnes, 1980; Corlett, 1983; Haslegrave, 1994). The potential redesigns and codes are shown in Appendix H. Potential redesign options included (a) engineering (e.g., mechanical: bearings, winches, pulleys, ramps, liquid-transfer pumps; optimal handles, grip shape and texture, surface grip and texture; combined functions; workplace layout, motion economy); (b) space modifications (e.g., surface height adjustments and areas provided to rest body parts); (c) biomechanical or physiological (e.g., shifting loads to larger muscle groups, improved posture, fitness training); (d) item modification (e.g., modularizing, lighter materials, single-use packs); (e) other redesigns (educational or procedural).

Finally, a second group of soldiers from each MOS was asked to rate each of the potential redesigns.

RESULTS

Publication Review

Publications that were reviewed are shown in Appendix I. The most useful documents were the soldier training publications (STPs) and the Army occupational surveys (now called Army Data Analysis Requirements and Structure Program). The STPs provided an element-by-element breakdown for the major tasks that soldiers performed. When these were mentioned during interviews, they often helped soldiers recall other difficult elements within the task(s) or conditions not previously mentioned.

Army occupational surveys are task and element lists developed by the Army Research Institute for the Behavioral and Social Sciences (ARI). Survey information is obtained from both respective MOS schools and direct interviews with soldiers. The surveys provided a relatively comprehensive list of all tasks that soldiers perform. Elements and tasks on the list are usually single line descriptions. Individual tasks are not described in detail as in the STPs. However, they cover a much wider range of tasks than the STPs do.

The Soldier's Manual of Common Tasks and ARTEPs were useful in describing some tasks that all soldiers were required to perform. These were individual tasks in the case of the Manual of Common Tasks, and group tasks in the case of ARTEPs. Common tasks with high physical demands included moving under direct fire, moving around obstacles, constructing fighting positions, setting up and striking tentage, setting up and striking camouflage nets, loading and off loading equipment and supplies, evacuating casualties, erecting barriers, damage control functions, and burying causalities. All ARTEPs examined were very similar in terms of the physically demanding tasks that were identified.

On first glance, physical requirements descriptions in AR 611-201 appeared to provide the most physically demanding tasks in each MOS. Load masses were reported and if the task involved lifting, lowering, pushing, pulling, or climbing, this was also given. The MOS was classified based on DOL standards (DOL, 1991). However, such information was not useful for our purposes because the actual task that was being described was not provided. In the soldier interviews, individuals were often unable to identify the task as it was described in the regulation. Also, some of the data in AR 611-201 may have been obsolete if they had not been updated by the responsible organization (Sharp, Patton, & Vogel, 1996).

We examined data from the Army Safety Center for injuries within each MOS during 1994. It must be realized that this database is limited to injuries for which a DA Form 285 was completed and reported electronically or by mail to the Army Safety Center, Fort Rucker, Alabama. The specific circumstances for which a DA Form 285 must be completed are listed in AR 385-40 (Accident Reporting and Records). At a minimum, this includes property damage of at least $2,000 or an injury involving time loss. The results of our review are presented in Appendix J. This database provided little information that was useful for the present purposes. Descriptions of accidents and injuries were of highly variable quality. One fact that did emerge was that accidents involving driving were by far the most common, accounting for 48% of the injuries in the five MOSs we examined; however, the vehicles involved were often not provided. Lifting and materials handling accounted for 13% of the injuries in the five MOSs.

Soldier Interviews

Structured Interviews

Table 1 shows the number of structured interviews conducted and the location of the interviews for each MOS. Questions were asked in order (see Appendix F) and attention was focused on the interviewee, with little further said by the interviewer until the interviewee stopped talking. Interviews were recorded and key points transcribed at a later time. Key points included demanding and potentially dangerous tasks, key elements of the tasks, and potential redesign solutions. Two raters independently reviewed each of the tapes. Agreement between raters was 88% for physically demanding tasks and 92% for redesign solutions developed during the course of the interview. MOS-specific tasks identified by the soldiers as physically demanding were extracted; a summary is listed in Appendix K.

Table 1

Characteristics of Individuals Participating in Soldier Interviews

MOS	Locations	Rank of interviewees		
		E1-E4	E5-E8	Officers (rank-corps or specialty)
54B	APG[a], MD (Edgewood)			
	Ft McClellan, AL	4	3	1 (CPT- Chemical)
63H	APG[a], MD	3	6	1 (CPT -Ordnance)
88M	APG[a], MD	3	3	1 (CPT-Transportation)
91B	APG[a], MD			
	Ft Indiantown Gap, PA	3	8	1 (LTC-Nurse)
92G	APG[a], MD			
	Ft Lee, VA	8	5	1 (WO1-Food Service)

[a]APG = Aberdeen Proving Ground

Large and Small Group Samples

To help us determine the number of soldiers needed for interview purposes, we sampled large (n=45) and small (n=6) groups of motor transport operators (88M). The large group was interviewed at Ft Hood, Texas, and the small group at APG, Maryland. Characteristics of the large group are shown in Table 2. There were 41 men and 4 women. Before the interview, we provided the questionnaire in Appendix L so that soldiers could list the four most physically demanding tasks in their MOS. To ascertain why the tasks were physically demanding, Fleishman and Quaintance's (1984) human physical performance factors were used to characterize each task; in addition, questions about safety and mission criticality were added (Myers, Gebhart, & Crump, 1984). For each task, soldiers were asked to rate each of Fleishman's factors (including safety and mission criticality) on a 7-point scale (Hogan & Fleishman, 1979), with 1 indicating a low requirement for that factor and 7 a high requirement for that factor. Explanations and examples for each factor were provided in the pre-questionnaire briefing. In the post-questionnaire debriefing, soldiers were asked if they understood the questionnaire. They expressed no problems with the concepts or questionnaire.

Results from the human performance factors part of the questionnaire are shown in Appendix M. We found the rating procedure unnecessary for our purposes of determining demanding tasks and potential redesigns. This was because similar and much more informative material could be obtained from the soldiers by direct interviewing and by observing and filming the actual tasks. Thus, the questionnaire was not used in further studies.

Table 2

Characteristics of 45 Interviewed Motor Transport Operators

	Rank[a]	Time in service (years)	Time in MOS (years)	Age (years)	Previous assignments (N)
Mean	5.5	12.1	11.2	32	4.1
SD	0.7	3.8	3.8	5	1.6
Range	3 to 7	1.2 to 19.4	1.0 to 19.4	19 to 44	1 to 7

[a]For rank: 3 = PFC, 4 = SPC, 5 = SGT, 6 = SSG, 7 = SFC

A smaller group of six motor transport operators was surveyed using the structured interview procedure. Characteristics of the group are shown in Table 3.

Table 3

Characteristics of Six Interviewed Motor Transport Operators

	Rank[a]	Time in service (years)	Time in MOS (years)	Age (years)	Previous assignments (N)
Mean	4.4	5.4	4.8	27	3.2
SD	0.6	1.1	1.9	7	1.3
Range	4 to 5	1.2 to 19.4	2 to 7	24 to 38	1 to 5

[a]For rank: 4 = SPC, 5 = SGT

Tables 4 and 5 show the physically demanding tasks and potential redesigns suggested by the large and small groups, respectively, of motor transport operators. Comparison of the tables suggests the task list was very similar for the two groups. Both reported changing wheels on vehicles or changing tires on rims as demanding tasks. Working on heavy equipment transporters (HETs) was described as difficult for a variety of reasons; the large group reported more difficult HET tasks, probably because this was a unit that was currently operating HETs. Chaining vehicles to the HETs was considered difficult by both groups, and items associated with chains (ratchets, shackles, etc.) were commonly reported as problems. The large group put more emphasis on the loading ramps of the HETs, although the small group also mentioned this. Other common areas included lifting and loading equipment and ammunition, winching and recovery of vehicles, physical training, climbing into or onto slippery vehicles, driving long hours, and driving during unusual conditions. Six items were specific to the large group (driving in urban areas, tying or securing loads, loading storage areas, lubricating HET, daily maintenance, scraping and painting vehicle). Five items were specific to the small group (driving in dusty conditions, driving at night, driving off road, lifting tongue of trailer to attach to hitch, lifting or lowering tailgates). Overall, the data suggest that a small group of SMEs could provide information similar to a much larger group.

Pre-interview Questionnaire

Our experience with the small and large group samples suggested that it was useful to provide a short questionnaire to the soldiers before the structured interview. The questionnaire we developed asked for only two items: (a) what were the most physically demanding tasks the soldier performed in his MOS and (b) did the soldier have any ideas for making the task easier. This questionnaire allowed the soldier to think in private about his experience before the group interview. When this technique was not used, a few individuals often dominated the group interview. When the technique was used, participation was improved, possibly because the soldiers had time to think about their own experiences and had listed tasks they wanted to talk about. A sample questionnaire is in Appendix N.

Task Filming

It was not possible to film all the tasks discussed by the soldiers as physically demanding because of the time and effort involved in obtaining an opportunity to do so. Filming was done at a number of locations where units agreed to cooperate with the investigators. These locations include Aberdeen Proving Ground, Maryland (63th Ordnance Brigade), Fort Hood, Texas (180th Transportation Battalion), Fort Bragg, North Carolina (1st COSCOM), Fort Indiantown Gap, Pennsylvania (Regional Training Site - Medical), and Fort Sam Houston, Texas (AMEDD Center and School). Tasks that were filmed and analyzed are listed in Appendix O. At the conclusion of the filming, we found it useful to have an open discussion with the soldiers who had just performed the task. They often had additional ideas about how a task could be redesigned to make it easier to perform.

Table 4

Summary of Physically Demanding Tasks and Potential Redesigns Provided by 45 Motor Transport Operators

Task	Potential redesign
Changing wheels on heavy vehicles	1. Air wrenches for nuts 2. Wheel jacks should be issued to all units
Breaking down tires	Tire changing machine in each unit
Chaining vehicle on HET	1. Improve materials on ratchets so they do not rust 2. Smaller chains 3. Smaller chock blocks 4. Hydraulic system to raise and lower landing legs 5. Improve or relocate landing leg cover
Loading ramps on HET	1. Put hydraulics on ramps to push them out and in 2. Make wider ramps that do not need to be pushed 3. A locking device to hold ramps in place after adjustment 4. Jack to slide the ramps from side to side
Driving long hours	Use hotels for rest
Driving in urban area	None
Lifting and loading equipment or ammunition	Mechanical hoist
Winching and recovery	Better winch cable roller system to "play cable out"
Tying or securing load	Replace canvas tarpaulins with lighter plastic tarpaulins
Loading storage areas	None
Climbing into vehicle	Put better steps on the trucks to reduce slipperiness when wet and muddy.
Lubricating HET	Lubricate in pits
Physical training	1. During adverse weather conditions, postpone until afternoon when the weather could change 2. Use gym to get out of the weather 3. Should be left to the individual soldier to become responsible for, not made mandatory for, company-size elements
Daily maintenance	None
Driving and hauling in hot weather	1.Develop cooler uniforms that shield against heat 2. Air conditioning in vehicle 3. Start driving earlier
Scraping and painting vehicles	None

Table 5

Summary of Physically Demanding Tasks and Potential Redesigns
Provided By Six Motor Transport Operators

Task	Potential redesign
Remove or replace a wheel from a vehicle (especially a HEMTT or HET)	1. Jack stand to support lug wrench 2. Second soldier to support lug wrench 3. Pneumatic attachment for impact wrench 4. Make lug wrench handles longer to make it easier to take the bolts off
Change a tire on a rim	1. Provide mechanical changer 2. Smaller tire
Chaining down cargo to a HET	1. Lighter chains 2. Pull pins on shackle 3. Lubricate shackle threads 4. Covers to protect ramp sliding areas from dirt
Driving for long periods of time	1. Two drivers 2. Radio to keep awake
Driving at night	1. Two drivers 2. Radio to keep awake
Driving in very dusty conditions	Light beam that detects when you are too close to another vehicle
Driving off road	None
Loading or unloading equipment, especially ammunition	Mechanical hoist
Recovery of a vehicle, especially if stuck in mud	None
Lifting tongue of trailer to attach to a hitch	None
Walking on vehicles in icy conditions	Sandpaper-like material on vehicles to prevent sliding
Lifting or lowering tailgates	Lighter material in tailgates
Physical training	None

Analysis of each film was performed by at least two, and usually three, investigators. Additional expert opinion was sought when appropriate. Analysis was performed by examining each task for physically demanding elements and coding those elements using the scheme in Appendix G. Potential redesigns were coded using Appendix H.

Whenever possible, object masses and forces were obtained from direct measurement following filming. When this was not done (especially early in the study), masses and forces were obtained from publications, or when other opportunities were provided. These object masses and forces are listed in Appendix P.

Posture Analysis of Tasks

We performed posture analysis of selected tasks to examine the possibility of identifying unfavorable body positions and using this in our analysis. We chose the Ovako Working Posture Analyzing System (OWAS) (Karhu, et al., 1981; Karhu, et al., 1977) since it appeared to be a simple and reliable method which had been successfully applied to a variety of situations (Lee & Chiou, 1995; Scott & Lamb, 1996). Some modifications were made in the original (Karhu, et al., 1977) in order to more fully account for the postures we observed in pilot studies.

Four tasks were selected for analyses: a wheel removal from a heavy expandable mobility tactical truck (HEMTT) (37 minutes of film), wheel replacement on a HEMTT (52 minutes of film), tire change on a HET (74 minutes of film) and a litter carriage task (0.5 minute of film). The videotape of each task was sent to a computer running a shareware program called MacWebCam 2.4. This program allowed frames of the task to be saved as pictures at predetermined rates, thus providing an objective sampling of the task. For all wheel tasks, frames were saved at 15-second intervals; for the litter carriage task, frames were saved at 3-second intervals. Figures were developed (posture selections) that represented various body positions. A computer program (Hypercard) was generated that allowed the user to see the posture selections along with the frame to be analyzed. A mouse was used to click on the appropriate selection and the data were stored for analysis.

Results are shown in Appendix Q. The method was found useful for identifying unfavorable postures (see literature review for definitions of these) that the subject assumed during performance of the task. For example, the individual performing wheel removal from a HEMTT was in positions requiring twisting of the trunk 33% of the time. Positions requiring bending of the trunk were present 69% of the time. While the soldier's arms were over his head less than 1% of the time, his upper arm was extended 90° or more 24% of the time. For another task (tire change on a HET), positions requiring twisting of the trunk accounted for 21% of the time, bending of the trunk 52% of the time, arms overhead 2% of the time, and upper arms extended 90° or more 31% of the time.

It appeared that this method may be useful for identifying unfavorable body postures and quantifying the amount of time in each position. It may be useful to examine tasks after they have been redesigned to see the reduction in the percentage of the time in the unfavorable postures.

Task Redesign Analysis

The development of task redesigns was an ongoing process that began with the publication review and continued through the analysis of the task filming and discussions with the schools and project managers. Potential redesigns developed during the course of the project are listed in Appendix R.

Most redesigns are much more complex than indicated by the summary information in Appendix R. Take, for example, the task of loading fog oil onto a general purpose truck, which is performed by the Chemical Operations Specialists. This task is a difficult one based on publications and structured interviews. Each barrel has a 474-pound mass and the vehicle often used to load these barrels is a general purpose 5-ton truck. The bed of the truck is 132 cm from the ground. Eighteen barrels are loaded per truck using two people to lift each barrel. The task takes about 15 minutes to perform by skilled individuals. A 12-foot ramp is recommended in the Soldier Training Publication (but is not part of the basic load) so the barrels can be manually rolled onto the truck bed. Trigonometric analysis indicates that 862 newtons of force are required to move the barrel up the ramp (33° angle), assuming no friction or momentum. The major concerns from an ergonomic point of view include the mass of the barrel (which increase the potential for hand and low back injury), load imbalances caused by individuals of different heights lifting or pushing the barrels, fatigue induced by repetitive manual handling, and pushing the barrels above shoulder level.

An alternate solution adopted by the Chemical School is to eliminate the requirement for barrels altogether by changing the delivery system. A 600-gallon tank with a pump is available that can be mounted on a 5-ton vehicle and used to directly fill 55-gallon drums on site with the smoke generator. This container and pump system is not often used because of the cost of maintaining this piece of equipment and the greater flexibility the individual drum system allows.

Another possible redesign solution is to mount on the truck bed a winch that pulls the barrel over a "pivot" point. The pivot point rights the barrel when more than half its weight crosses the pivot. Electric or mechanical winches (with adequate leverage) are most affordable; others result in major equipment maintenance concept changes and cost. Safety improvements include the facts that ramp-roll, load-shifting, and barrel-righting hazards are minimized; most operations are moved to the truck bed, away from potentially unstable ground. The remaining requirement is to "walk" the barrel into its location on bed. No lifting or pushing up a ramp is required, so soldier strength, balance, and coordination requirements are considerably reduced. The effects of body stature differences are minimized. Performance time becomes a function of time to attach the barrels to the winch and winch speed and time to "walk" the barrel to its bed location.

Another alternate solution is to place a hydraulic ramp on the back of the truck. This ramp would be similar to those commonly seen on the backs of moving trucks that fold under the truck bed when not in use. Several barrels could be placed on the ramp near ground level then hydraulically raised to the level of the truck bed. The requirement to move the barrel to the back of the truck remains but the potentially dangerous lifting or rolling operations are eliminated.

Soldier Redesign Evaluation

A second group of soldiers was asked to rate some of the potential redesigns. Table 6 shows the number of soldiers in each MOS who performed this evaluation. The first reevaluation was done on 88M, motor transport operators. A special questionnaire was developed to obtain detailed information about the subjects' opinions of the potential redesigns based on (a) reductions in physical requirements, (b) staffing reductions, (c) time or motion savings, (d) safety and health, (e) costs, (f) ease of fielding. The soldiers were asked to rate each of these factors on a 5-point scale ranging from "very ineffective" to "very effective". The 88M group interviewed had considerable problems rating some of these factors. These problems included difficulty in estimating cost and determining how easy it would be to field the item. The questionnaire and the responses of the 88M group are shown in Appendix S.

A considerably simplified format was developed and tested on 54Bs. For each potential redesign solution, soldiers were asked for an overall rating on a 5-point scale ranging from "much better" to "much worse". The response of the 54Bs and soldiers in other MOSs to this format was much more favorable and they had little trouble rating the potential redesigns. The problems evaluated, potential redesigns, soldier rating, and statistics on these ratings are shown in Appendix T.

Table 6

Characteristics of Soldiers Interviewed in Redesign Evaluation

MOS	Soldiers interviewed (No.) E1-E4	E5-E8	Officers	Time in MOS (yrs) M±SD
88M	4	1	0	6.7±3.1
54B	7	3	1 (2LT)	4.6±2.8
63H	3	4	0	11.0±13.6
91B	6	5	0	9.1±7.4
94G	2	8	0	15.0±4.2

In subsequent parts of the project, we found it was much more effective to discuss redesign solutions with the schools responsible for the MOS and (when appropriate as in the case of equipment) with project managers. In most cases, individuals at the schools could provide much more information than could field soldiers we interviewed about the feasibility of the potential redesigns, and they provided suggestions about how to work on potential redesigns as discussed next. The solider redesign evaluation is not recommended because of this.

Communication With Schools, Project Managers, and Other Agencies

In the process of conducting soldier interviews and during the soldier reevaluations, we were often informed that other groups (e.g., schools, project managers, etc.) were working on particular physical problems with equipment and techniques. Phone calls and meetings were conducted with these groups and the results are listed next. These results have been incorporated into the potential redesigns listed in Appendix R.

Chemical Operations Specialists

We had discussions with the Chemical School at Fort McClellan, the Edgewood Research Development and Engineering Center (ERDEC), and the Weapons Branch of HRED (ERDEC Field Element) regarding approaches that were already being considered to reduce some of the physically demanding tasks for the 54Bs. Issues currently being addressed are listed next.

The M3A4 portable smoke generator can be mounted on a high mobility multipurpose wheeled vehicle (HMMWV) (M998). However, the M3A4 has largely been replaced by the M157 system. Two M157 smoke generators can be mounted on a HMMWV (M1037) chassis. The school will discontinue teaching the M3A4 in 1997 and will concentrate on the M157. In a further development, the M56 will soon replace the M157. The M56 smoke generator was type classified in September 1994 and is scheduled to be fielded to TRADOC and FORSCOM units in 1997. The M56 will be mounted on a HMMWV (M1097) and will replace the M157 in Force Package I units.

Mounting and dismounting the batteries on the Fox vehicle to power the M21 detector has been known to be a problem for at least 2 years. Ergonomic specialists at ARL have been working on this problem. Current plans call for a slave cable to be attached from the batteries to the M21 so the batteries do not have to be removed from the vehicle.

The M21 standoff detector will be mounted on a retractable mast on the Fox vehicle. Crews may still be required to remove the detector for special operations or operator maintenance. Other units may still have to use the portable unit and there may still be a requirement for removing the M21 from the Fox in special circumstances.

In place of loading fog oil barrels onto trucks, a tank and pump unit is available that is mountable onto a 5-ton truck. The truck contains two 600-gallon tanks and can pump bulk fuel (50 gallons per minute using a one-cylinder, four-cycle engine) into 55-gallon drums or directly to smoke generators. However, there will still be a requirement to load individual smoke barrels because of the flexibility this allows and the fact that the number of 5-ton vehicles that would have to be dedicated to the 600-gallon tanks are difficult to support logistically.

The M17 lightweight decontamination apparatus is replacing some of the truck-mounted M12 apparatus. The M12 requires a truck for transportation because of its weight and the chemical units have logistical difficulty supporting the number of trucks required.

Mixing the DS2 (decontamination solution) with the chemical agent on vehicles and equipment requires scrubbing. These substances may successfully mix with a powered scrub brush head that reduces the number of "strokes" the soldier has to make. In addition, a longer handle on the scrub brush may reduce the number of times the soldier must climb onto a vehicle. However, overhead work is still required during the decontamination process, and preliminary analysis performed by ARL indicates these powered brushes are still physically demanding to use. Several improvements may be beneficial, based on limited biomechanical modeling. First, long brush handles result in high torques at different body joints, although it may be possible to reduce these torques by providing pivoting brush heads. Torques may also be reduced by placing motors at the end of the brush handle, thus providing a counter weight (McMahon & Shams, 1997).

Food Service Specialists

We talked to the Soldiers Systems Command (Food Service Systems Branch) and Quartermaster Center and School (Training Office, Concepts Systems & Policy, Facility and Equipment Division). The following information was relevant to the potential redesign solutions.

The major problems identified by the soldiers with the mobile kitchen trailer (MKT) included (a) lifting M2 burners out of the MKT to light them at a remote location (50 feet away) to reduce the possibility of fire in the MKT and (b) hoisting the top of the MKT. There are current plans to replace all M2 burners in the military with the new multifuel burner unit (MBU), starting in FY98. The MBU uses JP8 fuel that considerably reduces fire hazards, and the design of the burner allows it to be safely lit and refueled within the MKT. This eliminates the requirement for moving the burner. The remote refueling feature will also eliminate the requirement for opening the fuel tank to replace fuel. An MBU with these features was type classified in September 1996 and will be fielded in February 1998.

The MKT is also now supplied with manual cranks that can be used by individuals who have difficulty in erecting the roof because of lack of strength or short stature. Additionally, there is an active MKT improvement program at the U.S. Army Soldier Systems Command (Natick, Massachusetts) focusing on these and many other problems soldiers have identified, including difficulty operating in cold weather, lack of sufficient lighting, and heavy, ineffective, or obsolete equipment.

Garrison kitchen supplies are generally selected by the Quartermaster School, using devices available on the civilian market. Commanders can make decisions to purchase items locally. As facilities are modernized, new equipment is put in place. Food service personnel placing serving containers on steam trays are encouraged to use shallow pans that do not hold a large amount of food. This is in keeping with progressive cookery where food is served as it is prepared so it is as fresh as possible. Modern facilities have "pass-through" so food only has to be moved a short distance to the serving line.

Labor-saving devices are encouraged and used in many new facilities. Lifting food into ovens is being replaced with roll-in devices. Frying and brazing pans can now be tilted to draw off liquids, eliminating the need for lifting. Some pans have bottom drain valves that allow liquids to be tapped, again eliminating the need for lifting.

Newer facilities will have a remote waste disposal system that will involve a pulping machine. This will eliminate the need for garbage can in the mess hall and the need for moving garbage to the dumpster.

Many juice or flavored drink dispensers have been tried but few have been found satisfactory. These include a 5-gallon container that can be placed in the standard milk machine.

Tracked Vehicle Mechanic (63H)

We had conversations with the Ordnance School (APG, Maryland) and the Ordnance Product Development Team, Combined Arms Support Command, (Fort Lee, Virginia). There were no actions currently in progress that related to reducing any of the physical demands that the soldiers provided us.

Motor Transport Operators (88M)

We had conversations with Project Managers' Offices for the HEMTT and HET. There were no actions currently being performed by the HEMTT office that related to the physically demanding tasks cited by the soldiers.

On the other hand, the HET office is currently redefining the parameters of the system to see what could be technologically improved. That office is concentrating on crew safety and ergonomics. Many problems mentioned by the soldiers had been considered. Some foreign versions of the HET have loading ramps that involve a threaded rail that can be moved back and forth by a bar; however, this solution was not deemed much of an improvement over the current system. Winching system improvements for the HET included a device that allows the cable to "play out" easily and re-wind evenly on the spool. There was no immediate solution for the slippery decks on the HET; mud is often so thick that no appropriate redesign is apparent. Use of a sandpaper-like surface will not work for this reason. Air conditioning will seriously be considered in an improved HET. As we saw in the field, the HET already has an attachment for a pneumatic wrench that can be used to remove the lug nuts when tires need to be changed. Radios in the cab were difficult to justify even though individuals in the HET office were well aware of their importance to soldiers and the fact that they could help keep soldiers alert while driving.

Medical Specialists (91B)

Our conversations and meeting were primarily with different offices in the Army Medical Department (AMEDD) School and Center. Several individuals told us that it may always be necessary to move an injured individual by body carriage if no equipment is available in the field. The medic's major responsibility is to provide immediate care to the wounded soldier and then get that soldier to a higher level of medical care as soon as possible. The medic will do this by any means available in the field.

The AMEDD Center and School also provided us with samples of a new type of load-carrying vest that is currently being fielded for 91B's (Craig, 1996). This device is called the improved medic vest; it is similar to the integrated individual fighting system (IIFS) but provides specialized pouches on the front that allow medics easier access to medical supplies. It uses the same pistol belt as the one currently used in the IIFS vest. Earlier, we had discussed with the AMEDD Training Integration Office the possibility of combining the pistol belt with loops that could reduce the physical demands of litter carriage. They informed us that any method of making litter carriage easier would be worthwhile and thus we pursued systems to accomplish this.

Usability Analysis of Alternate Litter Carriage Methods

Not only were we consistently told by medics (MOS 91B) and by individuals at the AMEDD Center and School that litter carriage was one of the most physically demanding tasks they performed, but we also found that the requirement to "evacuate wounded" or "transport a casualty" was described in virtually all Army Test and Evaluation Program (ARTEP) manuals (e.g., ARTEP 55-188-30-DRILL, ARTEP 8-449-30-MPT, ARTEP 43-007-30-MPT) as well as the Soldier's Manual of Common Tasks (Skill Level 1, 1994). One of the most common ways to transport a wounded or otherwise incapacitated individual is by litter. This allows the casualty to be moved in a comfortable supine position and allows medically trained personnel relatively easy access to the body. For these reasons, we completed a usability analysis of potential redesigns for litter carriage.

Previous Work

Litters are generally carried by hand, using either a two- or four-person carry. However, alternate methods could provide great benefits. Lind and McNicol (1968) were the first to demonstrate that time to fatigue could be considerably extended when using a shoulder harness as opposed to hand carriage; however, they did not provide a description of the type of harness used. More recent studies by Rice and coworkers (Rice, Sharp, Tharion, & Williamson, 1996a; Rice, Sharp, Tharion, & Williamson, 1996b) confirmed and extended these findings. Longer times to fatigue were achieved when men and women carried an 82-kg manikin using specially designed and well-described shoulder harnesses. Carriage times to exhaustion were 23 minutes with the harness and 6 minutes with hand carriage (Rice, et al., 1996b). Thus, for carrying long distances, the shoulder harness was clearly superior.

In addition to lengthening the time a stretcher can be carried, there may be other favorable benefits from moving the load from the hands to other parts of the body. When soldiers use the harness, their fine motor performance is unaffected, which could be important for medical personnel who may be required to perform fine motor tasks on patients after litter carriage (Rice, et al., 1996a). Marksmanship accuracy following the litter carriage tasks is better when a harness was used (Tharion, Rice, Sharp, & Marlow, 1993). When the hands are free, they can perform other tasks while transporting patients.

The harnesses used by Rice and coworkers (Rice, et al., 1996a; Rice, et al., 1996b) were designed to move the load from the smaller muscle groups of the hands and arms to the larger muscle groups of the shoulder and back. Larger muscle groups should be expected to carry the load longer because the mass of the litter is spread over a greater amount of muscle tissue. The mass per unit muscle tissue is reduced. Further, the load pressure (which restricts cutaneous and intermuscular circulation) is moved from the relatively small area on the hands, to a greater area covered by the shoulder harness.

Improvements in Long-Term Litter Carriage

We made two types of litter carriage devices that incorporated suggestions from interviewed medics and conversations with the AMEDD Center and School, and we improved those designed by Rice and coworkers. The first system was a full harness that allowed the litter load to be carried on either the hips or the shoulders and allowed for load shifting among these locations. Load shifting may be advantageous because it may allow reductions in local fatigue, possibly because formerly loaded muscle groups are able to replenish energy substrates (Ahlborg & Felig, 1982) and clear lactate. Also, the pressure of the load is shifted from one body location to another, allowing a return of blood to muscular and the cutaneous areas where the load was first placed.

The second system we designed incorporated a clip and loop system that could be attached to the pistol belt of the soldier's IIFS or the improved medic vest. We called this the load-carrying equipment or LCE integrated system. This system was developed because medics told us that they did not want an additional piece of equipment to take to the field (the full harness) but would prefer a system that attached to the current load-carrying equipment.

We tested these systems (in addition to hand carriage) by having seven medics and four soldiers in ordnance MOSs (seven men and four women, mixed MOS) walk on a motor-driven treadmill at a pace of 3 miles per hour, clothed in physical training (PT) uniform. Only one person was tested at a time with at least 48 hours' rest between systems. The systems were presented in a partially counterbalanced order and all subjects were tested with all systems (within-subject design). Soldiers carried a 75-kg manikin on a stretcher, employing a two-person carry, with the subject in the forward position (looking away from the manikin). The rear portion of the stretcher was supported by straps attached to a frame. The subject was required to carry the litter until he or she was unable to continue or until 30 minutes had elapsed.

Results are shown in Table 7. There were significant differences among the carriage times ($F(2,20) = 47.92, p < 0.001$). There were no differences between the hip-shoulder and LCE integrated system ($p > 0.1$, Tukey Honestly Significant Difference [HSD] Test). However, compared to hand carriage, the LCE integrated system allowed soldiers an 8-fold increase in carrying time ($p < 0.001$, Tukey HSD Test) and the hip-shoulder system, a 9.4-fold increase in carrying time ($p < 0.001$, Tukey HSD Test). Times may have been even longer with these systems had the tests not been stopped at 30 minutes. While no subject was able to continue for longer than 6.4 minutes with hand carriage, six soldiers completed 30 minutes with the LCE integrated system and eight with the hip-shoulder system. The LCE integrated system is more useful from a practical point of view since it can be blended into existing U.S. Army equipment.

Table 7

Performance Times (minutes) for Three Litter Carriage Methods

	Hand	LCE integrated	Hip-shoulder
Mean	2.7	21.7	25.4
Standard deviation	1.4	9.9	8.1

This study indicated that the harnesses developed here could considerably extend litter carriage time. The harnesses take advantage of the simple principle of transferring the load from the relatively small muscle groups of the hands and forearms (hand carriage) to the much larger muscle groups of the hips and shoulders. This solution is only applicable to long-term litter carriage in unobstructed terrain.

DISCUSSION

Based on our studies and experience, we recommend that identification and potential redesign of physically demanding tasks be accomplished using the model shown in Figure 1. The initial three steps are the publications review, soldier interviews, and filming. The publication review can be limited to the soldier training publications and the Army occupational surveys (now called Army Data Analysis Requirements and Structure Program) since we found these to be the two most useful documents. For the soldier interviews, a group of about 10 soldiers with both recent (2 to 5 years in service) and longer (5 to 12 years in the MOS) experience need be interviewed (also see Virzi, 1992). The reason we suggest that both junior and senior soldiers be interviewed is that the former are usually those currently performing many of the physically demanding tasks, while the latter have a wider range of experience in the MOS. The soldier interview should start with a short introduction about the purpose of the interview, and then the questionnaire in Appendix N should be administered. After this is completed, a group-structured interview can proceed using the questions in Appendix F. Once the physically demanding tasks have been identified, it is necessary to observe and film them for a complete analysis because no amount of written or verbal description is adequate for understanding all the elements of the task. Identification of redesigns is an ongoing process at all stages, keeping in mind principles discussed in the introduction.

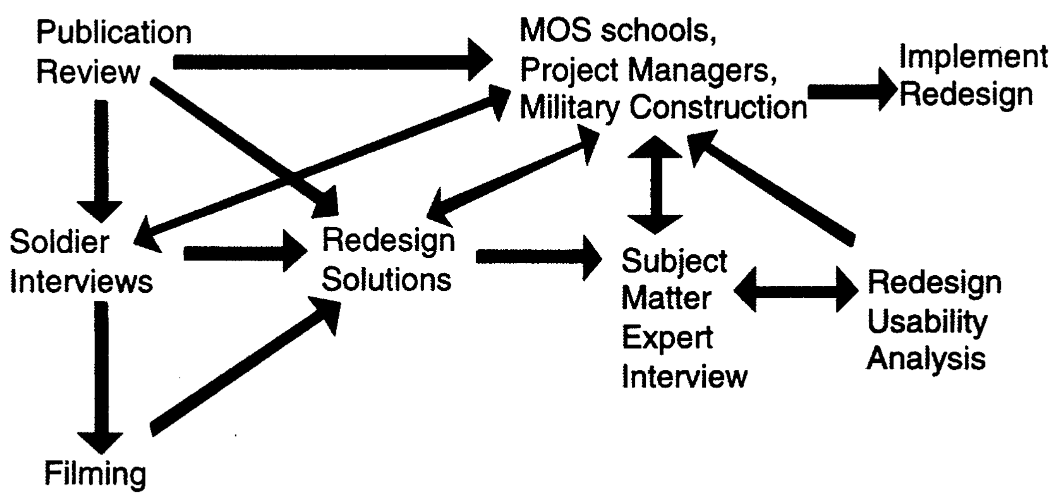


Figure 1. Model for identifying and redesigning physically demanding tasks in the U.S. Army.

After the publication review, we found it important to initiate communication with the schools responsible for the MOS or (when appropriate) talks with project managers responsible for equipment with high physical demands. This initial communication phase was to inform them of the project and to learn about efforts that may already be ongoing or have been accomplished with regard to reducing physical demands. This is also necessary after the soldier interviews since additional tasks are often identified. Both publications and the experience of the soldiers may be dated; the schools and project managers were often aware of problems soldiers were experiencing and if they were not working on these problems, they often had additional ideas about how problems could be addressed. In some cases, project managers or schools found our information very useful and expressed a desire to work together on a longer term basis (e.g., Quartermaster School and Project Manager-HET).

The schools and project managers can also provide guidance in the most profitable redesign solutions on which to work. We chose as a demonstration project a usability analysis of alternate methods of litter carriage since this was a task identified by virtually all medics interviewed and by the AMEDD Center and School. Having demonstrated that this redesign can considerably extend carriage times, our next step is to work with the AMEDD Center and School to implement this redesign, probably into the improved medic vest.

Problems and Unresolved Issues

Some of the information supplied by the soldiers was dated and even our filming of tasks was inadequate in some cases. For example, in initial interviews with a warrant officer (12 years in service) and a senior NCO (E-7, 16 years in service), both remembered difficulty raising the top on a mobile kitchen trailer (MKT). The difficulty stemmed from the height of the top (shorter soldiers could not reach the full height), the strength required for the lift, and the coordination required among the four people pushing up on the top. We filmed soldiers erecting an MKT and noted many of the problems cited. However, in discussions with the project manager at Soldier Systems Command (Natick, MA) we found that there had been six versions of the MKT since 1975 and on one of the newer versions, a manual crank had been added to raise the top. However, older MKTs were still being used by some units and this could obviously be a problem. The solution for older MKTs would require retrofitting with a manual crank.

At times, what appeared to be a single task from the soldier interviews was really many tasks or a task with highly variable elements. For example, motor transport operators told us that changing a wheel was one of the more difficult tasks they performed; however, wheel changing differed considerably, depending on the vehicle. A 5-ton truck tire had a 90-kg mass but a HEMTT tire had a mass of 238 kg. Changing the latter was more difficult and, we observed, usually required more personnel to complete. As another example, recovery of a vehicle (mentioned by both motor transport operators and tracked vehicle mechanics) differed, depending on the nature of the recovery. If the vehicle to be recovered was mired in mud, a long, heavy cable had to be released; if the vehicle was disabled on a hard-top road, recovery was a simple hook-up process.

Our experience and conversations with project managers indicated that potential redesigns involving equipment will probably take a long time to achieve. This is because (a) it costly to implement some solutions, (b) coordination must be accomplished with the project managers, (c) time is necessary to interface the redesign with other aspects of the equipment, (d) time is necessary to develop and test prototypes, (e) time is necessary to develop and contract a final design, and (f) once production starts, devices are slow in getting to the field. However, once a solution is in place, the benefits can be very great. For example, placing hydraulic, pneumatic, or electrical loading ramps on the rear of 5-ton vehicles (ramps that can elevate cargo from the ground to the bed of the truck) could considerably reduce physical demands. Virtually all soldiers that have to transport equipment use this general purpose truck to load and unload rations, tents, ammunition, and other equipment and supplies in the field and garrison; chemical operations specialists use this vehicle to load and unload smoke oil barrels and decontamination detergent; motor transport operators often load and unload equipment and supplies using this vehicle. This redesign could benefit many soldiers.

There is a lack of standardization in many military facilities that makes "global" solutions difficult in some cases. Most military facilities are not the same and redesigns may have to be performed on each individually. For example, our filming of the 94G garrison mess hall activities was mostly performed in the 1st COSCOM mess hall. This was a modern facility with some labor-saving devices (fixed kettles for soup making, food pass-throughs, etc.). A visit to a smaller mess hall revealed a lack of many of these devices and the potential for more redesigns. In fact, many "on-the-spot" suggestions could have been made for this mess hall that would have reduced soldier physical demands. For example, purchase of several roller carts could have reduced much of the carrying performed by food service personnel.

There may be a place for "on-the-spot" suggestions that could reduce soldier physical demands in fixed facilities. A small team of individuals trained in ergonomic principles could visit specific sites and look for ways to reduce soldier job stress. Suggestions could be made to supervisors and they could choose whether to act upon these suggestions, based on their more complete knowledge of the circumstances in that facility.

Many redesign solutions employed in industrial situations are not suitable to the field Army. In industry, changing the height of the work or providing movable carts and tables to move heavy items can reduce the physical load on the worker. This can work in the garrison Army, as the food service example in the previous paragraphs indicates. However, in the field, soldiers are often faced with uneven terrain, mud, and adverse weather conditions that must be considered in any redesign effort. Also, many systems are vehicle mounted, and the work space may be constrained because of the limits on the vehicle dimensions (vehicles must travel standard size roads). This should not preclude redesign efforts; it just makes them more difficult to accomplish because established industrial guidelines are more difficult to apply.

In the soldier interviews and during task filming, the ideas the soldiers had were numerous and accounted for the majority of the potential redesigns. Some of these did not relate to reducing physical demands but were important because they were solutions to chronic problems that soldiers faced with equipment or techniques that they used on a day-to-day basis. For this report, we have listed many of these. Examples include problems medics had with tent, expandable, modular, personnel (TEMPER) tents and isoshelters and some problems motor transport operators had with heavy equipment transporters (see Appendices R, S, and T).

One of the most difficult actions we performed was getting permission to film soldiers. Most filming resulted from personal contacts and "cold calls" to units that had appropriate MOSs. Commanders and staff were often reluctant to allow filming. We are not sure of the reasons for this but concern for liability, our safety, and the possibility that we would film soldiers performing inappropriate actions were probably among the concerns. In some cases, commanders wanted to assure that higher level commanders knew and consented to our filming; seeking permission from the staff and higher in the command chain was very time consuming. Higher level support is necessary to streamline the filming procedure. We were actually able to film only about 63% of all the physically demanding tasks identified.

CONCLUSIONS

This study demonstrates that even with limited resources and effort, many MOSs can benefit from task analysis and redesign. The first stages of our Army-specific paradigm are fairly simple, requiring reading, interviews, and analysis. There appears to be a high degree of agreement among soldiers experienced in the MOS about which tasks are most difficult, dangerous, or fatiguing to perform. In most cases, site visits and task observation (filming) are extremely useful to clarify the physical demand issues; however, obtaining permission to film can be difficult. Reducing the physical requirements of the task is more challenging. Ideas for workload reduction usually involve procedural changes (e.g., task reorganization) or equipment redesign. In some cases, equipment to support workload reduction have already been fielded but will not reach soldiers for years because of procurement lags. In other cases, the researchers and soldiers developed possible solutions and in one case, tested a potential solution (e.g., litter carriage harnesses). With adequate resources, additional procedural or equipment redesigns could be tested.

We initiated this project because there was no systematic task-redesign effort in the U.S. Army. During the course of the study, we found that part of the reason for this was that the problem cuts across several disciplines and the missions of several agencies. The most reasonable approach to reduce physical demands may involve a network of agency representatives whose charge it is to keep others informed of known problems, potential solution strategies, and implementation methods. The paradigm developed here uses standard ergonomic analysis tools and it seems reasonable to use this as a common approach to the complex multidisciplinary problem of system redesign. Specific agencies may be able to identify their individual mission areas within this paradigm and work appropriate problems.

Certainly, the soldier's job will remain physically and mentally demanding. However, this effort identified some physical demand reductions for every MOS considered. An ongoing effort to examine each MOS on a periodic basis to identify demanding tasks and potential solutions would enhance soldier and unit performance. We found that not all physically demanding tasks are amenable to change, and most potential solutions did not totally remove the physical burden from the soldier. However, by using the model described in this report, potential solutions can be identified and those with the greatest chance of reducing the soldiers' physical effort can be targeted and worked on. Such efforts may improve soldier health and safety, conserve fighting strength, and optimize personnel utilization.

REFERENCES

Adams, J.A. (1989). Human Factors Engineering. New York: Macmillan Publishing Co.

Ahlborg, G., & Felig, P. (1982). Lactate and glucose exchange across the forearm, legs, and splanchnic bed during and after prolonged exercise. Journal of Clinical Investigation, 69, 45-54.

Barnes, R.M. (1980). Motion and Time Study, Design and Measurement of Work. New York: John Wiley and Sons.

Bjelle, A., Hagberg, M., & Michaelson, G. (1981). Occupational and individual factors in acute shoulder-neck disorders among industrial workers. British Journal of Industrial Medicine, 38, 356-363.

Bly, J.L., Jones, R.C., & Richardson, J.E. (1986). Impact of worksite health promotion on health care costs and utilization-evaluation of the Johnson and Johnson Live for Life Program. JAMA, 256, 3235-3240.

Borg, G. (1970). Perceived exertion as an indicator of somatic stress. Scandinavian Journal of Rehabilitation Medicine, 2-3, 92-98.

Bouchard, C., Malina, R.M., & Perusse, L. (1997). Genetics of Fitness and Physical Performance. Champaign, IL: Human Kinetics.

Boussenna, M., Corlett, E.N., & Pheasant, S.T. (1982). The relation between discomfort and postural loading at the joints. Ergonomics, 25, 315-322.

Buse, N. (1990). Ergonomics, legislation and productivity in manual materials handling. Ergonomics, 33, 353-359.

Chaffin, D.B. (1973). Localized muscle fatigue-definition and measurement. Journal of Occupational Medicine, 15, 346-354.

Copley, F.B. (1923). Frederick W. Taylor. New York: Harper and Brothers.

Corlett, E.N. (1983). Analysis and evaluation of working postures. In T.O. Kvalseth (Eds.), Ergonomics of Workstation Design (pp. 27-42). Guildford England: Butterworth.

Corlett, E.N., Madeley, S.J., & Manenica, I. (1979). Posture targeting: a technique for recording working postures. Ergonomics, 22, 357-366.

Craig, D.N. (1996). Test report on the initial operational test and evaluation of the combat medic vest system (Report No. 5-94). Ft Sam Houston, TX: AMEDD Center and School.

Defense, U.S.A. (1992). People. Defense Almanac 92, September/October, 28-38.

Department of Labor (1972). Handbook for Analyzing Jobs. Washington, DC: U.S. Government Printing Office.

Department of Labor (1991). The Revised Handbook for Analyzing Jobs. Washington, DC: U.S. Government Printing Office.

Donelson, S.M., & Gordon, C.C. (1991). 1988 anthropometric survey of U.S. Army personnel: pilot summary statistics (Technical Report No. TR91/040). Natick, MA: U.S. Army Natick Research, Development and Engineering Center.

Fitzgerald, P.I., Vogel, J.A., Daniels, W.L., Dziados, J.E., Teves, M.A., Mello, R.P., & Reich, P.J. (1986). The body composition project: a summary report and descriptive data (Technical Report No. T5/87). U.S. Army Research Institute of Environmental Medicine.

Flanagan, J.C. (1954). The critical incident technique. Psychological Bulletin, 51, 327- 358.

Fleishman, E.A. (1964). The Structure and Measurement of Physical Fitness. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Fleishman, E.A. (1978). Relating individual differences to the dimensions of human tasks. Ergonomics, 21, 1007-1019.

Fleishman, E.A., & Quaintance, M.K. (1984). Taxonomies of Human Performance. New York: Academic Press Inc.

Fraser, T.M. (1992). Fitness for Work. Washington, DC: Taylor and Francis.

Gilbreth, F.W. (1911). Motion Studies. Princeton, NJ: MacMillan Co.

Gilbreth, F.B. (1912). The present state of the art of industrial management. Transactions of the ASME, 34, 1224-1226.

Hanman, B. (1945). Matching the physical characteristics of the worker and jobs. Industrial Medicine, 14, 405-430.

Hanman, B. (1946). Placing the handicapped. Industrial Medicine, 15, 597-604.

Haslegrave, C.M. (1994). What do we mean by "working posture"? Ergonomics, 37, 781- 799.

Herberts, P., Kadefors, R., & Broman, H. (1980). Arm positioning in manual tasks. An electromyographic study of localized muscle fatigue. Ergonomics, 23, 655-665.

Hogan, J. (1991). The structure of physical performance in occupational tasks. Journal of Applied Psychology, 76, 495-507.

Hogan, J.C., & Fleishman, E.A. (1979). An index of the physical effort required in human task performance. Journal of Applied Psychology, 64, 197-204.

Hogan, J.C., Ogden, D.G., Gebhart, D.L., & Fleishman, E.A. (1980). Reliability and validity of methods for evaluating perceived physical effort. Journal of Applied Psychology, 65, 672-679.

Holmes, R. (1985). Acts of War. The Behavior of Men in Battle. New York: MacMillan and Co.

Holzmann, P. (1982). ARBAN-A new method for analysis of ergonomic effort. Applied Ergonomics, 13, 82-86.

Jarvholm, U., Palmerud, G., Karlsson, D., Herberts, P., & Kadefors, R. (1991). Intramuscular pressure and electromyography in four shoulder muscles. Journal of Orthopeadic Research, 9, 609-619.

Jensen, R.C. (1988). Epidemiology of work-related back pain: a summary of job factors. In K.H.E. Kroemer, J.D. McGlothlin, & T.G. Bobick (Ed.), Manual Material Handling: Understanding and Preventing Back Trauma (pp. 43-50). San Francisco: American Industrial Hygiene Association.

Jones, B.H., Cowan, D.N., & Knapik, J.J. (1994). Exercise, training and injuries. Sports Medicine, 18, 202-214.

Kadefors, R., Petersen, I., & Herberts, P. (1976). Muscular reactions to welding work: an electromyographic investigation. Ergonomics, 19, 543-558.

Karhu, O., Harkonen, R., Sorvali, P., & Vepsalainen, P. (1981). Observing working postures in industry: examples of OWAS application. Applied Ergonomics, 12, 13-17.

Karhu, O., Kansi, P., & Kuorinka, I. (1977). Correcting working postures in industry: a practical method for analysis. Applied Ergonomics, 8, 199-201.

Keegan, J. (1976). The Face of Battle. London: Penguin Books.

Keyserling, W.M. (1986). Postural analysis of the trunk and shoulders in simulated real time. Ergonomics, 29, 569-583.

Knapik, J.J., & Gerber, J. (1996). Influence of physical fitness training on the manual material handling capability and road marching performance of female soldiers (Technical Report No. ARL-TR-1064). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Knapik, J.J., & Sharp, M.A. (1997). Task-specific and generalized physical training programs for improving manual material handling capability. International Journal of Industrial Ergonomics, In Press.

Koplan, J.P., Powell, K.E., Sikes, R.K., Shirley, R.W., & Campbell, C.C. (1982). An epidemiologic study of the benefits and risks of running. Journal of the American Medical Association, 248, 3118-3121.

Kroemer, K.H.E. (1969). Push forces exerted in sixty-five common working positions (Technical Report No. AMRL-TR-68-143). Wright Patterson Air Force Base, OH: Aerospace Medical Research Laboratory.

Kroemer, K.H.E., & Robinson, D.E. (1971). Horizontal static forces exerted by men standing in common working positions on surfaces of various traction (Technical Report No. AMRL-TR-70-114). Wright Patterson Air Force Base, OH: Aerospace Medical Research Laboratory.

Lakka, T.A., Venalainen, J.M., Rauramaa, R., Salonen, R., Tuomilehto, J., & Salonen, J.T. (1994). Relation of leisure-time physical activity and cardiorespiratory fitness to the risk of acute myocardial infarction in men. New England Journal of Medicine, 330, 1549-1554.

Lee, Y.H., & Chiou, W.K. (1995). Ergonomic analysis of working postures in nursing personnel: example of modified Ovako Working Analysis System application. Research in Nursing and Health, 18, 67-75.

Lind, A.R., & McNicol, G.W. (1967). Circulatory responses to sustained hand-grip contraction performed during other exercise both rhythmic and static. Journal of Physiology, 192, 595-607.

Lind, A.R., & McNicol, G.W. (1968). Cardiovascular responses to holding and carrying weights by hands and by shoulder harness. Journal of Applied Physiology, 25, 261-267.

Lopez, F.M., Kesselman, G.A., & Lopez, F.E. (1981). An empirical test of a trait-oriented job analysis technique. Personnel Psychology, 34, 479-502.

Lytel, R.B., & Botterbusch, K.F. (1981). Physical demands analysis: a new approach (Technical Report) Menomonie, WI: Stout Vocational Institute, University of Wisconsin - Stout.

McCormick, E.J., Jeanneret, P.R., & Mecham, R.C. (1972). A study of job characteristics and job dimensions as based on the position analysis questionnaire (PAQ). Journal of Applied Psychology, 56, 347-368.

McMahon, R., & Shams, T. (1997). Estimating body joint loads during equipment decontamination operations (Technical Report, in press). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Meister, D. (1985). Behavioral Analysis and Measurement Method. New York: John Wiley and Sons.

Myers, D.C., Gebhart, D.L., & Crump, C.E. (1984). Validation of the military entrance physical strength capacity test (Technical Report No. 610). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Myers, D.C., Gebhart, D.L., Crump, C.E., & Fleishman, E.A. (1993). The dimensions of human physical performance: factor analysis of strength, stamina, flexibility, and body composition measures. Human Performance, 6, 309-344.

Myers, D.C., Gebhart, D.L., & Fleishman, E.A. (1980). Development of physical performance standards for Army jobs: the job analysis methodology (Technical Report No. 446). Washington, DC: Advanced Research Resources Organization.

NIOSH (1981). National Institute of Occupational Safety and Health. Work practice guide for manual lifting (Report No. PB82-178948). Cincinnati, OH: U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health.

Paffenbarger, R.S., Hyde, R.T., Wing, A.L., & Hsieh, C. (1986). Physical activity, all-cause mortality, and longevity of college alumni. New England Journal of Medicine, 314, 605- 613.

Pleasant, S.T. (1984). Anthropometrics. An introduction for schools and colleges. London: British Standards Institution.

Priel, V.Z. (1974). A numerical definition of posture. Human Factors, 16, 576-584.

Prud'Homme, D., Bouchard, C., Leblanc, C., Landry, F., & Fontaine, E. (1984). Sensitivity of maximal aerobic power to training is genotype-dependent. Medicine and Science in Sports and Exercise, 16, 489-493.

Rice, V.J.B., Sharp, M.A., Tharion, W.J., & Williamson, T.L. (1996a). The effect of gender, team size, and a shoulder harness on a stretcher carry task and post task performance: Part II. A mass-casualty situation. International Journal of Industrial Ergonomics, 18, 41-49.

Rice, V.J.B., Sharp, M.A., Tharion, W.J., & Williamson, T.L. (1996b). The effects of gender, team size, and a shoulder harness on the stretcher-carry task and post task performance. Part I. A simulated carry from a remote site. International Journal of Industrial Ergonomics, 18, 27-40.

Rohmert, W. (1985). AET-a new job-analysis method. Ergonomics, 28, 245-254.

Rohmert, W., & Laundau, K. (1983). A New Technique for Job Analysis. New York: Francis and Taylor Ltd.

Sakakibara, H., Miyao, M., Kondo, T., & Yamada, S. (1995). Overhead work and shoulder-neck pain in orchard farmers harvesting pears and apples. Ergonomics, 38, 700-706.

Scott, G.B., & Lamb, N.R. (1996). Working practices in a perchery system, using the Ovako Working Posture Analyzing System (OWAS). Applied Ergonomics, 27, 281-284.

Sharp, M.A., Harman, E.A., Boutilier, B.E., Bovee, M.W., & Kraemer, W.J. (1993). Progressive resistance training program for improving manual materials handling performance. Work, 3, 62-68.

Sharp, M.A., Patton, J.F., & Vogel, J.A. (1996). A data base of physically demanding tasks performed by U.S. Army soldiers. In Human Factors and Ergonomics Society, 40th Annual Meeting, 1 (pp. 673-677). Philadelphia, PA: Human Factors and Ergonomics Society.

Sharp, M.A., Wright, J.E., & Vogel, J.A. (1985). Performance on selected candidate screening test procedures before and after Army Basic and Advanced Individual Training (Technical Report No. T13/85). Natick, MA: U.S. Army Research Institute of Environmental Medicine.

Sigholm, G., Herbert, P., Almstrom, C., & Kadefors, R. (1984). Electromyographic analysis of shoulder muscle load. Journal of Orthopeadic Research, 45, 379-386.

Sternfeld, B. (1992). Cancer and the protective effect of physical activity: the epidemiological evidence. Medicine and Science in Sports and Exercise, 24, 1195-1209.

Taylor, F.W. (1929). The Principles of Scientific Management. New York: Harper and Brothers.

Tharion, W.J., Rice, V., Sharp, M.A., & Marlow, B.E. (1993). The effects of litter carrying on rifle shooting. Military Medicine, 158, 566-570.

Torner, M., Zetterman, C., Anden, U., Hansson, T., & Lindell, V. (1991). Workload and musculoskeletal problems: a comparison between welders and officer workers (with reference also to fisherman). Ergonomics, 34, 1179-1196.

USAFAS (1984). White paper: self propelled howitzer crew and unit comparisons of US and selected foreign armies. U.S. Army Field Artillery School.

U.S. Army (1994). Military Occupational Classification and Structure. Army Regulation (AR) 611-201. Washington DC: Headquarters, Department of the Army.

Virzi, R.A. (1992). Refining the test phase of usability evaluation: how many subjects is enough? Human Factors, 34, 457-468.

Wagner, R. (1985). Job analysis at ARBED. Ergonomics, 28, 255-273.

Waters, T.R., Putz-Anderson, V., Garg, A., & Fine, L.J. (1993). Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics, 36, 749-776.

Wenger, H.A., & Bell, G.J. (1986). The interaction of intensity, frequency and duration of exercise training in altering cardiorespiratory fitness. Sports Medicine, 3, 346-356.

APPENDIX A

PRINCIPLES OF MOTION ECONOMY
(Barnes, 1980)

PRINCIPLES OF MOTION ECONOMY

As related to the use of the human body:

1. The two hands should begin as well as complete their motion at the same time.
2. The two hands should not be idle at the same time except during rest periods.
3. Motions of the arms should be made in opposite and symmetrical directions and should be made simultaneously.
4. Hand and body motions should be confined to the lowest classification with which it is possible to perform work satisfactorily.
5. Momentum should be employed to assist the worker wherever possible, and it should be reduced to a minimum if it must be overcome by muscular effort.
6. Smooth continuous curved motions of the hands are preferred to straight-line motions involving sudden and sharp changes of direction.
7. Ballistic movements are faster, easier, and more accurate than restricted (fixation) or "controlled" movements.
8. Work should be arranged to permit a natural rhythm wherever possible.
9. Eye fixations should be as few and as close together as possible.

As related to the workplace:

10. There should be a definite and fixed place for all tools and materials.
11. Tools, materials and controls should be located close to the point of use.
12. Gravity feed bins and containers should be used to deliver material close to the point of use.
13. Drop deliveries should be used wherever possible.
14. Materials and tools should be located to permit the best sequence of motions.
15. Provisions should be made for adequate conditions for seeing. Good illumination is the first requirement for satisfactory visual perception.
16. The height of the workplace and the chairs should be preferably arranged so that alternate sitting and standing at work are easily possible.
17. A chair of the type and height to permit good posture should be provided for every worker.

As relate to the design of tools and equipment:

18. The hands should be relieved of all work that can be done more advantageously by a jig, a fixture, or a foot-operated device.
19. Two or more tools should be combined whenever possible.
20. Tools and materials should be pre-positioned wherever possible.
21. Where each finger performs some specific movement, such as a typewriter, the load should be distributed in accordance with the inherent capacity of the fingers.
22. Levers, hand wheels, and other controls should be located in such positions that the operator can manipulate them with the least change in body position and with the greatest speed and ease.

APPENDIX B

PRINCIPLES FOR THE ARRANGEMENT OF THE WORKPLACE
(Corlett, 1983)

PRINCIPLES FOR THE ARRANGEMENT OF THE WORKPLACE

1. The worker should be able to maintain an upright and forward facing posture during the work.

2. Where vision is a requirement of the task, the necessary work points must be adequately visible with the head and trunk upright or just with the head inclined slightly forward.

3. All work activities should permit the worker to adopt several different but equally healthy and safe, postures without reducing the capacity to do the work.

4. Work should be arranged so that it may be done, at the worker's choice, in either a seated or standing position. When seated the worker should be able to use the backrest of the chair at will, without necessitating a change of movements.

5. The weight of the body, when standing, should be carried equally on both feet, and foot pedals designed accordingly.

6. Work activities should be performed with the joints at about the mid-point of their range of movement. This applies particularly to the head, trunk and upper limbs

7. Where muscular force has to be exerted it should be by the largest appropriate muscle group available and in a direction collinear with the limbs concerned.

8. Work should not be performed consistently at or above the level of the heart; even the occasional performance where force is exerted above the heart should be avoided. Where light hand work must be performed above heart level, rests for the upper arm are a requirement

9. Where a force has to be exerted repeatedly, it should be possible to exert it with either of the arms, or either of the legs, without adjustment to equipment.

10. Rest pauses should be allowed for all loads experienced at work, including environmental and informational loads, and the length of the work period between successive rest periods.

APPENDIX C

FREQUENCY MULTIPLIERS (F) FOR 1991 NIOSH LIFTING EQUATION

FREQUENCY MULTIPLIERS (F) FOR 1991 NIOSH LIFTING EQUATION

Frequency (lifts/min)	≤1 hour		≤2 hours		≤8 hours	
	V<75cm	V≥75cm	V<75cm	V≥75cm	V<75cm	V≥75cm
0.2	1.00	1.00	0.95	0.95	0.85	0.85
0.5	0.97	0.97	0.92	0.92	0.81	0.81
1	0.94	0.94	0.88	0.88	0.75	0.75
2	0.91	0.91	0.84	0.84	0.65	0.65
3	0.88	0.88	0.79	0.79	0.55	0.55
4	0.84	0.84	0.72	0.72	0.45	0.45
5	0.80	0.80	0.60	0.60	0.35	0.35
6	0.75	0.75	0.50	0.50	0.27	0.27
7	0.70	0.70	0.42	0.42	0.22	0.22
8	0.60	0.60	0.35	0.35	0.18	0.18
9	0.52	0.52	0.30	0.30	0.00	0.15
10	0.45	0.45	0.26	0.26	0.00	0.13
11	0.41	0.41	0.00	0.23	0.00	0.00
12	0.37	0.37	0.00	0.21	0.00	0.00
13	0.00	0.34	0.00	0.00	0.00	0.00
14	0.00	0.31	0.00	0.00	0.00	0.00
15	0.00	0.28	0.00	0.00	0.00	0.00
>15	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX D

COUPLING MULTIPLIER (C) FOR 1991 NIOSH LIFTING EQUATION

COUPLING MULTIPLIER (C) FOR 1991 NIOSH LIFTING EQUATION

Coupling Estimate	V<75 cm	V≥75 cm
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

APPENDIX E

FORM USED TO RECORD INFORMATION FROM PUBLICATIONS

FORM USED TO RECORD INFORMATION FROM PUBLICATIONS

Publications Review of Physically Demanding Tasks

MOS________

Document Title ____

____

Document Number ____

Date of Publication ____

Page	Task and Elements of Task	Questions for Soldiers

APPENDIX F

STRUCTURED INTERVIEW FORM

STRUCTURED INTERVIEW FORM

Introductory Comments

We have been directed to see if we can make some of the tasks in your MOS physically easier to perform. We're doing this because heavy physical demands often make up a small part of the MOS, but can keep out a lot of people who are otherwise fully qualified. As you probably know, heavy tasks can fatigue you faster so you don't perform as well and they can lead to health and safety problems.

We are studying 5 MOS right now, including yours. Our approach is to 1) read the publications relating to the MOS so we have some idea of what it is that you do, 2) talk to the subject matter experts (SMEs), like yourself who have been in the MOS for a while, then 3) film some people doing the physically demanding tasks.

Having worked in the MOS for period of time we'd like to ask you some task-related questions and get any ideas that you have for making the MOS physically less difficult to perform.

So, let me begin by asking you:

1. What are the most physically demanding tasks that a (91B, 54B, 94G, 88M, 63H) performs?
   a. (*Ask SMEs to recount how each task is performed*).
   b. Which are the most repetitive heavy tasks?

2. Can you think of any tasks which are "dangerous" to perform? Can you think of a "dangerous" incident in which you were involved in or saw; for example, some sort of emergency, accident or near accident?

3. For the demanding tasks you have described, do you know any way we can make the job easier?

4. Can you think of a particularly demanding task you performed and found a unique or unusual solution?

5. These are the physically demanding tasks for your MOS described in AR 611-201. (*Read MOS-specific list.*) Do you know what these might be?

6. There are some other tasks we read about in publications relating to your MOS. Are these tasks very physically demanding? (*Read MOS-specific list.*)

APPENDIX G

CODES USED TO DESCRIBE PROBLEMS WITH PHYSICALLY DEMANDING TASKS

CODES USED TO DESCRIBE PROBLEMS WITH PHYSICALLY DEMANDING TASKS

Code	Problem
A	Working Space Problems
A0	Other
A1	Restricted movement
A2	Restricted hearing
A3	Restricted vision
A4	Uneven working surface
A5	Slippery working surface
A6	Poor Lighting
A7	Poor organization of working space
B	Load Problems
B0	Other
B1	Load characteristics
B1.0	Other
B1.1	Hard to grasp
B1.2	Bulky
B1.3	Heavy
B1.4	Risk of sudden movement
B1.5	Requires high force
B2	Distance
B2.1	Long lifting or lowering distance
B2.2	Long carry
B2.3	Long push or pull
C0	Posture and Stability
C1	Other
C2	Holding objects away from trunk
C3	Twisting of trunk (e.g., asymmetric lifting)
C4	Stooping
C5	Highly repetitive movements
C6	Lift above shoulders
C7	Lift from below knees
C8	Difficult body position for intended movement
D	User Problems
D0	Other
D1	Requires excessive strength
D2	Requires excessive height
D3	Requires excessive reach
D4	Dangerous to those with health problems
D5	Requires special training
D6	Induces excessive fatigue
E	Effected by protective gear
F	Risk of damage (sharp, hot, hazard)
G	Tool Problems
G1	Not adequate
G2	Breaks often
H	Material Problems (e.g., tears easily)
I	Other

APPENDIX H

REDESIGN CODES

REDESIGN CODES

A	Mechanical/Equipment		
A1		New Tool or device	
A1.1			Winch
A1.2			Pulley
A1.3			Ramp
A1.4			Handhold
A1.5			Cart/Dolly
A1.6			Transfer pump
A1.7			Hose
A1.8			Conveyor belt
A2		Improve existing tool or device	
A3		New Material (fabric, lubrication, etc.)	
A4		Lighter material	
A5		Improve working surface	
A6		Improve adjustability	
B	Space redesign		
B1		Working area	
B2		Surface height adjustment	
B3		Rest Area	
C	Biomechanical or Physiological		
C1		Shifting Load to larger muscle group	
C2		Remove load from body	
C3		Fitness training	
C4		Teamwork (lifting/relay)	
C5		Improve Posture	
D	Item Modification		
D1		Smaller volume/size	
D2		Bulk Volume	
D3		Lighter packaging	
D4		Improve material strength	
D5		Improved Labeling	
D6		Hand holds or cut outs	
E	Education		
F	Procedural		
F1		Task segmentation	
F2		Task reorganization	

APPENDIX I

PUBLICATIONS REVIEWED

PUBLICATIONS REVIEWED

1. Track Vehicle Mechanic (63H)

STP9-63H12-SM - Soldier's Manual, MOS 63H, Track Vehicle Repairer, Skill Level /2 (1JUL92)

STP9-63H34-SM-TG - Soldier's Manual and Training Guide, MOS 63H, Track Vehicle Repairer, Skill Levels 3/4 (1JUL92)

ARTEP 43-649-30-MTP - Mission Training Plan for Headquarters and Main Support Company (29AUG89)

ARTEP 43-007-30-MTP - Mission Training Plan for Light Ordnance (Maintenance Company), Main Support, Heavy Division (26JUL94)

POI for 63H Track Vehicle Mechanic AIT, Ordnance School and Center, Aberdeen Proving Ground, MD

U.S. Army Safety Center Database for 1994 incidents involving MOS 63H

2. Food Service Specialist (92G)

STP10-94B1-SM - Soldier's Manual, MOS 94B, Food Service Specialist, Skill Level 1 (18MAR93)

STP10-94B25-SM-TG - Soldier's Manual and Training Guide, MOS 94B, Food Service Specialist, Skill Levels 2/3/4/5 (12 SEP 86)

POI 800-92G10 Food Service Specialist AIT, Quartermaster School and Center, Ft Lee, VA

U.S. Army Safety Center Database for 1994 incidents involving 92B

U.S. Army Occupational Survey Program Data for 94B

3. Medical Specialist (91B)

STP8-91B15-SM-TG - Soldier's Manual and Training Guide, MOS 91B, Skill Levels 1/2/3/4/5 (3OCT95)

ARTEP 8-437-30-MTP - Mission Training Plan for the Medical Company, Support Battalion, Heavy Separate Brigade/Separate Infantry Brigade and Medical Troop, Support Squadron, Armored Cavalry Regiment (30SEP93)

ARTEP 8-432-MTP - Mission Training Plan for the Headquarters Medical Group

ARTEP 8-058-30-MTP - Mission Training Plan for the Medical Company, Forward Support Battalion, Support Command, Heavy Division (24SEP93)

ARTEP 8-507-30-MTP - Mission Training Plan for the Medical Company, Main Support Battalion, Heavy Division (24SEP94)

ARTEP 8-485-MTP Mission Training Plan for the Medical Battalion, Logistics (FWD and REAR) (14APR93)

ARTEP 8-457-30-MTP - Mission Training Plan for the Area Support Medical Company

ARTEP 8-456-30-MTP - Mission Training Plan for the Support Company, Crew Support, Medical Battalion (1NOV93)

ARTEP 8-449-30-MTP - Mission Training Plan for the Medical Company Ground Ambulance (25FEB92)

ARTEP 8-446-MTP - Mission Training Plan for the Medical Evacuation Battalion Headquarters (20SEP94)

ARTEP 8-765-30-MTP - Mission Training Plan for the Mobile Army Surgical Hospital (MASH)

ARTEP 8-725-MTP - Mission Training Plan for the General Hospital (500 Bed) (7MAY93)

U.S. Army Safety Center Database for 1994 incidents involving MOS 91B

U.S. Army Occupational Survey Program Data for 91B

4. Motor Transport Operator (88M)

STP55-88M12-SM - Soldier's Manual, MOS 88M, Motor Transport Operator, Skill Levels 1 and 2 (23DEC93)

ARTEP 55-816-MTP - Mission Training Plan for Headquarters, Transportation Terminal Battalion (10SEP93)

ARTEP 55-717-30-MTP - Mission Training Plan for the Transportation Command Support Company, Transportation Light Truck Company, Transportation Light-Medium Truck Company, Transportation Medium Truck Company, and Transportation Heavy Truck Company, Transportation Motor Transport Battalion (1SEP94)

ARTEP 55-716-MTP - Transportation Motor Transport Battalion (3NOV93)

ARTEP 55-188-30-Drill - Battle Drills for Motor Transport Company, Motor Support Battalion, Heavy Division (9MAY89)

ARTEP 55-158-30-Drill - Battle Drills for the Motor Transport Company, Supply and Transport Battalion, Airborne, Air Assault and Light Divisions (4OCT89)

ARTEP 55-604-MTP - Mission Training Plan for Transportation Movement Control Center (Corps) (1SEP94)

ARTEP 55-158-30-MTP - Mission Training Plan for the Transportation Motor Transport Company, Supply and Transport Battalion, Airborne, Air Assault and Light Divisions (9OCT89)

ARTEP 55-157 - Army Training and Evaluation Program for Transport Floating Craft General Support, Maintenance Company and Transportation Lighterage Maintenance Company Direct Support (31MAY83)

ARTEP 55-188-30-MTP - Mission Training Plan for the Transportation Motor Transport Company, Main Support Battalion, Heavy Division (9MAY89)

U.S. Army Safety Center Database for 1994 incidents involving MOS 88M

U.S. Army Occupational Survey Program Data for 88M

5. Chemical Operations Specialist (54B)

STP3-54B1-SM - Soldier's Manual, MOS 54B, Chemical Operations Specialist, Skill Level 1 (16JUN95)

STP3-54B2-SM-TG - Soldier's Manual and Training Guide, MOS 54B, Chemical Operations Specialist, Skill Level 2 (3OCT95)

ARTEP3-457-30-MTP

ARTEP3-117-40-MTP

ARTEP3-116-MTP

U.S. Army Safety Center Database for 1994 incidents involving MOS 54B

U.S. Army Occupational Survey Data for MOS 54B

APPENDIX J

INJURIES AND INCIDENTS REPORTED IN ARMY SAFETY CENTER DATABASE FOR FIVE MOSs DURING 1994

INJURIES AND INCIDENTS REPORTED IN ARMY SAFETY CENTER DATABASE FOR FIVE MOSs DURING 1994

Injuries or Incidents Reported for Food Service Specialists (92G)[a]

Activity	Injuries		Days Lost		Days/injury[b]	Fatal Injuries[a]
	Number	Percent of Total	Number	Percent of Total		
Driving	30	31	616	53	26	4
Food Preparation						
Burns	4	4	33	3	8	0
Cuts/Lacerations	4	4	43	4	11	0
Stumble	2	2	21	18	11	0
Lifting	4	4	9	1	2	0
Heat-Related	1	1	1	0	1	0
Material Handling	15	16	74	6	5	1
Sports	9	9	129	11	14	0
APFT[c]	3	3	14	1	5	0
Tactical Parachute	3	3	42	4	14	0
MKT[d] Incidents	8	8	18	2	2	0
Other	13	14	152	13	12	0

[a]Does not include 25 fatalities attributable to a mid-air aircraft collision

[b]Does not include fatalities

[c]APFT = Army Physical Fitness Test

[d]MKT = mobile kitchen trailer

Injuries or Incidents Reported for Motor Transport Operators (88M)

Activity	Injuries		Days Lost		Days/injury[a]	Fatal Injuries
	Number	Percent of Total	Number	Percent of Total		
Driving	50	44	226	31	5	3
Vehicle Related						
Maintenance	8	5	31	4	5	0
Mount/Dismount	6	7	39	5	7	0
Changing Tires	4	4	17	2	4	0
Ground Guide	1	1	10	1	10	0
Material Handling	13	12	87	12	7	0
Sports/PT[b]	19	17	216	30	11	0
Walking	4	4	52	7	13	0
Weapons Handling	2	2	2	0	1	0
Other	6	5	56	8	9	0

[a]Does not include fatal injuries

[b]PT = physical training

Injuries or Incidents Reported for Chemical Operations Specialists (54B)

Activity	Injuries		Days Lost		Days/injury[a]	Fatal Injuries
	Number	Percent of Total	Number	Percent of Total		
Driving	16	34	197	54	12	3
Mount/Dismount Vehicle	2	4	15	4	8	0
Material Handling	7	15	46	13	7	0
Sports/PT[b]	11	23	82	23	7	0
Walking/Climbing	2	4	4	1	2	0
Tactical Parachute	3	6	12	3	4	0
Aircraft Collusion	1	2	-	-	-	1
Other	5	11	8	1	2	0

[a]Does not include fatal injuries
[b]PT = physical training

Injuries or Incidence Reported for Tracked Vehicle Mechanics (63H)

Activity	Injuries		Days Lost		Days/injury	Fatal Injuries
	Number	Percent of Total	Number	Percent of Total		
Driving	5	19	93	30	19	0
Mount/Dismount Vehicle	1	4	1	0	1	0
Material Handling	3	12	44	15	15	0
Sports/PT[a]	6	23	26	8	4	0
Walking/Climbing	5	19	40	13	8	0
Other	6	23	102	33	17	0

[b]PT = physical training

Injuries or Incidence Reported for Medical Specialists (91B)

Activity	Injuries		Days Lost		Days/injury[a]	Fatal Injuries
	Number	Percent of Total	Number	Percent of Total		
Driving	17	17	84	9	3	1
Driving (Passenger)	4	4	130	14	33	
Vehicle Related						
Maintenance	2	2	7	1	4	
Mount/Dismount	4	4	10	1	3	
Ground Guide	1	1	4	0	4	
Material Handling	10	10	52	6	5	
Sports/PT[b]	28	28	208	23	7	
Walking	10	10	54	6	5	2
Weapons Handling	3	3	48	5	16	
Training (Misc.)	6	6	32	4	5	1
Tactical Parachute	4	4	64	7	16	
Other	11	11	219	24	20	1

[a]Does not include fatal injuries
[b]PT = physical training

APPENDIX K

TASKS IDENTIFIED AS PHYSICALLY DEMANDING FROM SOLDIER INTERVIEWS

TASKS IDENTIFIED AS PHYSICALLY DEMANDING FROM SOLDIER INTERVIEWS

Food Service Specialist (92G)

- Lifting pots full of water (commonly 15-gal pot with 10 gal water)
- Carrying various containers full of food in kitchen
- Filling beverage containers
- Filling milk machines
- Emptying garbage
- Storing bulk rations
- Setting up and striking mobile kitchen trailer (MKT)
- Lighting and lifting M2 burner
- Lifting M59 range
- Workload in field food preparation (usually no rotation of cooks)
- Unloading T-rations
- Setting up company level kitchen (KCLFF)
- Setting up and taking down mess kit laundry
- Working in hot kitchens

Medical Specialists (91B)

- Patient Evacuation:
  - Carrying patients (2- to 4-person litter, pistol belt, or body carriage)
  - Loading patients into vehicles
  - Extracting patients from vehicles (especially tanks)
- Moving patients (hospital)
- Moving Equipment (ACLS units, aid chests)
- Setting up TEMPER Tents
- Setting up ISO Shelters
- Chemical decontamination
- Road marching
- Prolonged cardiopulmonary resuscitation (CPR)

Motor Transport Operators (88M)

- Changing wheels (especially on larger vehicles such as HEMTTs or HETs)
- Changing tires on wheels
- Loading cargo onto a heavy equipment transporter (HET)
- Driving:
  - For long periods
  - At night and in blackout conditions
  - In areas where there is a lot of dust (Saudi Arabia, NTC)
  - In urban areas
  - In hot weather
- Lowering or lifting tailgates on some vehicles
- Lifting trailers when hitching to prime mover

- Loading/unloading vehicles, especially ammunition (required on some missions)
- Vehicle recovery
- Climbing into or walking on vehicles in icy conditions
- Painting and removing paint from vehicles

Tracked Vehicle Mechanic (63H)

- Pulling engine components
    - Power Pack
    - Transmissions
    - Final Drives
    - Suspensions
- Changing or replacing track
- Vehicle recovery (especially when mired)
- Changing fuel cells
- Taking components out of shipping containers
- Lifting and carrying portable generators
- Lifting tool boxes
- Torquing down or loosening bolts (especially rusted ones)
- Tensioning track
- Lifting 50-caliber machine gun
- Removing track end caps in the field
- Lining up bolts on replacement parts

54B

- Loading drums of fog oil onto truck
- Lifting and carrying a M3A4 smoke generator
- Removing batteries from Fox vehicle to support M21 detector
- Decontamination involving vehicle scrubbing
- Changing track on an M113
- Lifting and carry a 50-caliber machine gun
- Lifting, carrying, and mounting M21 standoff detector
- Unloading containers of liquid decontamination agent (55-gal drums)
- Using ground sampler glove port on Fox vehicle
- Installing and removing BIDS sampler
- Moving or unloading the M17 Lightweight Decontamination System
- Loading and unloading the 65-gpm pump

APPENDIX L

PHYSICAL DEMANDS QUESTIONNAIRE

PHYSICAL DEMANDS QUESTIONNAIRE

NAME AND RANK ____

TIME IN SERVICE (years and months) ______________ TIME IN MOS (years and months) __________

AGE (years) ____________ GENDER: Male _____ Female _____

List your previous military assignments (do not list the current one).

Location	Unit	Length of Time (months)

1. List and rate the three or four most physically demanding jobs that you have **typically** performed in your MOS.

TASK		Overall Difficulty	Reasons why task is difficult to perform: Requires Muscular Strength	Requires Explosive Strength	Requires Muscular Endurance	Requires Cardiovas Endurance	Requires Flexibility	Requires Coordination	Requires Safety	Balance Concerns	How Critical to the Mission	Times per Year on Average
	Low	1	1	1	1	1	1	1	1	1	1	
		2	2	2	2	2	2	2	2	2	2	
		3	3	3	3	3	3	3	3	3	3	
a. ____________		4	4	4	4	4	4	4	4	4	4	
		5	5	5	5	5	5	5	5	5	5	____
		6	6	6	6	6	6	6	6	6	6	
	High	7	7	7	7	7	7	7	7	7	7	
	Low	1	1	1	1	1	1	1	1	1	1	
		2	2	2	2	2	2	2	2	2	2	
		3	3	3	3	3	3	3	3	3	3	
b. ____________		4	4	4	4	4	4	4	4	4	4	
		5	5	5	5	5	5	5	5	5	5	____
		6	6	6	6	6	6	6	6	6	6	
	High	7	7	7	7	7	7	7	7	7	7	
	Low	1	1	1	1	1	1	1	1	1	1	
		2	2	2	2	2	2	2	2	2	2	
		3	3	3	3	3	3	3	3	3	3	
c. ____________		4	4	4	4	4	4	4	4	4	4	
		5	5	5	5	5	5	5	5	5	5	____
		6	6	6	6	6	6	6	6	6	6	
	High	7	7	7	7	7	7	7	7	7	7	
	Low	1	1	1	1	1	1	1	1	1	1	
		2	2	2	2	2	2	2	2	2	2	
		3	3	3	3	3	3	3	3	3	3	
d. ____________		4	4	4	4	4	4	4	4	4	4	
		5	5	5	5	5	5	5	5	5	5	____
		6	6	6	6	6	6	6	6	6	6	
	High	7	7	7	7	7	7	7	7	7	7	

2. List and rate the three or four most physically demanding jobs you **have ever had** to perform in your military career:

TASK		Overall Difficulty	Reasons why task is difficult to perform: Requires Muscular Strength	Requires Explosive Strength	Requires Muscular Endurance	Requires Cardiovas Endurance	Requires Flexibility	Requires Coordination	Requires Safety Balance Concerns		How Critical to the Mission	Times per Year on Average
	Low	1	1	1	1	1	1	1	1	1	1	
		2	2	2	2	2	2	2	2	2	2	
		3	3	3	3	3	3	3	3	3	3	
a. ________		4	4	4	4	4	4	4	4	4	4	____
		5	5	5	5	5	5	5	5	5	5	
		6	6	6	6	6	6	6	6	6	6	
	High	7	7	7	7	7	7	7	7	7	7	
	Low	1	1	1	1	1	1	1	1	1	1	
		2	2	2	2	2	2	2	2	2	2	
		3	3	3	3	3	3	3	3	3	3	
b. ________		4	4	4	4	4	4	4	4	4	4	____
		5	5	5	5	5	5	5	5	5	5	
		6	6	6	6	6	6	6	6	6	6	
	High	7	7	7	7	7	7	7	7	7	7	
	Low	1	1	1	1	1	1	1	1	1	1	
		2	2	2	2	2	2	2	2	2	2	
		3	3	3	3	3	3	3	3	3	3	
c. ________		4	4	4	4	4	4	4	4	4	4	____
		5	5	5	5	5	5	5	5	5	5	
		6	6	6	6	6	6	6	6	6	6	
	High	7	7	7	7	7	7	7	7	7	7	
	Low	1	1	1	1	1	1	1	1	1	1	
		2	2	2	2	2	2	2	2	2	2	
		3	3	3	3	3	3	3	3	3	3	
d. ________		4	4	4	4	4	4	4	4	4	4	____
		5	5	5	5	5	5	5	5	5	5	
		6	6	6	6	6	6	6	6	6	6	
	High	7	7	7	7	7	7	7	7	7	7	

3. List the most physically demanding tasks you have had to perform in adverse weather conditions (for example, rain, snow, cold, or heat)

TASK	Type of weather (heat, cold rain, etc.)	Times per year on average

4. For the demanding tasks you have described, please list any ways you have found or can recommend to maker the job easier (e.g., using better equipment, techniques, or a different approach to job).

5. List any "dangerous" incidents in which you were involved in or saw, that involved for example, some sort of emergency, accident or near accident (e.g. overexertion, long working hours, etc.).

APPENDIX M

RESULTS OF HUMAN PERFORMANCE FACTORS PORTION OF PHYSICAL DEMANDS QUESTIONNAIRE

RESULTS OF HUMAN PERFORMANCE FACTORS PORTION OF PHYSICAL DEMANDS QUESTIONNAIRE

Physically Demanding MOS-Related Tasks From 45 Motor Transport Operators With Rating on Fleishman's Physical Performance Factors
(only tasks with a frequency of 5 or more are considered)

Task	St*	Muscular Strength	Explosive Strength	Muscular Endurance	Stamina	Flexi-bility	Coordi-nation	Balance	Safety Concerns	Mission Criticality
Chaining Vehicle to a HET (n=30)	M	6.1	5.5	6.2	5.8	5.0	5.3	4.7	6.2	6.8
	SD	1.2	1.8	1.2	1.5	1.6	1.6	1.9	1.5	0.6
	MD	7.0	6.0	7.0	6.0	5.0	6.0	5.0	7.0	7.0
Changing Wheels (n=31)	M	6.4	5.9	5.7	4.8	4.9	5.4	4.9	6.7	6.7
	SD	1.0	1.3	1.3	1.8	1.6	1.6	1.8	0.6	0.8
	MD	7.0	6.0	6.0	5.0	5.0	5.5	5.0	7.0	7.0
Pushing Ramps on a HET Trailer (n=21)	M	6.4	6.2	5.2	4.7	4.3	4.6	4.5	6.1	7.0
	SD	0.9	1.7	1.7	1.9	1.7	1.8	1.9	1.3	0.3
	MD	7.0	7.0	5.0	5.0	4.0	5.0	5.0	7.0	7.0
Raising and Lowering HET Ramps (n=11)	M	6.1	6.0	5.4	5.2	4.4	4.2	4.2	6.4	6.4
	SD	1.4	2.0	1.5	1.8	1.6	1.9	1.2	1.3	1.3
	MD	7.0	7.0	5.0	5.0	4.0	4.0	4.5	7.0	7.0
Driving Long Hours (n=10)	M	4.1	2.6	4.7	6.5	5.7	6.5	3.9	6.9	7.0
	SD	2.3	2.4	2.1	1.0	1.6	1.0	2.2	0.3	0.0
	MD	4.5	2.0	4.5	7.0	6.5	7.0	3.5	7.0	7.0
Vehicle Recovery and Winching (n=8)	M	6.6	4.9	6.3	5.1	5.1	5.8	5.8	7.0	6.7
	SD	0.7	1.6	1.2	1.8	1.7	1.2	1.6	0.0	0.8
	MD	7.0	4.0	7.0	5.0	5.5	5.5	6.5	7.0	7.0
Lifting Equipment or Ammunition (n=8)	M	6.6	5.4	6.1	5.9	5.1	5.3	5.6	6.7	6.6
	SD	0.8	1.8	1.1	2.0	2.2	1.4	1.7	0.8	0.8
	MD	7.0	6.0	7.0	7.0	5.0	5.0	6.0	7.0	7.0
Tying Down and Securing Equipment (n=7)	M	6.9	5.9	5.7	5.3	5.4	5.6	4.4	6.9	7.0
	SD	0.4	1.2	1.8	1.8	1.0	1.4	2.8	0.4	0.0
	MD	7.0	6.0	6.0	6.0	5.0	6.0	5.0	7.0	7.0
Driving a Truck (n=5)	M	3.4	3.2	3.2	3.8	3.6	4.2	3.6	7.0	5.5
	SD	2.6	2.6	2.7	2.7	1.9	2.3	1.9	0.0	3.0
	MD	3.0	2.0	2.0	5.0	5.0	5.0	3.0	7.0	7.0

* St=Statistic: M=Mean, SD=Standard Deviation of Mean, MD=Median

Physically Demanding Tasks Experienced in Military Career From 45 Motor Transport Operators With Rating on Fleishman's Physical Performance Factors (only tasks with a frequency of 5 or more are considered)

Task	St*	Muscular Strength	Explosive Strength	Muscular Endurance	Stamina	Flexi-bility	Coordi-nation	Balance	Safety Concerns	Mission Criticality
Changing Tires (n=15)	M	6.7	6.4	6.3	5.5	4.7	5.6	4.9	6.8	6.8
	SD	0.7	0.7	0.9	1.8	1.6	1.4	1.8	0.4	0.6
	MD	7.0	7.0	6.0	6.0	4.0	6.0	5.0	7.0	7.0
Digging Foxholes or Fighting Positions (n=13)	M	6.3	5.9	6.6	6.4	5.0	4.5	4.4	5.4	4.9
	SD	1.0	1.0	0.8	0.9	0.9	1.1	1.4	1.7	1.7
	MD	7.0	5.5	7.0	7.0	5.0	4.0	4.5	6.0	5.0
Loading Ammunitio n (n=10)	M	6.8	6.8	6.8	6.6	6.2	6.1	6.0	6.8	6.8
	SD	0.4	0.6	0.4	0.7	1.1	1.0	1.0	0.5	0.6
	MD	7.0	7.0	7.0	7.0	7.0	6.0	6.0	7.0	7.0
Chaining Vehicle to HET (n=9)	M	6.8	6.6	6.5	6.4	5.6	5.8	5.7	7.0	6.6
	SD	0.7	0.7	0.8	0.9	1.8	1.8	2.0	0.0	1.1
	MD	7.0	7.0	7.0	7.0	6.0	6.5	7.0	7.0	7.0
Driving Long Hours (n=9)	M	4.5	3.1	5.1	6.3	4.7	6.2	4.6	6.9	6.4
	SD	2.1	2.0	2.3	1.8	1.8	1.8	2.0	0.3	1.4
	MD	5.0	3.0	6.0	7.0	5.0	7.0	4.0	7.0	7.0
Road Marching (n=9)	M	6.4	4.1	6.9	7.0	4.9	4.4	5.0	6.2	4.2
	SD	1.1	1.8	0.3	0.0	1.9	1.7	1.2	0.8	1.7
	MD	7.0	4.0	7.0	7.0	5.0	4.5	4.5	6.0	4.0
Physical Training (n=6)	M	6.4	4.7	6.9	6.8	6.1	5.7	5.0	5.9	4.7
	SD	1.5	2.2	0.4	0.4	1.4	1.7	2.2	1.5	1.9
	MD	7.0	5.0	7.0	7.0	7.0	7.0	6.0	7.0	4.0

* St=Statistic: M=Mean, SD=Standard Deviation of Mean, MD=Median

APPENDIX N

SAMPLE PHYSICAL DEMANDS QUESTIONNAIRE

SAMPLE PHYSICAL DEMANDS QUESTIONNAIRE

List the most physically demanding tasks you have performed in your MOS. If you have any ideas on how to make these tasks easier list these ideas also.

Physically Demanding Tasks	Ways to Make the Task Easier
______________________________	______________________________
	______________________________
______________________________	______________________________
	______________________________
______________________________	______________________________
	______________________________
______________________________	______________________________
	______________________________
______________________________	______________________________
	______________________________
______________________________	______________________________

APPENDIX O

TASKS FILMED AND LOCATION OF FILMING

TASKS FILMED AND LOCATION OF FILMING

Tracked Vehicle Mechanic (63H) Tasks

- Aberdeen Proving Ground, MD
  - - Pulling engine components - Transmissions
  - - Replacing track
  - - Lifting tool boxes
  - - Torquing down or loosening bolts
- Ft Bragg, NC (1st COSCOM)
  - - Taking components out of shipping containers

Chemical Operations Specialist (54B) Tasks

- Ft McClellan, AL (Chemical School)
  - - Loading drums of fog oil onto truck
  - - Lifting and carrying a M3A4 smoke generator
  - - Moving batteries on a Fox vehicle
  - - Decontamination involving vehicle scrubbing
  - - Lifting and carrying M21 stand-off detector

Motor Transport Operator (88M) Tasks

- Ft Hood, TX (180th Transportation Battalion)
  - - Chaining down cargo (vehicles) to a heavy equipment transporter (HET)
  - - Changing wheels and tires on a HET
- Ft Bragg, NC (1st COSCOM)
  - - Changing tire on a HET
    - Unbolting
    - Removing and replacing tube
    - Filling tire with air
    - Putting tire back on
  - - Lowering or lifting tailgates on 2-1/2- and 5-ton vehicles

Food Service Specialist (92G) Tasks

- Ft Bragg, NC (1st COSCOM)
  - - Lifting pots full of water
  - - Carrying various containers full of food in kitchen
  - - Filling beverage containers
  - - Filling milk machines
  - - Emptying garbage
  - - Storage of bulk rations
  - - Setting up mobile kitchen trailer (MKT)
  - - Lighting and lifting M2 burner
  - - Lifting M59 range
  - - Unloading T-rations
  - - Setting up and taking down mess kit laundry
  - - Working in hot kitchens

Medical Specialist (91B) Tasks

- Ft Indiantown Gap, PA
  - Patient Evacuation
    - Carrying patients - 2- to 4-person litter carry
    - Loading patients into vehicle
  - Setting up TEMPER Tents
  - Setting up ISO Shelters
- Ft Sam Houston, TX (photographs only)
  - Long distance patient evacuation in the field

APPENDIX P

OBJECT WEIGHTS AND FORCES

OBJECT WEIGHTS AND FORCES

This appendix contains object weights and forces obtained from both direct measurement and from publications. When information was obtained from publications, these are listed (TM = technical manual). Otherwise, information was obtained from direct measurements using digital scales (Seca, Model 410) or force gauges (Chatillon Model CSD200, Greensboro, NC)

88M (Motor Transport Operators)

Tires on a HET (prime mover) and HEMTT - 238 kg (TM9-232-360-20-2). The tires on the HET, HEMTT and palletized loading system are identical (personal communication with James Thomas, PM-HEMTT, 16APR96). Thirty-six newtons of force were required to initiate rolling a HEMTT tire on concrete.

Tire on a 5-ton (M939) - 90 kg. About 10 newtons of force were required to initiate rolling the tire on concrete and on packed dirt. About 110 newtons of force were required to hold the tire at about a 10° angle

Tire on a 2-1/2-ton truck - 71 kg. About 10 newtons of force were required to roll this tire on concrete and on packed dirt. About 105 newtons of force were required to hold this tire at about a 10° angle

HET Chains

Heavy Chains (two chains) - when lifted 62 cm, the mass was 15 kg; when lifted 132 cm, the mass was 22 kg.

Light Chains (two chains) - when lifted 62 cm, the mass is 8 kg; when lifted 132 cm, the mass was 12 kg.

HET ramps (force required to move ramps) - Measured on two HETs: HET 1-initial force=559 N; moving force=490 N; HET 2 - initial force=490 N; moving force=421 N.

91B (Medical Specialists)

Litter - Chemical litter=6.7 kg

Patient weight varies

Average male soldier=78 kg; 5th and 95th percentiles are 55 and 98 kg, respectively (Donelson & Gordon, 1991; Fitzgerald, Vogel, Daniels, Dziados, Teves, Mello et al., 1986).

Average female soldier = 62 kg; 5th and 95th percentiles are 50 and 77 kg, respectively (Donelson & Gordon, 1991; Fitzgerald, et al., 1986).

54B (Chemical Operations Specialists)

DECON detergent containers - 55-gallon drum - 202 kg

Smoke oil containers (55-gal drums) - 199 kg

M17 lightweight DECON system - 168 kg (TM 3-4230-228-10).

M3A4 smoke generator - empty 82 kg, full 91 kg (TM 1040-276-10).

M21 standoff detector - 47 kg in case; detector is 23 kg alone

94B (Food Service Specialists)

- 15-gal pot with 10 gallons water - 43 kg
- 55-gallon trash cans - Highly variable; ranges in 7 measurements - 8 to 21 kg
- T-Rations containers - 16 kg
- Ranges in MKT
  - Range Outfit M59 - 114 lb (TM 10-7360-204-13&P)
  - M2 Burners - 42 lb (empty-no gas) (TM 10-7360-204-13&P)

63H (Tracked Vehicle Mechanic)

- 50-cal machine gun: gun - 38 kg; tripod - 20 kg
- 16 shoe track assembly - 485 kg

APPENDIX Q

POSTURE ANALYSIS

POSTURE ANALYSIS USING THE OWAS

Wheel Removal from HEMTT

Code	Forearm	Upper Arm	Trunk	Lower Limbs	Hands	Body Reference	Load
0 Frames not analyzed	10.9%	10.7%	10.7%	10.7%	10.7%	10.9%	10.7%
1	12.9% 0°	28.4% 0°	15.8% 0°	4.7% MOVE	2.4% FREE	87.8% STAND	23.3% < 10
2	33.6% 45°	37.3% 45°	22.7% 45°	70.4% 0°	2.4% HOLD	0.2% LIE ON SIDE	60.9% 10 - 50
3	37.8% 90°	22.9% 90°	18.2% 90°	2.4% 90°	1.6% LOWER	LIE ON BACK	5.1% > 50
4	4.9% 135°	0.7% 135°	4.9% 0°	2.4%	6.0% RAISE	1.1% Sit	
5		180°	13.3% 45°	3.8% 1KNEE	3.3% PULL		
6			14.4% 90°	5.6% 2KNEE	14.0% PUSH		
7					59.6% TWIST		

Wheel Replacement on HEMTT

Code	Forearm	Upper Arm	Trunk	Lower Limbs	Hands	Body Reference	Load
0 Frames not analyzed	12.8%	12.8%	13.1%	13.5%	13.0%	13.3%	13.0%
1	12.3% 0°	27.1% 0°	23.2% 0°	2.2% MOVE ←	3.9% FREE	82.5% STAND	19.2% < 10
2	31.6% 45°	35.0% 45°	22.0% 45°	58.2% 0°	8.5% HOLD	LIE ON SIDE	63.8% 10 - 50
3	35.1% 90°	20.2% 90°	5.0% 90°	2.2% 90°	5.9% LOWER	LIE ON BACK	4.0% > 50
4	8.2% 135°	5.0% 135°	11.9% 0°	9.6%	5.8% RAISE	4.2% Sit	
5		180°	20.7% 45°	5.8% 1KNEE	1.4% PULL		
6			4.2% 90°	8.5% 2KNEE	22.1% PUSH		
7					39.4% TWIST		

Tire Change on HET

Code	Forearm	Upper Arm	Trunk	Lower Limbs	Hands	Body Reference	Load
0 Frames not analyzed	15.2%	15.1%	14.9%	14.9%	15.2%	15.2%	15.4%
1	21.0% 0°	17.7% 0°	27.1% 0°	1.7% MOVE	7.1% FREE	75.3% STAND	33.2% < 10
2	28.2% 45°	37.0% 45°	19.3% 45°	53.6% 0°	13.0% HOLD	0.1% LIE ON SIDE	45.3% 10 - 50
3	26.4% 90°	28.1% 90°	18.5% 90°	5.5% 90°	6.0% LOWER	LIE ON BACK	3.1% > 50
4	9.3% 135°	1.9% 135°	5.6% 0°	4.5%	10.3% RAISE	9.5% Sit	
5		0.2% 180°	10.9% 45°	8.8% 1KNEE	12.3% PULL		
6			3.7% 90°	11.0% 2KNEE	18.4% PUSH		
7					17.4% TWIST		

Litter Carriage

Code	Forearm	Upper Arm	Trunk	Lower Limbs	Hands	Body Reference	Load
0 Frames not analyzed						2.6%	2.6%
1	89.7% 0°	89.7% 0°	66. 7% 0°	46.2% MOVE	18.0% FREE	89.7% STAND	38.5% < 10
2	10.3% 45°	2.6% 45°	7.7% 45°	20.5% 0°	38.5% HOLD	LIE ON SIDE	10 - 50
3	90°	7.7% 90°	7.7% 90°	10.3% 90°	LOWER	LIE ON BACK	59.0% > 50
4	135°	135°	18.0% 0°	12.8%	43.6% RAISE	7.7% Sit	
5		180°	45°	10.3% 1KNEE	PULL		
6			90°	2KNEE	PUSH		
7					TWIST		

APPENDIX R

PHYSICALLY DEMANDING TASKS AND POTENTIAL REDESIGN SOLUTIONS IDENTIFIED DURING THE COURSE OF THE PROJECT

PHYSICALLY DEMANDING TASKS AND POTENTIAL REDESIGN SOLUTIONS IDENTIFIED DURING THE COURSE OF THE PROJECT

MOS	Tasks	Potential Redesigns
54B	Loading fog oil into truck	1. Fabricated ramp[b] 2. Tanker truck (in use in some cases) 3. Mechanical winch or crank 4. Hydraulic ramp on back of truck
	Lifting and carrying M3A4 smoke generators	1.Mount generators on vehicle (M157 or M56)[a] 2. Hydraulic ramp on back of truck
	Move batteries that power NBC detector (M21) for field operation	1. Slave cable[a] 2. Batteries on slide to get to back of Fox vehicle
	Decontamination involving vehicle scrubbing	Power sprayer and brush (XM12)[a]
	Changing track on M113	Include hydraulic impact wrench in vehicle
	Lifting and carrying M21 Standoff Detector	Mount detector in Fox vehicle
	Unloading containers of liquid decontamination detergent (55 gallon)	1. Hydraulic lift on back of truck 2. Smaller sized containers
	Loading and unloading 65-gpm pump	Hydraulic lift on back of truck
	Install and remove BIDS sampler	Make seat in Fox vehicle movable
	Move or unload M17 Lightweight Decontamination System	1. 8-person lift 2. Improve handle placement 3. Mechanical winch or lift on vehicle
	Lifting and carrying the 50-caliber machine gun	Titanium alloy
	Using the ground sampler glove port on a Fox vehicle	Redesign equipment to take advantage of smaller body sizes
94G	Carrying water in a large pot	1. Hose attachment from water source to pot 2. Hip belt to take load off hands and put on hips
	Carrying containers of heavy foods through mess hall	1. Hip belt to take load off hands and put on hips 2. Pass-throughs from kitchen to service line to minimize walking[a] 3. Put handles on steam table devices[b]
	Filling beverage containers (e.g., flavored drink or milk dispensers)	1. Provide a small pump 2. Water source in beverage container 3. Stool to reduce lifting height
	Emptying garbage containers	1. Improved automatic garbage disposals[a] 2. Smaller containers with more hand holds
	Lifting, carrying, and placing in storage bulk rations	1. Use roller carts[b] 2. Organize building with minimal distance from loading dock to storage area 3. Smaller containers with less weight
	Setting up and striking mobile kitchen trailers	1. Place longer levers on landing gear crank 2. Use electric motor to drive leveling struts 3. Put crank mechanism on roof-raising device[a] 4. Lift roof by hydraulic means

	Lifting, carrying, and lighting M2 burners	1. Place fuel container outside kitchen area so burners do not have to be removed 2. Use JP8 fuel so burners can be lit in kitchen[a] 3. Design roller device for M2 burner
	Lifting and carrying M59 range	
	Field food preparation (long hours)	Have more personnel available
	Unloading T-rations	Incorporate handles into cardboard containers
	Setting up company level kitchen	
	Setting up and striking mess kit laundry	
	Working in hot kitchens	Air conditioning
	Lifting and lower food from ovens to check and stir	Use device that allows food to be rolled in and out of ovens
63H	Pulling engine components	1. Design jack for field use 2. Use ceramic components to make parts lighter
	Changing or replacing track	1. Use roller cart to transport track on ground 2. Use four men to carry track[b]
	Vehicle recovery	
	Changing fuel cells	
	Taking components out of shipping containers	Package in smaller units requiring more assembly
	Lifting and carrying portable generators	Use lighter commercial generators
	Lifting tool boxes	1. Put tools in more than one box 2. Put most used tools in tool vest
	Torquing down and loosening bolts	Pneumatic wrench
	Tensioning track	1. Design wrench with 30^{o} angle 2. Design standard extender bar[b]
	Lifting 50-caliber machine gun	Titanium alloy
	Removing end caps from track in field	Pneumatic impact wrench in basic load
	Lining up bolts when replacing components	1. Put track on components that allows part to slide into place 2. Use bar to slide into place[b] 3. Ceramic components make part lighter and easier to handle
91B	Litter carriage	1. Design harness to take load off hands and place on shoulders or hips 2. Design Litter that can fold in middle for easier transportation 3. Lighter litter materials
	Carrying patients by body carriage	Physical training emphasizing body carriage
	Extracting patients from vehicles	
	Moving patients in hospital environment	
	Loading patients into vehicles (ground or air)	
	Prolonged cardiopulmonary resuscitation	
	Lifting, lowering, and carrying medical equipment in the field (ACLS units, aid chests, etc.)	Set up aid station in "expand-o-van"

	Setting up and striking TEMPER tents	1.Use push pins instead of pins with retainers 2. Lighter weight material instead of canvas 3. Use nylon rope and heat seal ends 4. Put handles on side of poles so shorter individuals can push tent up easier 5. Teach soldiers knot tying 6. Physical training for the upper body
	Setting up and striking ISO shelters	1. Put handles on side of roof so shorter individuals can easily push up roof 2. Improve landing gear mechanism with ratchet device
	Chemical decontamination	
	Road marching	
88M	Changing wheels	1. Pneumatic or electric impact wrench 2. Wheel jacks in basic load[b] 3. Jack stand to support lug wrench[b] 4. Second soldier to support lug wrench[b]
	Changing tires on rims	1. Mechanical tire changer in unit 2. Smaller tires
	Operating and chaining cargo to a HET	1. Lighter chains 2. Cables in place of chains 3. Pull pins on shackles 4. Make ratchets out of non-rusting materials 5. Smaller chock blocks 6. Hydraulic or pneumatic system to lower ramps 7. Covers to prevent mud from sticking to ramp sliding areas 8. Make ramps wider so they do not have to be pushed in and out 9. Develop jack-type device to slide ramps 10. Develop locking device to hold ramps in place once adjusted 11. Move landing leg covers to avoid damage to them
	Driving for long hours or at night	1. Use hotels for rest[b] 2. Two drivers[b] 3. Radio to assist with alertness[b]
	Driving in blackout conditions, or dusty conditions	Develop light beam that detects when driver is too close to vehicle and alarm that sounds in cab[a]
	Driving off road or in urban environ-ments	
	Lifting, lowering, carrying and securing cargo	1. Mechanical hoist 2. Hydraulic lift on back of truck 3. Use lighter weight material for tarpaulins
	Vehicle recovery	Improve winch cable roller system
	Climbing into vehicles, especially in icy conditions	1. Use sandpaper-like material for better footing 2. Additional steps on vehicles for shorter people
	Driving in hot weather	1. Air conditioning 2. Better hot weather uniforms (synthetic materials) 3. Drive in cooler hours of day[b]
	Lifting and lowering tailgates	Lighter tailgates
	Lifting trailer to attach to another vehicle	Counter weight trailer tongue so it can be lifted easily
	Scraping and painting vehicles	

[a]This potential redesign has been considered and is being developed by another agency
[b]Soldiers often use this method

APPENDIX S

TASKS EVALUATED, POTENTIAL REDESIGNS, AND RESPONSES OF MOTOR TRANSPORT OPERATORS TO POTENTIAL REDESIGN SOLUTIONS

TASKS EVALUATED, POTENTIAL REDESIGNS, AND RESPONSES OF MOTOR TRANSPORT OPERATORS TO POTENTIAL REDESIGN SOLUTIONS

TASK	Ways to Make it Easier	Criteria on Which to Rate	Ratings[a] 1 2 3 4 5 N	Stats[b] M	SD
Unbolt Tire From Hub or Bolt Tire to Hub	Jack stand to support lug wrench	Reduces physical requirements	- - 1 2 2	4.2	0.8
		Opens MOS to more people	- - 1 3 1	4.0	0.7
		Reduces number of people necessary	- - 2 2 1	3.8	0.8
		Saves time or motion	- - 1 3 1	4.0	0.7
		Improves safety or health	- - 1 3 1	4.0	0.7
		Costs less	- 3 - 1 - 1	2.5	1.0
		Ease of fielding	- 1 2 2 -	3.2	0.8
	Second soldier to support lug wrench	Reduces physical requirements	- - - 4 1	4.2	0.4
		Opens MOS to more people	- - 4 1 -	3.4	3.2
		Reduces number of people necessary	- - 4 - 1	3.4	0.9
		Saves time or motion	- 1 1 2 1	3.6	1.1
		Improves safety or health	- - 4 1 -	3.2	0.4
		Costs less	1 - 1 2 1	3.4	1.5
		Ease of fielding	- 1 - 3 1	3.8	1.1
	Pneumatic attachment for impact wrench	Reduces physical requirements	- - 1 3 1	4.0	0.7
		Opens MOS to more people	- - 3 2 -	3.4	0.5
		Reduces number of people necessary	- - 2 3 -	3.6	0.5
		Saves time or motion	- - 1 2 2	4.2	0.8
		Improves safety or health	- - 3 2 -	3.4	0.5
		Costs less	- 1 3 1 -	3.0	0.7
		Ease of fielding	- 1 3 1 -	3.0	0.7
	Provide NATO standard plug fitting in cab to attach an electric impact wrench	Reduces physical requirements	- 3 1 1 -	2.6	0.9
		Opens MOS to more people	- - 4 1 -	3.2	0.4
		Reduces number of people necessary	- 1 3 1 -	3.0	0.7
		Saves time or motion	- 1 4 - -	2.8	0.4
		Improves safety or health	- 1 4 - -	2.8	0.4
		Costs less	- - 4 1 -	3.2	0.4
		Ease of fielding	- 1 3 1 -	3.2	1.1
	Additional PT for strengthening the arms so it is easier to use the lug wrench	Reduces physical requirements	- - - 3 2	4.4	0.5
		Opens MOS to more people	- - 3 1 1	3.6	0.9
		Reduces number of people necessary	- - 2 2 1	3.8	0.8
		Saves time or motion	1 - - 3 1	3.6	1.5
		Improves safety or health	- - 2 2 1	3.8	0.8
		Costs less	- 3 1 1 -	2.6	0.9
		Ease of fielding	- 1 2 1 - 1	3.0	0.8

	Make lug wrench handles longer to make it easier to take the bolts off	Reduces physical requirements	- - 1 3 1	4.0	0.7
		Opens MOS to more people	- - 4 1 -	3.2	0.4
		Reduces number of people necessary	- - 5 - -	3.0	0.0
		Saves time or motion	- - 2 3 -	3.6	0.5
		Improves safety or health	- - 3 2 -	3.4	0.5
		Costs less	- 1 4 - -	2.8	0.4
		Ease of fielding	- 1 2 2 -	3.2	0.8
Pulling Tire off Hub	Smaller tires with less weight	Reduces physical requirements	- - - 3 2	4.4	0.5
		Opens MOS to more people	- - 3 1 1	3.6	0.9
		Reduces number of people necessary	- - 1 3 1	4.0	0.7
		Saves time or motion	- 1 2 1 1	3.4	1.1
		Improves safety or health	- - 1 2 2	4.2	0.8
		Costs less	- - 2 1 - 2	3.3	0.6
		Ease of fielding	- 2 1 2 -	3.0	1.0
Putting Tire Back on the Hub	Slide tire up with tanker bar	Reduces physical requirements	- 1 - 3 1	3.8	1.1
		Opens MOS to more people	- 1 3 1 -	3.0	0.7
		Reduces number of people necessary	- 1 2 2 -	3.2	0.8
		Saves time or motion	- 1 1 3 -	3.4	0.9
		Improves safety or health	- 2 1 1 1	3.2	1.3
		Costs less	- 1 4 - -	2.8	0.4
		Ease of fielding	- 1 2 2 -	3.2	0.8
	Provide a cone adapter to make it easier to slide the wheel back on the hub	Reduces physical requirements	2 - 2 1 -	2.4	1.3
		Opens MOS to more people	2 - 3 - -	2.2	1.1
		Reduces number of people necessary	2 1 2 - -	2.0	1.0
		Saves time or motion	2 1 2 - -	2.0	1.0
		Improves safety or health	2 2 1 - -	1.8	0.8
		Costs less	- - 3 - -	3.0	0.0
		Ease of fielding	1 - 4 - -	2.6	0.8
	Smaller tires with less weight	Reduces physical requirements	- - - - 5	5.0	0.0
		Opens MOS to more people	- - 3 - 2	3.8	1.1
		Reduces number of people necessary	- - 1 1 3	4.4	0.9
		Saves time or motion	- - - - 5	5.0	0.0
		Improves safety or health	- - 2 - 3	4.2	1.1
		Costs less	1 2 - - - 2	1.7	0.6
		Ease of fielding	1 - 1 2 1	3.6	1.1
Unchain an M1 from HET	Lighter chains	Reduces physical requirements	- - - - 5	5.0	0.0
		Opens MOS to more people	- - 3 2 -	3.8	1.1
		Reduces number of people necessary	- - 2 1 2	4.0	1.0
		Saves time or motion	- - 1 - 4	4.6	0.9
		Improves safety or health	- 1 1 - 3	4.0	1.4
		Costs less	1 1 1 - - 2	2.0	1.0
		Ease of fielding	- 1 2 1 1	3.4	1.1

	Pull pins on shackle	Reduces physical requirements	2 1 1 1 -	2.2 1.3
		Opens MOS to more people	1 - 3 1 -	2.8 1.1
		Reduces number of people necessary	1 - 3 1 -	2.8 1.1
		Saves time or motion	1 2 2 - -	2.2 0.8
		Improves safety or health	1 1 3 - -	2.4 0.9
		Costs less	1 - 3 - 1	3.0 1.4
		Ease of fielding	1 1 3 - -	2.4 0.9
	Lubricate shackle threads	Reduces physical requirements	- - 2 2 1	3.8 0.8
		Opens MOS to more people	- - 4 1 -	3.2 0.4
		Reduces number of people necessary	- - 4 1 -	3.4 0.9
		Saves time or motion	- - 4 1 -	3.2 0.4
		Improves safety or health	- 1 4 - -	2.8 0.4
		Costs less	- 1 4 - -	2.8 0.4
		Ease of fielding	- 1 4 - -	2.8 0.4
	Use body weight to loosen chains before unshackle	Reduces physical requirements	1 - 1 3 -	3.2 1.3
		Opens MOS to more people	1 - 4 - -	2.6 0.9
		Reduces number of people necessary	1 - 1 3 -	3.2 1.3
		Saves time or motion	1 - - 4 - 1	3.3 1.5
		Improves safety or health	1 - 4 - -	2.6 0.9
		Costs less	1 - 3 1 -	2.8 1.1
		Ease of fielding	2 - 2 2 -	2.4 1.3
Lower rear landing gear of HET	Have handle to turn landing gear bolts on side to replace cover on top	Reduces physical requirements	- - 1 3 1	4.0 0.7
		Opens MOS to more people	- - 3 1 1	3.6 0.9
		Reduces number of people necessary	- 1 2 1 1	3.4 1.1
		Saves time or motion	- 1 3 1 -	3.8 1.1
		Improves safety or health	- 1 3 1 -	3.0 0.7
		Costs less	- - 5 - -	3.0 0.0
		Ease of fielding	- 1 2 1 1	3.4 1.1
Lower ramps on HET	Use graphite on roller to allow them to move outward easier	Reduces physical requirements	1 - - 2 2	3.8 1.6
		Opens MOS to more people	1 - 3 1 -	2.8 1.1
		Reduces number of people necessary	1 1 2 1 -	2.6 1.1
		Saves time or motion	1 1 - 3 -	3.0 1.4
		Improves safety or health	1 1 1 2 -	2.8 1.3
		Costs less	1 1 3 - -	2.4 0.9
		Ease of fielding	1 - 3 1 -	2.8 1.1
	Use crank to lower ramps	Reduces physical requirements	1 - - 3 1	3.6 1.5
		Opens MOS to more people	1 - 3 - 1	3.0 1.4
		Reduces number of people necessary	1 1 2 1 -	2.6 1.1
		Saves time or motion	1 1 1 2 -	2.8 1.3
		Improves safety or health	1 - 3 1 -	2.8 1.1
		Costs less	1 - 3 - - 1	2.5 1.0
		Ease of fielding	1 1 3 - -	2.4 0.9

[a]Ratings: 1=Very Ineffective, 2=Ineffective, 3=No Change, 4=Effective, 5=Very Effective, N=No Response or No Opinion
[b]Stats=Statistics; M=Mean Value, SD=standard Deviation (for 1 to 5 rating)

APPENDIX T

SUMMARY OF PHYSICALLY DEMANDING TASKS, REDESIGN SOLUTIONS, AND SOLDIER REVALUATION TO POTENTIAL REDESIGN SOLUTIONS

SUMMARY OF PHYSICALLY DEMANDING TASKS, REDESIGN SOLUTIONS, AND SOLDIER REVALUATION TO POTENTIAL REDESIGN SOLUTIONS

Chemical Operations Specialists (54B)

Problem	Potential Solution	Soldiers' Responses[a]						Statistics[b]	
		1	2	3	4	5	N	M	SD
1. Decontamination and Scrubbing	Maintain a work-rest cycle	2	1	6	-	1		2.7	1.2
	XM12 being developed (DS2 power sprayer & brush)	9	1	-	-	-		1.1	0.3
2. Unloading containers of liquid DECON detergent. The container size can vary, as big as 55 gal	The container size could be broken down to "Jerry"-size cans or dispensed to decontamination mix containers (G.I. trash cans, etc.)	5	5	-	-	-		1.5	0.5
3. Unload the 65-gpm pump and place it on the ground. This classifies as a two-man lift; sometimes only ONE person is available	The pump can be modified to include front rollers and rear handles IF a ramp is available. The pump would not have to be lifted; it could be rolled	3	6	1	-	-		1.8	0.6
4. Stature of the crew is not interchangeable with most 54Bs. That is, reconnaissance operator must be 5 ft 1 in. minimum for MM1 unit in Fox. Ground sampler glove-port: Operator must be 5 ft 4 in. minimum to reach the ground	The Army should cross-train the entire crew to include other RECONNAISSANCE vehicles, to take advantage of more body sizes	3	4	3	-	-		2.0	0.8
	The equipment should be redesigned to accommodate the smaller size	2	2	2	2	2		3.0	1.5
5. Loading trucks with fog oil	Install a ramp lift device for the 55-gal drum	7	1	1	1	-		1.6	1.1
	Repackage fog oil to a bulk dispensing system (tanker truck with a hose)	7	2	1	-	-		1.4	0.7
6. Loading or unloading 55-gal fog-oil drums in the field with a fabricated ramp	Standardize ramp design	2	5	2	1	-		2.2	0.9
	Manufacture or buy off-the-shelf lightweight metal ramp and make it part of the basic load	4	6	-	-	-		1.6	0.5

7. Move the batteries that power the NBC detection system (Fox vehicle). They must be moved to the rear of the vehicle and carried through the rear hatch down a step to the ground	Design a tray with slides or rollers to get the battery to the back door so soldiers can prepare for the lift	3	5	1	1	-		2.0	0.9
8. Mounting the M21 standoff detector (Fox vehicle). Presently, seats are in the way for a direct lift (overhead and through the hatch roof)	Make operator seat movable (i.e., swing away, tilt, fold, etc.)	3	6	1	-	-		1.8	0.6
9. Install and remove BIDS sampler	Make seats movable so they swing aside, unlatch, and move)	3	5	2	-	-		1.9	0.7
10. Move or unload the M17 lightweight decontamination system (LDS)	8-person lift	3	3	3	1	-		2.2	1.0
	Improve lift handle placement	2	4	3	1	-		2.3	0.9
	Crane or hand crank installed on vehicle	5	1	2	1	1		2.2	1.5
11. Lifting an M3A4 smoke generator from the transport vehicle and placing it on the ground	Increase the number of personnel available for the lift and the number of handles on the device to accommodate these people	2	4	3	1	-		2.3	0.9
12. Break track on an M113 or other tracked vehicle in the field	If dirty or contaminated, start with hands on tools and work until support vehicle arrives to tow vehicle	2	3	5	-	-		2.3	0.8
	Include a 24-volt impact wrench that plugs into the NATO slave connection.	3	4	3	-	-		2.0	0.8

[a]Responses: 1=better, 3=no change, 5=worse, N=No Response
[b]Statistics: M=mean response; SD=standard deviation of responses

Food Service Specialists (94G)

Problem	Potential Solution	Soldiers' Responses[a] 1	2	3	4	5	N	Statistics[b] M	SD
1. Putting water into 15-gallon pot, then carrying it	Attach hose to sink faucet, which can be directed to any container that needs to be filled with water	1	4	2	2	1		2.8	1.3
	Develop hip belt with platform on which heavy pots could rest	1	-	-	4	5		4.2	1.3
2. Transferring liquids (such as flavored drink) from a 15-gal pot into a dispenser	Provide small pump	1	6	1	1	1		2.5	1.2
	Run water line to dispenser	2	4	1	2	1		2.6	1.3
	Use stool to reduce the height of lift	-	3	3	4	-		3.1	0.9
3. Transporting steam table pans when heavy and filled with hot food	Change design of pan to include handles on each side	2	6	2	-	-		2.0	0.7
	Make apron to provide resting point against the body	1	3	3	3	-		2.8	1.0
4. Moving loaded trash containers and emptying them into a dumpster	Redesign garbage cans to be smaller and have more grip points	1	3	3	3	-		2.8	1.0
	Dispose of all organic waste by automatic disposal system	1	6	2	-	1		2.4	1.1
5. Lowering landing gear on an MKT	Place longer levers on the crank	-	10	-	-	-		2.0	0.0
	Use electronic motor to drive the leveling struts	2	6	-	1	1		2.3	1.3
6. Raising the roof on an MKT	Include a stool to help shorter people	-	1	4	4	1		3.5	0.8
	Put ratchet mechanism on each pole	1	5	2	-	-	2	2.1	0.6
	Redesign trailer with hydraulic pump to raise poles	3	5	-	1	-	1	1.9	0.6
7. Unloading T-rations from a truck	Incorporate handles on the containers	1	7	2	-	-		2.1	0.6
8. Filling M2 burners with fuel from a 5-gal container	Use a bulb siphon to reduce spills and work of pouring from a can	2	6	1	-	-	1	1.7	0.5
9. Transporting M2 burner to MKT	Redesign M2 so it shuts off if only one person carries it	-	1	5	3	1		3.4	0.8

	Develop a cart or dolly to allow a single person to carry the M2	1	5	3	1	-		2.4	0.8
10. Storage and transport of bulk food	Redesign shipping containers to be smaller and have handles	1	4	5	-	-		2.4	0.7
	Design cart to allow food to be better transported	-	5	5	-	-		2.5	0.5
11. Placing food in ovens	Use a roller device that allows food to be rolled out for checking and stirring	2	6	1	-	1		2.2	1.1
12. Lighting and transporting the M2 burner to the MKT	Redesign the M2 so the fuel tank is outside the MKT and the device does not have to be moved to be lit	4	5	1	-	-		1.7	0.7

[a]Responses: 1=better, 3=no change, 5=worse, N=no response or no opinion
[b]Statistics: M=mean response; SD=standard deviation of responses

Tracked Vehicle Mechanics (63H)

Problem	Potential Solution	Soldiers' Responses[a]						Statistics[b]	
		1	2	3	4	5	N	M	SD
1. Lifting Army standard portable generators onto trucks	Use commercial generators which are lighter	-	4	2			1	2.3	0.5
2. Releasing tension on a track	Design standard wrench extender for more leverage	1	6	-	-	-		1.9	0.4
	Design a wrench with an angle (about 30°)	1	4	1	-	-	1	2.0	0.6
3. Lifting 50-cal machine gun	Use titanium alloy weapons, which are lighter	-	4	1	-	-		2.2	0.4
4. Lifting of heavy items such as hydraulic pumps, fuel injection pumps, turbo chargers, and alternators	Design a jack that could be used in the field	-	5	-	-	1	1	2.5	1.2
	Use ceramic components to make the parts lighter	-	7	-	-	-		2.0	0.0
5. Replacing the track on a tracked vehicle	Use a roller cart to set the track on and wheel track into place	-	3	1	-	2	2	3.2	1.5
	Use four men to lift and put the track in place	-	-	4	1		2	3.2	0.4
6. Removing cap ends from a track in the field	Provide pneumatic impact wrench that can be carried on the vehicle for immediate use	3	2	1	-	-	1	1.7	0.8
7. Torquing down or loosening bolts	Design a standard wrench extender for more leverage	2	3	1	-	-	1	1.8	0.8
	Use pneumatic or electrical wrench	1	4	2				2.1	0.7
8. Aligning bolts when pulling or replacing units such as power packs, transmissions, suspensions, or radiators	Put a track on the unit that allows it to slide into place	1	3	1	1	-	1	2.3	1.0
	Use "cheater bars" to slide it into place	-	1	4	-	-	2	2.8	0.4
	Use ceramic components to make it lighter	1	1	3	1	-	1	2.7	1.0
9. Taking components out of shipping containers	Package in smaller units requiring more assembly	-	-	2	3		2	3.6	0.5
10. Lifting 70-lb tool box	Put into two units of 35 lb each	1	1	4	-	-	1	2.5	0.8
	Carry most used tools in a tool vest	1	-	4	2	-		3.0	1.0

[a]Responses: 1=better, 3=no change, 5=worse, N=No Response
[b]Statistics: M=mean response; SD=standard deviation of responses

Medical Specialists (91B)

Problem	Potential Solution	Soldiers' Responses[a]						Statistics[b]	
		1	2	3	4	5	N	M	SD
1. When erecting the central poles of a TEMPER tent, the pins used to hold poles in place frequently break off at the retainer cable.	Use push pins instead of pins with retainers.	4	3	1	2	-	1	2.1	1.2
2. The green canvas on top of the TEMPER tent is heavy and this makes it difficult to put up.	Use lighter weight material for cover.	-	7	-	3		1	2.6	1.0
3. Lines on TEMPER tents are hemp rope and fray frequently.	Use nylon or polypropylene rope in place of hemp.	4	4	1	-	-	2	1.7	0.7
	Heat, tape or use dip-it to seal rope ends	-	6	3	-	-	2	2.3	0.5
4. When lifting sides of a TEMPER tent, it is difficult to grasp poles effectively.	Put handles on sides of poles to assist with lifting.	2	5	1	2	-	1	2.3	1.1
5. Many soldiers do not know how to tie proper knots on lines of TEMPER tent	Develop a training program for soldiers to learn to tie knots	1	7	2	-	-	1	2.1	0.6
6. Erecting a TEMPER tent is very physically demanding, requiring a lot of upper body work and overhead labor.	Physical training should emphasize more above-the-head exercises (i.e., over-head log drills, military presses, lateral raises) as well as more upper body exercises	-	4	6	-	-	1	2.6	0.5
7. The current landing gear system used to level ISO shelter is time consuming because of low gearing and confined turning area.	Use ratchet with same gearing level	3	4	3	-	-	2	2.0	0.8
8. Erecting the roof on an ISO shelter is very difficult because of weight and height to which it must be lifted.	Place handles on sides of roof to assist with pushing up.	1	6	1	1	-	2	2.2	0.8
9. When loading a litter patient into an ambulance, the legs of the loading ramp can fall down.	Lock the ramp legs with a pin or strap to prevent ramp from falling down.	1	4	5	-	-	2	2.4	0.7

10. When loading an ambulance with a litter patient, the handles of the litter must be strapped in. This can take time.	Develop a device that "snaps" the litter handles in place and locks the patient into the rack.	2	5	2	1	-	1	2.2	0.9
11. Litters are bulky and difficult to carry in the field because of their length.	Create a litter that can fold in the center during transportation. This would reduce the length of the litter.	1	2	3	1	-	4	2.6	1.0
12. Litters are heavy because of the wood and canvas construction.	Construct litter from lighter weight material. This could include materials such as titanium poles and nylon webbing.	2	2	7	-	-		2.5	0.8
13. In some cases, you must carry litter patients for very long distances.	Develop a belt that goes over the shoulders and around the waist that allows the weight of the litter to be supported on the hips. You would be able to shift the weight from your hands to your hips and back again.	3	3	3	1	-	-	2.2	1.0

[a]Responses: 1=better, 3=no change, 5=worse, N=No Response
[b]Statistics: M=mean response; SD=standard deviation of responses

NO. OF COPIES	ORGANIZATION
2	ADMINISTRATOR DEFENSE TECHNICAL INFO CENTER ATTN DTIC DDA 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL CS AL TA RECORDS MANAGEMENT 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL CI LL TECHNICAL LIBRARY 2800 POWDER MILL RD ADELPHI MD 207830-1197
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL CS AL TP TECH PUBLISHING BRANCH 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	CECOM SP & TERRESTRIAL COM DIV ATTN AMSEL RD ST MC M H SOICHER FT MONMOUTH NJ 07703-5203
1	PRIN DPTY FOR TECH GY HDQ US ARMY MATL CMND ATTN AMCDCG T M FISETTE 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	PRIN DPTY FOR ACQTN HDQ US ARMY MATL CMND ATTN AMCDCG A D ADAMS 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	DPTY CG FOR RDE HDQ US ARMY MATL CMND ATTN AMCRD BG BEAUCHAMP 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001

NO. OF COPIES	ORGANIZATION
1	DPTY ASST SCY FOR RSRCH & TECH SARD-TT F MILTON RM 3EA79 THE PENTAGON WASHINGTON DC 20310-0103
1	ODCSOPS D SCHMIDT WASHINGTON DC 20310-1001
1	OSD OUSD(A&T)/ODDDR&E(R) J LUPO THE PENTAGON WASHINGTON DC 20301-7100
1	USAASA MOAS-AI W PARRON 9325 GUNSTON RD STE N319 FT BELVOIR VA 22060-5582
1	CECOM PM GPS COL S YOUNG FT MONMOUTH NJ 07703
1	GPS JOINT PROG OFC DIR COL J CLAY 2435 VELA WAY STE 1613 LOS ANGELES AFB CA 90245-5500
3	DARPA L STOTTS J PENNELLA B KASPAR 3701 N FAIRFAX DR ARLINGTON VA 22203-1714
1	DIRECTORATE FOR MANPRINT ATTN DAPE MR DEPUTY CHIEF OF STAFF PERSONNEL 300 ARMY PENTAGON WASHINGTON DC 20310-0300
1	OUSD(A)/DDDR&E(R&A)/E&LS PENTAGON ROOM 3D129 WASHINGTON DC 20301-3080
1	CODE 1142PS OFFICE OF NAVAL RESEARCH 800 N QUINCY STREET ARLINGTON VA 22217-5000
1	WALTER REED ARMY INST OF RSCH ATTN SGRD UWI C (COL REDMOND) WASHINGTON DC 20307-5100

NO. OF COPIES	ORGANIZATION
1	COMMANDER US ARMY RESEARCH INSTITUTE ATTN PERI ZT (DR E M JOHNSON) 5001 EISENHOWER AVENUE ALEXANDRIA VA 22333-5600
1	DEFENSE LOGISTICS STUDIES INFORMATION EXCHANGE ATTN DIRECTOR DLSIE ATSZ DL BLDG 12500 2401 QUARTERS ROAD FORT LEE VA 23801-1705
1	DEPUTY COMMANDING GENERAL ATTN EXS (Q) MARINE CORPS RD&A COMMAND QUANTICO VA 22134
1	HEADQUARTERS USATRADOC ATTN ATCD SP FORT MONROE VA 23651
1	COMMANDER USATRADOC COMMAND SAFETY OFFICE ATTN ATOS (MR PESSAGNO/MR LYNE) FORT MONROE VA 23651-5000
1	COMMANDER US ARMY MATERIEL COMMAND ATTN AMCAM 5001 EISENHOWER AVENUE ALEXANDRIA VA 22333-0001
1	DIRECTOR TDAD DCST ATTN ATTG C BLDG 161 FORT MONROE VA 23651-5000
1	COMMANDER USA OPERATIONAL TEST & EVAL AGENCY ATTN CSTE TSM 4501 FORD AVE ALEXANDRIA VA 22302-1458
1	USA BIOMEDICAL R&D LABORATORY ATTN LIBRARY FORT DETRICK BUILDING 568 FREDERICK MD 21702-5010
1	HQ USAMRDC ATTN SGRD PLC FORT DETRICK MD 21701

NO. OF COPIES	ORGANIZATION
1	COMMANDER USA AEROMEDICAL RESEARCH LAB ATTN LIBRARY FORT RUCKER AL 36362-5292
1	US ARMY SAFETY CENTER ATTN CSSC SE FORT RUCKER AL 36362
1	CHIEF ARMY RESEARCH INSTITUTE AVIATION R&D ACTIVITY ATTN PERI IR FORT RUCKER AL 36362-5354
1	US ARMY NATICK RD&E CENTER ATTN STRNC YBA NATICK MA 01760-5020
1	US ARMY TROOP SUPPORT CMD NATICK RD&E CENTER ATTN BEHAVIORAL SCI DIV SSD NATICK MA 01760-5020
1	US ARMY TROOP SUPPORT CMD NATICK RD&E CENTER ATTN TECH LIBRARY (STRNC MIL) NATICK MA 01760-5040
1	DR RICHARD JOHNSON HEALTH & PERFORMANCE DIVISION US ARIEM NATICK MA 01760-5007
1	MEDICAL LIBRARY BLDG 148 NAVAL SUBMARINE MEDICAL RSCH LAB BOX 900 SUBMARINE BASE NEW LONDON GROTON CT 06340
1	USAF ARMSTRONG LAB/CFTO ATTN DR F WESLEY BAUMGARDNER SUSTAINED OPERATIONS BRANCH BROOKS AFB TX 78235-5000
1	COMMANDER USAMC LOGISTICS SUPPORT ACTIVITY ATTN AMXLS AE REDSTONE ARSENAL AL 35898-7466
1	ARI FIELD UNIT FORT KNOX BUILDING 2423 PERI IK FORT KNOX KY 40121-5620

NO. OF COPIES	ORGANIZATION
1	COMMANDANT USA ARTILLERY & MISSILE SCHOOL ATTN USAAMS TECH LIBRARY FORT SILL OK 73503
1	COMMANDER WHITE SANDS MISSILE RANGE ATTN STEWS TE RE WHITE SANDS MISSILE RANGE NM 88002
1	USA TRADOC ANALYSIS COMMAND ATTN ATRC WSR (D ANGUIANO) WHITE SANDS MISSILE RANGE NM 88002-5502
1	STRICOM 12350 RESEARCH PARKWAY ORLANDO FL 32826-3276
1	COMMANDER USA TANK-AUTOMOTIVE R&D CENTER ATTN AMSTA RS/D REES WARREN MI 48090
1	COMMANDER USA TANK-AUTOMOTIVE R&D CENTER ATTN AMSTA TSL (TECH LIBRARY) WARREN MI 48397-5000
1	INSTITUTE FOR DEFENSE ANALYSES ATTN DR JESSE ORLANSKY 1801 N BEAUREGARD STREET ALEXANDRIA VA 22311
1	PURDUE UNIVERSITY SERIALS UNIT CDM KARDEX 1535 STEWART CENTER WEST LAFAYETTE IN 47907-1535
1	GOVT PUBLICATIONS LIBRARY 409 WILSON M UNIVERSITY OF MINNESOTA MINNEAPOLIS MN 55455
1	DR RICHARD PEW BBN SYSTEMS AND TECH CORP 10 MOULTON STREET CAMBRIDGE MA 02138
1	MR R BEGGS BOEING-HELICOPTER CO P30-18 PO BOX 16858 PHILADELPHIA PA 19142

NO. OF COPIES	ORGANIZATION
1	DR ROBERT KENNEDY ESSEX CORPORATION SUITE 227 1040 WOODCOCK ROAD ORLANDO FL 32803
1	MR LARRY W AVERY BATTELLE PACIFIC NW LABS PO BOX 999 MAIL STOP K6-66 RICHLAND WA 99352
1	DR BEN B MORGAN DEPARTMENT OF PSYCHOLOGY UNIVERSITY OF CENTRAL FLORIDA PO BOX 25000 ORLANDO FL 32816
1	AFHRL/CA BROOKS AFB TX 78235
1	DR ARTHUR S KAMLET BELL LABORATORIES 6200 EAST BROAD STREET COLUMBUS OH 43213
1	GENERAL MOTORS CORPORATION NORTH AMERICAN OPERATIONS PORTFOLIO ENGINEERING CENTER HUMAN FACTORS ENGINEERING ATTN MR A J ARNOLD STAFF PROJ ENG ENGINEERING BLDG 30200 MOUND RD BOX 9010 WARREN MI 48090-9010
1	GENERAL DYNAMICS LAND SYSTEMS DIV LIBRARY PO BOX 1901 WARREN MI 48090
1	DR LLOYD A AVANT DEPARTMENT OF PSYCHOLOGY IOWA STATE UNIVERSITY AMES IA 50010
1	DR PAUL R MCCRIGHT INDUSTRIAL ENGINEERING DEPT KANSAS STATE UNIVERSITY MANHATTA KS 66502
1	DR MM AYOUB DIRECTOR INST FOR ERGONOMICS RESEARCH TEXAS TECH UNIVERSITY LUBBOCK TX 79409

NO. OF COPIES	ORGANIZATION
1	MR KENNETH C CROMBIE TECHNICAL LIBRARIAN E104 DELCO SYSTEMS OPERATIONS 6767 HOLLISTER AVENUE GOLETA CA 93117
1	MR WALT TRUSZKOWSKI CODE 522.3 NASA/GODDARD SPACE FLIGHT CENTER GREENBELT MD 20771
1	DIRECTOR US ARMY AEROFLIGHT DYNAMICS DIR ATTN SAVRT AF D (A W KERR) AMES RESEARCH CENTER (MS 215-1) MOFFETT FIELD CA 94035-1099
1	COMMANDER US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE NATICK MA 01760-5007
1	DR DANIEL J POND BATTELLE PNL/K6-66 PO BOX 999 RICHLAND WA 99350
1	HQDA (DAPE ZXO) ATTN DR FISCHL WASHINGTON DC 20310-0300
1	HUMAN FACTORS ENG PROGRAM DEPT OF BIOMEDICAL ENGINEERING COLLEGE OF ENGINEERING & COMPUTER SCIENCE WRIGHT STATE UNIVERSITY DAYTON OH 45435
1	COMMANDER USA MEDICAL R&D COMMAND ATTN SGRD PLC (LTC K FRIEDL) FORT DETRICK MD 21701-5012
1	PEO STANDARD ARMY MGMT INFORMATION SYSTEM ATTN AS PES STOP C-3 FT BELVOIR VA 22060-5456
1	PEO ARMORED SYS MODERNIZATION US ARMY TANK-AUTOMOTIVE CMD ATTN SFAE ASM S WARREN MI 48397-5000

NO. OF COPIES	ORGANIZATION
1	PEO COMBAT SUPPORT ATTN AMCPEO CS US ARMY TANK AUTOMOTIVE CMD WARREN MI 48397-5000
1	PEO MGMT INFORMATION SYSTEMS ATTN AS PEM STOP C-2 BLDG 1465 FT BELVOIR VA 22060-5456
1	PEO ARMAMENTS ATTN AMCPEO AR BLDG 171 PICATINNY ARSENAL NJ 07806-5000
1	PEO AIR DEFENSE ATTN SFAE AD S US ARMY MISSILE COMMAND REDSTONE ARSENAL AL 35898-5750
1	PEO STRATEGIC DEFENSE PO BOX 15280 ATTN DASD ZA US ARMY STRATEGIC DEFENSE CMD ARLINGTON VA 22215-0280
1	PROGRAM MANAGER RAH-66 4300 GOODFELLOW BLVD ST LOUIS MO 63120-1798
1	DENNIS L SCHMICKLY CREW SYSTEMS ENGINEERING MCDONNELL DOUGLAS HELICOPTER 5000 EAST MCDOWELL ROAD MESA AZ 85205-9797
1	JON TATRO HUMAN FACTORS SYSTEM DESIGN BELL HELICOPTER TEXTRON INC PO BOX 482 MAIL STOP 6 FT WORTH TX 76101
1	CHIEF CREW SYSTEMS INTEGRATION SIKORSKY AIRCRAFT M/S S3258 NORTH MAIN STREET STRATFORD CT 06602
1	GENERAL ELECTRIC COMPANY ARMAMENT SYSTEMS DEPT RM 1309 ATTN HF/MANPRINT R C MCLANE LAKESIDE AVENUE BURLINGTON VT 05401-4985
1	JOHN B SHAFER 250 MAIN STREET OWEGO NY 13827

NO. OF COPIES	ORGANIZATION
1	OASD (FM&P) WASHINGTON DC 20301-4000
1	COMMANDER US ARMY MATERIEL COMMAND ATTN AMCDE AQ 5001 EISENHOWER AVENUE ALEXANDRIA VA 22333
1	COMMANDANT US ARMY ARMOR SCHOOL ATTN ATSB CDS (MR LIPSCOMB) FT KNOX KY 40121-5215
1	COMMANDER US ARMY AVIATION CENTER ATTN ATZQ CDM S (MR MCCRACKEN) FT RUCKER AL 36362-5163
1	COMMANDER US ARMY SIGNAL CTR & FT GORDON ATTN ATZH CDM FT GORDON GA 30905-5090
1	DIRECTOR US ARMY AEROFLIGHT DYNAMICS DIR MAIL STOP 239-9 NASA AMES RESEARCH CENTER MOFFETT FIELD CA 94035-1000
1	PROJECT MANAGER SIGNALS WARFARE ATTN SFAE IEW SG (ALAN LINDLEY) BLDG P-181 VINT HILL FARMS STATION WARRENTON VA 22186-5116
1	COMMANDER MARINE CORPS SYSTEMS COMMAND ATTN CBGT QUANTICO VA 22134-5080
1	DIRECTOR AMC-FIELD ASSIST IN SCIENCE & TECHNOLOGY ATTN AMC-FAST (RICHARD FRANSEEN) FT BELVOIR VA 22060-5606
1	COMMANDER US ARMY FORCES COMMAND ATTN FCDJ SA BLDG 600 AMC FAST SCIENCE ADVISER FT MCPHERSON GA 30330-6000
1	COMMANDER I CORPS AND FORT LEWIS AMC FAST SCIENCE ADVISER ATTN AFZH CSS FORT LEWIS WA 98433-5000
1	HQ III CORPS & FORT HOOD OFFICE OF THE SCIENCE ADVISER ATTN AFZF CS SA FORT HOOD TX 76544-5056
1	COMMANDER U.S. ARMY NATL TRAINING CENTER AMC FAST SCIENCE ADVISER ATTN AMXLA SA FORT IRWIN CA 92310
1	COMMANDER HQ XVIII ABN CORPS & FORT BRAGG OFFICE OF THE SCI ADV BLDG 1-1621 ATTN AFZA GD FAST FORT BRAGG NC 28307-5000
1	SOUTHCOM WASHINGTON FIELD OFC 1919 SOUTH EADS ST SUITE L09 AMC FAST SCIENCE ADVISER ARLINGTON VA 22202
1	HQ US SPECIAL OPERATIONS CMD AMC FAST SCIENCE ADVISER ATTN SOSD MACDILL AIR FORCE BASE TAMPA FL 33608-0442
1	HQ US ARMY EUROPE AND 7TH ARMY ATTN AEAGX SA OFFICE OF THE SCIENCE ADVISER APO AE 09014
1	COMMANDER HQ 21ST THEATER ARMY AREA CMD AMC FAST SCIENCE ADVISER ATTN AERSA APO AE 09263
1	COMMANDER HEADQUARTERS USEUCOM AMC FAST SCIENCE ADVISER UNIT 30400 BOX 138 APO AE 09128

NO. OF COPIES	ORGANIZATION
1	HQ 7TH ARMY TRAINING COMMAND UNIT #28130 AMC FAST SCIENCE ADVISER ATTN AETT SA APO AE 09114
1	COMMANDER HHC SOUTHERN EUROPEAN TASK FORCE ATTN AESE SA BUILDING 98 AMC FAST SCIENCE ADVISER APO AE 09630
1	COMMANDER US ARMY PACIFIC AMC FAST SCIENCE ADVISER ATTN APSA FT SHAFTER HI 96858-5L00
1	COMMANDER US ARMY JAPAN/IX CORPS UNIT 45005 ATTN APAJ SA AMC FAST SCIENCE ADVISERS APO AP 96343-0054
1	AMC FAST SCIENCE ADVISERS PCS #303 BOX 45 CS-SO APO AP 96204-0045
1	COMMANDER ALASKAN COMMAND ATTN SCIENCE ADVISOR (MR GRILLS) 6-900 9TH ST STE 110 ELMENDORF AFB ALASKA 99506
1	CDR & DIR USAE WATERWAYS EXPERIMENTAL STATION ATTN CEWES IM MI R (A S CLARK) CD DEPT #1153 3909 HALLS FERRY ROAD VICKSBURG MS 39180-6199
1	MR GARY PERLMAN COMPUTER & INFORMATION SCIENCE OHIO STATE UNIV RM 228 BOLZ HALL 2036 NEIL AVENUE COLUMBUS OH 43210-1277
1	DR SEHCHANG HAH DEPT OF BEHAVIORAL SCIENCES & LEADERSHIP BUILDING 601 ROOM 281 US MILITARY ACADEMY WEST POINT NEW YORK 10996-1784

NO. OF COPIES	ORGANIZATION
1	US ARMY RESEARCH INSTITUTE ATTN PERI IK (DOROTHY L FINLEY) 2423 MORANDE STREET FORT KNOX KY 40121-5620
1	DENNIS SCHMIDT HQDA DAMO FDQ 400 ARMY PENTAGON WASHINGTON DC 20310-0460
1	US MILITARY ACADEMY MATHEMATICAL SCIENCES CENTER OF EXCELLENCE DEPT OF MATHEMATICAL SCIENCES ATTN MDN A MAJ DON ENGEN THAYER HALL WEST POINT NY 10996-1786
1	NAIC/DXLA 4180 WATSON WAY WRIGHT PATTERSON AFB OH 45433-5648
1	USARIEM MARILYN SHARP NATICK LABS NATICK MA 01760
1	HEAD OCC HEALTH SECTION ATTN JOY ERDMAN CHIEF OF NAVAL OPERATIONS (N45) 2000 PENTAGON WASHINGTON DC 20350
1	SNR OCC HEALTH NURSE ATTN NANCY CRAFT NAVY ENVIRONMENTAL HEALTH CTR 2510 WALMER AVE NORFOLK VA 23513-2617
1	HQ USACE ATTN CESO I ROBERT STOUT ROOM 4122 C 20 MASSACHUSETTS AVE NW WASHINGTON DC 20314-1000
1	AMEDD CENTER & SCHOOL C OT BRANCH LTC V J B RICE 3141 BING-ENGLEMANN ROAD FORT SAM HOUSTON TX 78234
1	WRAMC PREVENTIVE MED SVC ATTN MCHL HO MAJ R PIPKIN WASHINGTON DC 20307-5001

NO. OF COPIES	ORGANIZATION
1	US ARMY SAFETY CENTER ATTN CSSC RT M L BOND BLDG 4905 5TH AVE 1209 FT RUCKER AL 36362-5363
4	AL/OEMO ATTN MAJ E KLINENBERG MAJ R STOUT MAJ D GODDARD MAJ C COGBURN 2402 E DRIVE BROOKS AFB TX 78235-5114
1	HQ AFSC/SEGS ATTN LES KINKLE 9700 G AVE STE 230 KIRTLAND AFB NM 87117-5670
1	HQ AFMOA/SGOE ATTN OFC SURG GEN LTC S ZELNICK 110 LUKE AVE SUITE 400 BOLLING AFB WASHINGTON DC 20332-7050
1	HQ MARINE CORPS (SD) ATTN IND HYGIENE PROG MGR DR J AKINYEMI 2 NAVY ANNEX ROOM 2403 WASHINGTON DC 20380-1775
1	OSHA US DOL N3653 DIR OFC OF ERG SPT DR R STEPHENS 200 CONSTITUTION AVE NW WASHINGTON DC 20210
2	NIOSH C PSYCHOPHYSIOLOGY & BIOMECHAN SECTION DR V P ANDERSON LT LIBBY COLE 4676 COLUMBIA PARKWAY MS C24 CINCINNATI OH 45226-1998
1	NIOSH DIV OF SAFETY RSCH M/S P-198 ATTN DR L GARDNER 1095 WILLOWDALE ROAD MORGANTOWN WV 26505
1	OFC OF THE SEC OF DEFENSE OFC OF THE DPTY UNDERSECY OF DEF FOR ENVIRON SECURITY ASST FOR OCC HEALTH POLICY ATTN ODUSD (ES) SH LTC J SEIBERT 3400 DEFENSE PENTAGON WASHINGTON DC 20301-3400

NO. OF COPIES	ORGANIZATION
1	OSD/WHS/RE&F ATTN SEMD SAFETY & OCC HEALTH BR M LANGONE 1155 PENTAGON 2D533 WASHINGTON DC 20301-1155
1	OSD/WHS/RE&F ATTN SEMD INDUS HYGIENE BR M SKOWRONSKI 1155 PENTAGON 2C431 WASHINGTON DC 20301-1155
1	UNIFORMED SVC UNIV OF THE HEALTH SCIENCES DIR CLINICAL PSYCH PROGRAM DEPTS OF MED & CLIN PSYCH AND PREV MED & BIOMETRICS ATTN DR M FEUERSTEIN 4301 JONES BRIDGE ROAD BETHESDA MD 20814-4799
1	ARL HRED AVNC FIELD ELEMENT ATTN AMSRL HR MJ (R ARMSTRONG) PO BOX 620716 BLDG 514 FT RUCKER AL 36362-0716
1	ARL HRED MICOM FIELD ELEMENT ATTN AMSRL HR MO (T COOK) BUILDING 5400 ROOM C242 REDSTONE ARSENAL AL 35898-7290
1	ARL HRED USAADASCH FLD ELEMENT ATTN AMSRL HR ME (K REYNOLDS) ATTN ATSA CD 5800 CARTER ROAD FORT BLISS TX 79916-3802
1	ARL HRED ARDEC FIELD ELEMENT ATTN AMSRL HR MG (R SPINE) BUILDING 333 PICATINNY ARSENAL NJ 07806-5000
1	ARL HRED ARMC FIELD ELEMENT ATTN AMSRL HR MH (J JOHNSON) BLDG 1109B 3RD FLOOR FT KNOX KY 40121-5215
1	ARL HRED CECOM FIELD ELEMENT ATTN AMSRL HR ML (J MARTIN) MYER CENTER RM 3C214 FT MONMOUTH NJ 07703-5630
1	ARL HRED FT BELVOIR FIELD ELEMENT ATTN AMSRL HR MK (P SCHOOL) 10115 GRIDLEY ROAD SUITE 114 FORT BELVOIR VA 22060-5846

NO. OF COPIES	ORGANIZATION
1	ARL HRED FT HOOD FIELD ELEMENT ATTN AMSRL HR MV (E SMOOTZ) HQ TEXCOM BLDG 91012 RM 111 FT HOOD TX 76544-5065
2	ARL HRED NATICK FIELD ELEMENT ATTN AMSRL HR MQ (M FLETCHER) ATTN SSCNC A (D SEARS) USASSCOM NRDEC BLDG 3 RM R-140 NATICK MA 01760-5015
1	ARL HRED FT HUACHUCA FLD ELEMENT ATTN AMSRL HR MY (B KNAPP) GREELY HALL (BLDG 61801 RM 2631) FORT HUACHUCA AZ 85613-5000
1	ARL HRED FT LEAVENWORTH FLD ELE ATTN AMSRL HR MP (D UNGVARSKY) TPIO ABCS 415 SHERMAN AVE RM 327 FT LEAVENWORTH KS 66027-1344
1	ARL HRED FLW FIELD ELEMENT ATTN AMSRL HR MZ (A DAVISON) 320 ENGINEER LOOP STE 166 FT LEONARD WOOD MO 65473-8929
1	ARL HRED OPTEC FIELD ELEMENT ATTN AMSRL HR MR (D HEADLEY) PARK CENTER IV RM 1450 4501 FORD AVENUE ALEXANDRIA VA 22302-1458
1	ARL HRED SC&FG FIELD ELEMENT ATTN AMSRL HR MS (L BUCKALEW) SIGNAL TOWERS RM 207 FORT GORDON GA 30905-5233
1	ARL HRED STRICOM FIELD ELEMENT ATTN AMSRL HR MT (A GALBAVY) 12350 RESEARCH PARKWAY ORLANDO FL 32826-3276
1	ARL HRED TACOM FIELD ELEMENT ATTN AMSRL HR MU (M SINGAPORE) BLDG 200A 2ND FLOOR WARREN MI 48397-5000
1	ARL HRED USAFAS FIELD ELEMENT ATTN AMSRL HR MF (L PIERCE) BLDG 3040 RM 220 FORT SILL OK 73503-5600

NO. OF COPIES	ORGANIZATION
1	ARL HRED USAIC FIELD ELEMENT ATTN AMSRL HR MW (E REDDEN) BLDG 4 ROOM 332 FT BENNING GA 31905-5400
1	ARL HRED USASOC FIELD ELEMENT ATTN AMSRL HR MN (F MALKIN) HQ USASOC BLDG E2929 FORT BRAGG NC 28307-5000
1	US ARMY RSCH DEV STDZN GP-UK ATTN DR MICHAEL H STRUB PSC 802 BOX 15 FPO AE 09499-1500
	<u>ABERDEEN PROVING GROUND</u>
2	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL CI LP (TECH LIB) BLDG 305 APG AA
1	LIBRARY ARL BLDG 459 APG-AA
1	ARL HRED ERDEC FIELD ELEMENT ATTN AMSRL HR MM (R MCMAHON) BLDG 459 APG-AA
2	US ARMY CHPPM ATTN MCHB DC LTC SMITH D M DOGANIERO CIH APG EA
2	US ARMY CHPPM ATTN MCHB DC OER LTC M LOPEZ A CUTLER APG EA
1	ARL SLAD ATTN AMSRL BS (DR JT KLOPCIC) BLDG 328 APG-AA
1	USMC LIAISON OFFICE ATTN AMST ML RYAN BUILDING APG-AA
1	USATECOM RYAN BUILDING APG-AA

NO. OF COPIES	ORGANIZATION
1	COMMANDER CHEMICAL BIOLOGICAL AND DEFENSE COMMAND ATTN AMSCB CI APG-EA
1	CDN ARMY LO TO TECOM ATTN AMSTE CL TECOM HQ RYAN BLDG

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1997	Final

4. TITLE AND SUBTITLE

Feasibility of MOS Task Analysis and Redesign to Reduce Physical Demands in the U.S. Army

5. FUNDING NUMBERS

AMS Code 622716.H700011
PR: 1L162716AH70
PE: 6.27.16

6. AUTHOR(S)

Knapik, J.J. (CHIPPM); de Pontbriand, R.J.; Harper, W.H.; Tauson, R.A.; Swoboda, J.C.; Doss, N.W. (all of ARL)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
Human Research & Engineering Directorate
Aberdeen Proving Ground, MD 21005-5425

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
Human Research & Engineering Directorate
Aberdeen Proving Ground, MD 21005-5425

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

ARL-TR-1594

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Heavy physical demands characterize a large number of U.S. Army military occupational specialties (MOSs). About 45% of the Army's 277 MOSs require at least occasional lifting of 100 pounds or more and frequent lifting of 50 pounds or more. In an effort to reduce these physical requirements, we developed and tested an Army-specific ergonomic task analysis and redesign procedure. Five MOSs were selected for this feasibility project: Food Service Specialist, Medical Specialist, Motor Transport Operator, Tracked Vehicle Mechanic, and Chemical Operations Specialist. Literature review, numerous pilot investigations, and professional experience produced a multiphase process involving (a) review of military publications describing specific occupational tasks, (b) a questionnaire and structure interview with five junior and five senior soldiers working in the MOS, and (c) filming of tasks identified in the first two phases. Contact with military schools responsible for the MOS, project managers (individuals responsible for specific pieces of equipment or projects), or military construction (agencies responsible for new buildings) was found useful in all phases of the process. Potential redesign solutions could also be identified at all phases with soldiers themselves an especially good source of ideas. The feasibility of the potential redesigns was discussed with the schools, project managers, or military construction personnel, and specific solutions were targeted for testing in a usability analysis. In one usability analysis, we identified and improved stretcher carrying methods by moving the stretcher load from the small muscle mass of the hands and forearms to the larger muscle mass of the shoulders and hips. Stretcher carriage time was extended 9.4-fold and soldiers' subjective impression of effort was reduced. These and other redesigns proven to reduce physical demands could be implemented through the appropriate agencies, usually the schools. Not all physically demanding tasks appear amenable to change, and most redesigns did not totally remove the physical burden from the soldier. However, the paradigm developed here allowed identification of the most demanding tasks, some potential redesigns, and targeted solutions with the greatest chance of reducing the soldiers' physical effort.

14. SUBJECT TERMS

carrying	interview	load carriage	workload
ergonomics	lifting	posture	

15. NUMBER OF PAGES 170

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

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